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Micronutrient cations and their spatial variability in soils of Virudhunagar district of Tamil Nadu

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Abstract: In India the food grain production has exponentially increased from 50.8 Mt (1951) to 250.14 Mt (2013) which closely coincides with increase in consumption of plant nutrients from 0.07 to 18 Mt (Soil Survey Reports 2007). It has been estimated that fertilizers alone contributed to one third of crop productivity (Soil Survey Reports 2006). In India the arable land is limited therefore there is a compelling need to increase agricultural productivity. Increased production of crops per unit time utilizing high yielding varieties requires larger input of macronutrients which has accelerated micronutrient deficiencies in soils. Status of micronutrient fertilization is required in order to have relation of different soil series, improve micronutrient use efficiency. It indicates extent of depletion and future projections for prediction of micronutrient requirements, refinement of critical level and delineation of micronutrient deficient and toxic areas. Many reasons have been attributed which include imbalance of nutrients in the soils due to increased demand from high yielding crops, intensive cropping, continued expansion of cropping on to marginal lands with the levels of micronutrients (Richard Bell and Bernie Dell 2006) increased use of chemically pure micronutrient free fertilizers, decreased recycling of crop residues and limited use of animal wastes (Setia and Sharma 2004).

Key words : *Micronutrient delineation, micronutrient deficiency*

Introduction

In India it has been reported that occurrence of micronutrient deficiencies is to an extent of 48.7, 12.0, 5.4, 3.1 and 35% in zinc, iron, copper, manganese and boron respectively (Maleswar 2005). In Tamil Nadu, the continuous cultivation of crops with high analysis straight fertilizers led to a sharp decline in availability of micronutrients in soil, reduction in crop yields and nutritional qualities of agricultural produce (Anonymous 2003). A number of soil delineation studies for various micronutrients indicated existence of the following deficiencies *i.e.*, Zinc - 52%, Copper - 30%, Iron- 23% and Manganese - 8% of the total cultivated area in Tamil Nadu (Anonymous 2007). According to previous reports, Virudhunagar district has registered 83% of the soils had zinc deficiency, 86% of the soils were deficient in copper, 59% in iron and 37% in manganese (Anonymous 2007).

Virudhunagar district was selected for delineation and reassessment work in order to have vital information regarding fertility status of micronutrients in soil at village level so that efforts could be directed towards improvement of crop yield in order to meet the rising population. Survey in Virudhunagar district was conducted in 1992 and zinc deficiency (67%), iron deficiency (10%), copper deficiency (4%) and boron deficiency

(36%) was reported. In previous survey it was found that the soils in Virudhunagar district were mostly affected by zinc and copper deficiency (Kumaresan *et al*. 1989). Almost all districts in Tamil Nadu were surveyed during 1962-1992. The spatial variability maps for individual nutrient (Zn, Fe, Cu and Mn) were prepared using GIS software (Minakshi *et al.* 2005; Nayak *et al*. 2006) and multi micronutrient maps were generated by integrating individual maps of Fe, Mn, Zn and Cu in the GIS (Sood *et al.* 2004).This will help in monitoring changes in micronutrient status over a period of time.

The present research work was taken as an effort to re-evaluate the micronutrient status of Virudhunagar district of Tamil Nadu with the help of GIS and GPS techniques and their interrelationships with soil characteristics.

Experimental details

Virudhunagar district has an area of 4,24,323 ha and is bound on the north by Theni and Madurai districts, on the east by Sivagangai and Ramanathapuram districts, on the south by Thoothukudi and Tirunelveli districts and on the west by Kerala state. The Virudhunagar district is divided into 8 Taluks, 11 blocks and 450 Villages. The district lies between 09^{o}02' to 09^{o}47' N latitude and 77^{o}20' to 78^{o}24' E longitude at an altitude of 1500 to 1700 m above mean sea level. Virudhunagar district consists mainly of Archaean type which includes charnockite, granite and various groups of gneissic rocks. In many places of Virudhunagar district, black soils are dominant.

Major crops grown are paddy, sorghum, pearl millet, finger millet, groundnut, red gram, black gram, green gram, cotton, chillies, sugarcane, *etc.* Except chillies and finger millet others crops are grown under rainfed conditions. The average annual rainfall of the study area is 780.86 mm out of which 80% is received during north-east monsoon (October-December). The soils of the study area have an ombrothermic temperature regime.

