



HAL
open science

Spatial distribution of macro- and micro- nutrients in soils of Saharsa district of Bihar

Ajeet Kumar

► **To cite this version:**

Ajeet Kumar. Spatial distribution of macro- and micro- nutrients in soils of Saharsa district of Bihar. AN ASIAN JOURNAL OF SOIL SCIENCE, 2015, 10 (2), pp.276-282. <10.15740/HAS/AJSS/10.2/276-282>. <hal-04676717>

HAL Id: hal-04676717

<https://hal.science/hal-04676717v1>

Submitted on 3 Sep 2024

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire HAL, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



Distributed under a Creative Commons CC BY 4.0 - Attribution - International License

Research Article

DOI: 10.15740/HAS/AJSS/10.2/276-282

Spatial distribution of macro- and micro- nutrients in soils of Saharsa district of Bihar

■ AJEET KUMAR

Received : 08.08.2015; Revised : 07.11.2015; Accepted : 22.11.2015

AUTHOR FOR CORRESPONDENCE :

AJEET KUMAR, Regional Research Station, Madhopur, WEST CHAMPARAN (BIHAR) INDIA
Email: ajeetrau@gmail.com

Summary

The soils samples (0-30 cm depth) were collected from ten block