Geo-referenced surface soil samples (1308) from eleven blocks of Virudhunagar district representing different soil units as per the soil map prepared on 1:50,000 scales were collected randomly at 0-15 cm depth by adopting the standard procedures of soil sample collection. The GPS data (Latitude °N and Longitude °E) were collected from each sampling site by using Rikaline Bluetooth GPS 6031- X7 model. Analytical data and the GPS data were used for the preparation of thematic map showing spatial distribution of micronutrient status block wise in the district. Geographical area and number of geo-referenced soil samples were collected block- wise. The collected soil samples were dried, gently pounded, sieved to pass through a 2 mm sieve and preserved in polythene bags for analysis. Locations of soil sampling sites of Virudhunagar district were marked on base map on 1: 50,000 scale prepared from State Revenue Maps and digitized using Arc-info GIS.

The pH of soil was determined by potentiometry method using HI9812 portable soil pH meter in the soil water suspension of 1: 2.5 ratio (Jackson 1973). The electrical conductivity of soil was determined by conductometry method using HI9812 portable soil EC meter in the soil water suspension of 1: 2.5 ratio (Jackson 1973). The organic carbon content of soil was estimated by chromic acid wet digestion method (Walkley and Black 1934). The free calcium carbonate in soil was determined by rapid titration method (Piper 1966). The available micronutrients (Zn, Fe, Mn and Cu) were extracted with DTPA extractant using Atomic Absorption Spectrophotometer Model cary50 of Varison (Lindsay and Norvell 1978). Available boron was measured by colour intensity at 420 nm using a UV- Visible Spectrometer model cary 50 of Varison (Berger and Troug 1944). Available sulphur was read in a spectrophotometer at 420 nm using the standard curve (Jackson 1973).

The Virudhunagar district map (1:50,000) was procured from the department of Soil Survey and Land Use Organisation, Coimbatore. The map was vectorised using Raster to Vector software (RiV), and then it was exported into Arc-GIS software. Database on soil micronutrient status of the study area was developed using Microsoft Excel package. Then the database was exported to Arc. GIS software and the thematic maps on different available micronutrients status were generated.

The present investigation linear directional semivariogram are constructed for the selected soil available micronutrients in spatial dependent models by plotting the semi-variance r (h) as a function of lag between neighboring observations. Suitable models such as linear with sill model was fitted to semivarogram in order to create continuous surface for the estimated soil properties by using model fitting interface. Based on the percentage of nugget, spatial dependence classes were categorized in spatial variability map as strong, moderate and weak by showing colour difference on the maps.

Statistical analysis

The database on the analysis of soil available micronutrient content were developed using Microsoft Excel.

Table 1. Collection of geo-referenced soil samples in different blocks of Virudhunagar district

S.No.	Name of the Taluka	Total Area (ha)*	Name of Panchyat Union	No. of surface soil samples collected
1.	Virudhunagar	43,613	Virudhunagar	171
2.	Kariapatti	55,584	Kariapatti	136
3.	Rajapalayam	53,251	Rajapalayam	96
4.	Sattur	49,324	Sattur	172
5.	Sivakasi	57,670	1.Sivakasi	104
			2.Vembakottai	119
6.	Srivilliputhur	61,781	1.Srivilliputhur	93
			2.Watrap	98
7.	Tiruchuli	39,895	1.Narikudi	119
			2.Tiruchuli	116
8.	Aruppukottai	63,205	Aruppukottai	84
			Total	1308

*Source: Soil Survey and Land Use Organisation, 2005.

Results and Discussion

Surface soil characteristics

The soils of Virudhunagar district were alkaline (pH 7.71 to 8.56) with an average of 8.23 which is ideally suited for cultivation of wide range of crops with no limitation. In different blocks of Virudhunagar district the calcium carbonate content was non calcareous to slightly calcareous (4.99 to 8.90%) in all the samples analysed (Table 2).

The organic carbon content was medium in all the 11 blocks with a mean of 0.57%. The medium status of organic carbon content indicates the practice of organic manure application regularly.

Table 2. Range and mean values of physico-chemical properties of soils of different blocks of Virudhunagar district

	pH		EC (dS $^{-1}$)		OC (%)		$CaCO_3$ (%)	
Block	Mean	Range	Mean	Range	Mean	Range	Mean	Range
Virudhunagar	8.25	8-8.5	0.69	0.35-0.83	0.58	0.31-0.82	7.71	4.5-5.2
Sattur	8.26	8-8.5	0.67	0.35-0.88	0.65	0.42-0.98	7.67	5.2-9.8
Aruppukottai	8.22	8-8.5	0.62	0.35-0.84	0.58	0.46-0.87	7.64	5.3-9.8
Vembakottai	8.19	8-8.4	0.61	0.35-0.86	0.57	0.43-0.75	7.64	5.2-9.7
Watrap	8.18	8-8.5	0.63	0.34-0.87	0.51	0.41-0.74	7.34	4.9-9.5
Sivakasi	8.18	7.8-8.4	0.77	0.35-0.83	0.54	0.30-0.79	7.32	4.2-9.6
Srivilliputhur	8.22	8- 8.4	0.61	0.36-0.85	0.55	0.43-0.79	7.71	4.5-5.2
Rajapalayam	8.21	8- 8.4	0.71	0.42-0.88	0.59	0.43-0.86	7.67	5.2-9.7
Thiruchuli	8.17	8 -8.4	0.65	0.35-0.86	0.61	0.45-0.76	7.73	5.3-9.8
Kariapatti	8.16	8-8.3	0.66	0.35-0.88	0.55	0.21-0.87	7.69	5.3-9.8
Arikudi	8.91	8-8.7	0.66	0.35-0.88	0.52	0.33-0.86	7.74	5.3-9.8
Overall district	8.23	8-8.7	0.66	0.34-0.88	0.57	0.2-10.9	7.62	4.2-9.8
SD	0.22		0.12		0.1		0.15	
CV (%)	0.03		0.18		0.18		0.02	

Organic carbon plays a pivotal role in controlling the availability of Zn when the soil pH is alkaline. The presence of organic matter reduces pH, promotes soil structure and aeration, which increases the availability of micronutrients (Gupta and Srivastava 1990). Further organic matter increases the availability of micronutrients through chelating process. The organic acids released from organic matter serve as chelating agents which facilitate in binding with metallic cations thereby reducing leaching losses apart from precipitation and fixation by chemical reactions (Sahoo *et al*. 2003; Singh *et al*. 2005).

Available micronutrient status

There were wide variations in DTPA-Zn content of different blocks of Virudhunagar district surveyed, which varied from 0.11 to 22.26 mg kg^{-1} with a mean value of 1.30 mg kg^{-1} soil (Table 3). Considering the critical limit of DTPA-Zn which is 1.2 mg kg^{-1} (Krishnaswamy *et al*. 1994), about 64.42 percent of samples in this district were deficient in zinc. This clearly indicates the need for regular application of this nutrient to the crops for realizing the optimum yields.Organic carbon is one of the factors influencing the availability of zinc. When the soil is low in organic matter and not supplemented by mineral fertilization, it is prone to zinc deficiency (Takkar *et al.* 1997).

The content of DTPA- Fe varied from 0.13 to 51.04 mg kg^{-1} with an average of 14.15 mg kg^{-1} in soil. The DTPA-Fe was in sufficient amount (>3.7 mg kg^{-1}) in 81.80 per cent samples of this district. The sufficiency status of iron may be attributed to the non-calcareous to slightly calcareous nature of soil found in this region. Among the blocks studied, Narikudi block showed the highest mean value of 28.13 mg kg^{-1} with respect to available Fe followed by Sivakasi as 26.39 mg kg^{-1}, while the soils of Virudhunagar block showed the lowest mean value (5.21 mg kg^{-1}) of available Fe content. This can be attributed to low to slightly calcareous nature of $CaCO_3$ (7.62 %) and medium amount of organic carbon (0.57 %) present in soils of this block. The $CaCO_3$ content has significant negative influence on the DTPA extractable iron content. Deficiency of iron also in the non- calcareous soils is well documented (Lindsay and Norwell 1978).

The content of available manganese varied from 1.08 to 41.77 mg kg^{-1} with an average of 14.49 mg kg^{-1} soil. Sattur block registered lowest mean value of 9.87mg kg^{-1}, while the rest of the block falls in the range of 11.97 to 19.20 mg kg^{-1}.

Table 3. Range and mean values of micronutrient cations of different blocks of Virudhunagar district

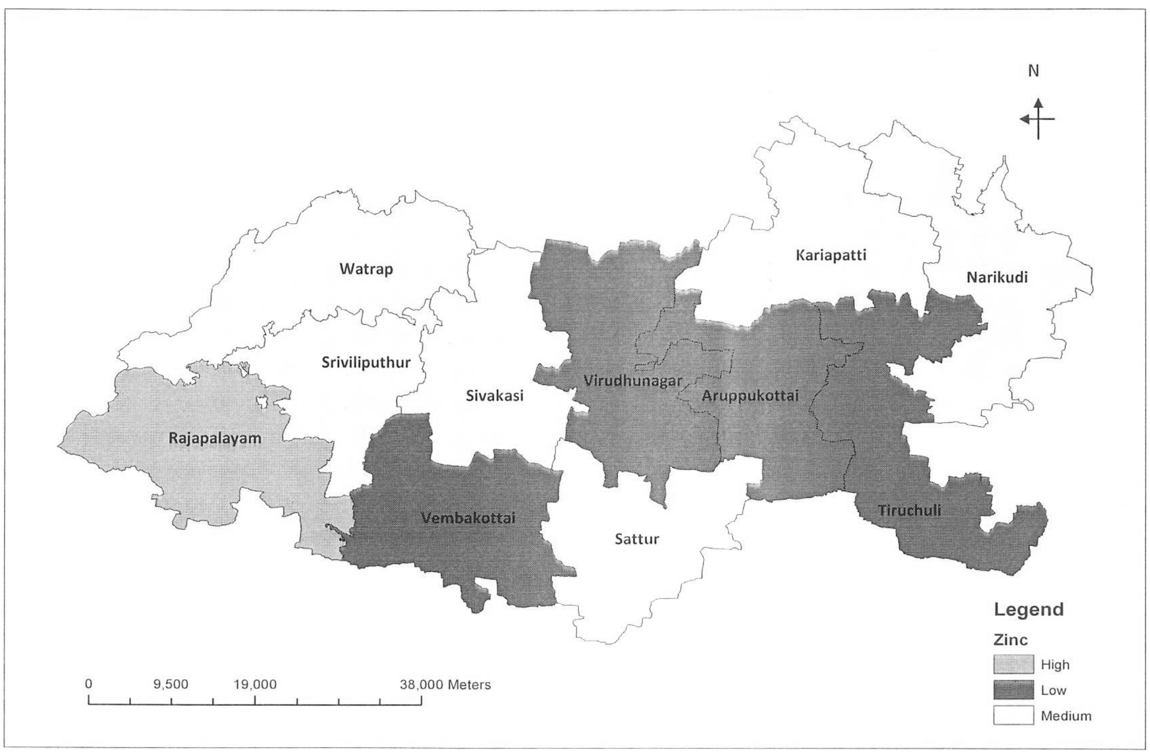
Block name	Micronutrients (mg kg^{-1})									
	Fe		Mn		Zn		Cu		B	
	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range
Virudhunagar	5.21	0.13-24.69	12.66	4.40-21.98	0.98	0.14-7.29	1.79	0.20-5.14	1.62	0.20-4.50
Sattur	7.85	0.15-51.04	9.87	7.26-10.77	1.54	0.11-8.15	2.13	0.38-6.96	1.16	0.10-5.20
Aruppukottai	5.65	0.61-31.41	16.76	6.80-27.32	0.57	0.11-1.64	1.23	0.10-3.50	2.42	0.10-12.80
Vembakottai	6.52	0.26-24.17	11.97	1.11-13.35	0.8	0.16-4.51	1.51	0.40-4.33	1.27	0.10-4.50
Watrap	10.51	1.99-43.89	12.85	8.38-17.46	1.26	0.11-6.55	2.51	0.99-6.36	1.98	0.40-4.20
Sivakasi	26.39	2.30-43.57	16.11	10.83-6.29	1.65	0.16-10.84	2.81	0.18-8.86	1.86	0.20-5.20
Srivilliputhur	19.09	15.35-7.81	15.34	3.71-41.77	1.27	0.26-5.63	2.5	0.65-6.64	2.34	1.32-2.89
Rajapalayam	20.14	0.81-46.99	19.2	1.08-19.97	2.04	0.41-8.39	2.29	0.26-5.81	2.02	0.50-4.00
Thiruchuli	13.25	0.41-38.34	17.68	11.14-8.54	1.18	0.12-6.59	2.19	1.14-4.99	0.89	0.20-2.60
Kariapatti	12.87	0.19-43.78	13.0	2.32-23.55	1.65	0.19-22.26	2.14	0.18-7.39	2.63	0.10-12.70
Narikudi	28.13	11.5542.03	14.0	8.99-16.52	1.40	0.36-8.40	2.18	0.34-6.07	1.58	0.20-5.20
Overall district	14.15	0.13-51.04	14.49	1.08-41.77	1.3	0.11-22.26	2.11	0.1-5.14	1.80	0.10-12.80
Deficiency (%)	20.74		0.08		64.42		4.46		8.92	
SD	7.28		2.73		1.18		1.08		1.10	
CV (%)	0.51		0.19		0.91		0.51		0.61	

The DTPA-Cu ranged between 0.10 to 15.14 mg kg^{-1} in the soils of different blocks of the study area with an average value of 2.11 mg kg^{-1}. The results indicated that copper was in sufficient amount in nearly 90.44 per cent of samples. Generally in all the blocks the available copper shows mean values more than its critical value of 1.2 mg kg^{-1} (Krishnaswamy *et al*. 1994).

The hot water soluble boron content varied from 0.1 to 12.8 mg kg^{-1} with an overall mean value of 1.80 mg kg^{-1}. Out of 1308 soil samples analyzed, 91.13 per cent of samples were found to be sufficient for boron (Table 3).

Delineation of micronutrient status by thematic maps

The DTPA extractable soil micronutrients and hot water soluble boron status of different blocks of the were grouped into three categories based on the critical limits. The thematic map clearly shows the blocks that are deficient in micronutrient status which require utmost attention to sustain the soil productivity. The available Zn status suggests that out of eleven blocks, four blocks namely Virudhunagar, Aruppukottai, Vembakottai and Tiruchuli are low in available zinc status, six blocks namely Watrap, Srivilliputhur, Sivakasi, Sattur, Kariapatti and Narikudi are medium in available zinc, only one block namely Rajapalayam was high in available zinc (Fig.1). The available iron status suggests that out of eleven blocks, four blocks namely Vembakottai, Virudhunagar, Aruppukottai and Tiruchuli are low in available zinc status, six blocks namely Watrap, Srivilliputhur, Sivakasi, Sattur, Kariapatti and Narikudi are medium in available iron, only one block namely Rajapalayam was high in available iron (Fig. 2). The available manganese status suggests that all eleven blocks are high in available manganese. The available copper status suggests that all eleven blocks are high in available copper. The hot water soluble boron status suggests that all blocks are high except Tiruchuli block which is medium in boron level.



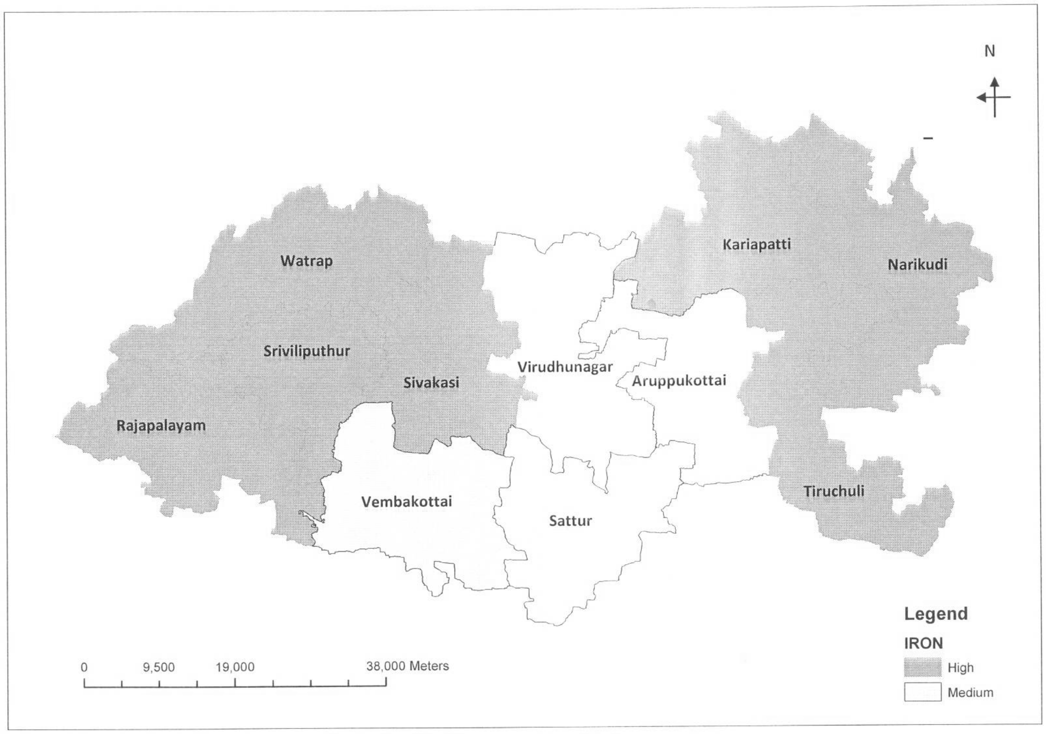


Fig 2. Available Iron Status in Virudhunagar District (at block level)

Interaction between soil properties and available micronutrient status

The simple correlation was worked out to ascertain the degree of relationship between soil properties and DTPA-extractable micronutrients status of the study area. In the alkaline conditions, the availability of zinc, iron and manganese reduces due to the precipitation process. In alkaline pH range particularly above pH 7.5, zinc forms negatively charged ions called zincate ion. Probably in alkali solution, the hydroxides of zinc are formed. The change in pH may alter the stability of soluble and insoluble organic complexes of zinc or the solubility of antagonistic ions (Singh and Singh 1996). The correlation study indicated negative correlation with pH (r = - 0.012). This may be due to formation of insoluble zinc hydroxides (Singh *et al.* 2005). Similarly the DTPA- Mn was positively correlated (r=0.005) with pH and this might be due to conversion of Mn^{2+} to manganese oxides, which are water insoluble and cannot be extracted with DTPA (Parmer *et al.* 1999).The DTPA-Fe was positively correlated with pH (r = 0.036). The reduction in availability of iron with an increase in pH may be attributed to conversion of Fe^{2+} ions to Fe^{3+} ions. At high pH, iron may precipitate as insoluble Fe $(OH)_2$ (Sharma *et al.,* 2003). The availability of DTPA-Cu was positively correlated with pH (r = 0.007). Singh *et al.* (1997) and Lal and Mathur (1989) also obtained a positive correlation between DTPA Cu and soil pH. But hot water soluble boron was negatively correlated with pH (r = - 0.013).

The DTPA – Fe was positively correlated with EC (r = 0.011). The increasing levels of total soluble salts concentration and its composition have a differential effect on the availability of iron (Sakal *et al.* 1988; Gupta *et al.* 2003). The DTPA-Zn (r = 0.007), DTPA – Mn (r = 0.030) are positively correlated with soil EC. DTPA-Cu (r = -0.008) was negatively correlated with soil EC. Hot water soluble boron increased with electrical conductivity. It was negatively correlated (r = -0.026) with EC. Due to increasing concentration of soluble salts, the available boron content of irrigated soils increased (Talati and Agarwal 1974) and Choudhary and Shukla 2004). Generally in Virudhunagar district all the agricultural fields are irrigated by well water, hence this may be one of the reasons for high level of boron.

A negative correlation existed between organic carbon and DTPA micronutrients *viz.,* Fe (r = -0.158), Mn (r = -0.021), Cu (r = -0.039), Zn (r = -0.041) and hot water soluble boron (r = -0.035) content of the soil. Similar relationship has been reported by Katyal and Sharma (1991). This may be attributed to the inability of organic matter in inhibiting the complexation and unavailability of zinc in soil (Hodgson 1963; Sakal 1988). The DTPA–Cu was negatively correlated (r = -0.039) with soil organic carbon. These results also find support from the works of Dhane and Shukla (1995). There also existed a negative correlation between DTPA-Fe and organic carbon (r = -0.158). Katyal and Sharma (1991) also found a decrease DTPA- Fe with increasing organic matter. The DTPA-Mn distribution was negatively correlated with organic carbon (r = -0.021). The hot water soluble boron was negatively correlated with organic carbon (r = -0.045). Negative correlation between organic carbon and micronutrients reveals that organic carbon has no influence on micronutrient availability in soil.

The availability of Zn, Fe and B are negatively correlated with soil $CaCO_3$ due to precipitation or oxidation of Zn into its carbonates like $ZnCO_3$ and oxidation of Fe^{2+} to Fe^{3+} oxides or transformation of available iron into carbonates or retention by the $CaCO_3$ present on the surface of the calcium carbonate particles (Sharma *et al.* 2003). While the available copper had positive correlation with $CaCo_3$ Singh *et al*. (1997) and Minakshi *et al*. (2006) also found a similar relationship. The DTPA-Zn was negatively correlated (r = -0.009) with calcium carbonate. The DTPA-Cu was positively correlated (r = 0.025) with calcium carbonate. The DTPA-Fe was negatively correlated (r = -0.037) with calcium carbonate. The DTPA-Mn was positively correlated (r = 0.057) with calcium carbonate. The hot soluble boron was negatively correlated (r = -0.023) with calcium carbonate. The findings of Sanjay Arora and Chahal (2001) corroborates with the above findings.

Conclusion

From the investigations it is very clear that the soils of Virudhunagar district are severely deficient in available zinc. While iron, copper and boron are moderately deficient. The availability of Mn is sufficient in general and required to be applied in specific situations as per the need. To overcome the deficiency of zinc and iron, which is declining, the need for sustained application of organic manures or through supplementation with inorganic fertilizers is essential. Besides, the edaphic factors such as organic carbon content and free lime status are widely believed to be circumventing the availability of micronutrients, which also needs to be addressed to develop strategies for alleviation of micronutrient deficiencies in Virudhunagar district of Tamil Nadu.

References

Anonymous (2003). Annual report of the All-India Coordinated Scheme of Micro and Secondary nutrients and polluted elements in the soils and plants, Tamil Nadu Agricultural University, Coimbatore.

Anonymous (2007). Annual report of the All-India Coordinated Scheme of Micro and Secondary nutrients and polluted elements in the soils and plants, Tamil Nadu Agricultural University, Coimbatore.

Chaudhary, D.R. and Shukla, L.M. (2004). Boron forms and their relationship with characteristics of Arid soil of Western Rajasthan. *Journal of the Indian Society of Soil Science* **52**, 197-199.

Dhane, S.S. and Shukla, L.M. (1995). Distribution of DTPA - extractable Zn, Cu, Mn and Fe in some soil series of Maharashtra and their relationship with some soil properties. *Journal of the Indian Society of Soil Science* **43**, 597-600.

Gupta, R.K. and Srivastava, P.C. (1990). Distribution of different forms of micronutrient cations in some cultivated soils of Sikkim. *Journal of the Indian Society of Soil Science* **38:** 558-560.

Hodgson, J. F. (1963). Chemistry of micronutrient elements in soils. *Advances in Agronomy* **15**, 15-19.

Jackson, M.L. (1973). *Soil chemical analysis* - An advanced course, Second Edition, University of Wisconsin, Madison, USA.

Katyal, J.C. and Sharma, B.D. (1991). DTPA-extractable and total Zn, Cu, Mn, and Fe in Indian soils and their association with some soil properties. *Geoderma* **49**, 165-179.

Krishnasamy,R., Shanmugam. M., Poongothai. S., Valliappan, K., Mani. S., Mallika Vanangamudi, Santhi, P. and Devarajan, R. (1994). Twenty five years of micronutrients research in soils and crops of Tamil Nadu 1967-1992. *Research Bulletin*, Department of Soil Science and Agricultural Chemistry, Tamil Nadu Agricultural University, Coimbatore.

Lal, S. and Mathur, B.S. (1989). Effect of long term application of manures and fertilizers on the DTPA extractable micronutrients in arid soil. *Journal of the Indian Society of Soil Science* **37**, 588-590.

Lindsay, N.L. and Norvell, W.A. (1978). Development of DTPA soil test for zinc, iron, manganese and copper. *Soil Science Society of America* 42, 421-428.

Minakshi, N.S. Tur., Nayyar, V.K., Sharma, P.K. and Sood, A.K. (2005). Spatial distribution of micronutrients in soils of Patiala district -A GIS approach. *Journal of the Indian Society of Soil Science* **53,** 324-329.

Nayak, A.K., Chinchamalatpure, Anil. R., Gururaja Rao, G., Khandelwal, M.K. and Tyagi, N.K. (2006). Spatial variability of DTPA extractable micronutrients in soils of Bara tract of Sardar Sarovar canal command in Gujarat state India. *Journal of the Indian Society of Soil Science* **42**, 137-145.

Parmer, D.K., Sharma, V., Sharma, K.D. and Sharma, T.R. (1999). Micronutrient status of vegetables growing pockets in cold desert area of Himachal Pradesh. *Journal of the Indian Society of Soil Science* **47**, 280-283.

Piper, C.S. (1966). *Soil and plant analysis*. Hans Publishers, Bombay.

Richard Bell and Bernie Dell (2006). Importance of Micronutrients in Crop Production: A Review of the Changing Scene.*18th World Congress of Soil Science,* July 9-15, Philadelphia, Pennsylvania, USA.

Sahoo, A.K., Chattopadhyay, T., Singh, R.S. and Shyampura, R.L. (2003). Characterization of soils and vertical distribution of available micronutrients under different landforms of Malwa plateau, Rajasthan. *Indian Agriculture* **47**, 217-223.

Sakal, R., Sing, A.P. and Singh, S.P. (1988). Distribution of available zinc, copper, iron and manganese in old alluvial soils as related to certain soil characteristics, *Journal of the Indian Society of Soil Science* **36**, 59-63,

Sanjoy Arora and Chahal, D. S. (2001). Available boron status in major soil series of Punjab in relation with soil characteristics. *In: Proceedings of 4th Punjab soil congress.* Ludhiana, Feb., 9-10, India.

Setia, R.K. and Sharma, K.N. (2004). Effect of continuous cropping and long-term differential fertilization on profile stratification of DTPA extractable micronutrients. *Journal of Food, Agriculture and Environment* **2**, 206.

Sharma, P.P., Singh,M. and Sharma, J.P. (2003). Correlation studies on micronutrients vis –a- vis soil properties in some soil of Nagpur district in semi arid region of Rajasthan. *Journal of the Indian Society of Soil Science* **51**, 522-527.

Singh, A.K., Grace, D., Dkhar. and Nongkyrih, P. (1997). Effect of some soil properties on availability of micronutrients in Entisols of Magalaya. *Journal of Indian Society of Soil science* **45**, 581-583

Singh, S.P., Gupta, R.A. and Singh, H.N. (2005). Distribution of micronutrient cations in some soils of Kumaon region of Uttranchal. *Agropedology* **15**, 117-119

Soil Survey and Land Use Organization (2006). Soil Resources of Pudukottai district. Report No.80 Published by SSLUO, Thanjavur.

Soil Survey and Land Use Organization (2007). Soil Resources of Pudukottai district. Report No.81 Published by SSLUO, Thanjavur.

Takkar, P.N., Nayyar, V.K., Bansal, R.L., Dwivedi, R.S., and Manna, M.S. (1997). *Annual progress report of ICAR co-ordinated micronutrient scheme* 1996-97. Punjab Agricultural University, Ludhiana.

Talati, N.R., and Agarwal, S.K. (1974). Distribution of variable forms of Boron of North-West Rajasthan soils. *Journal of Indian Society of Soil Science* **22**, 262-268.

Walkley, A., and Black, I.A. (1934). An examination of soil organic carbon by chromic acid titration method. *Soil Science* **37**, 29.

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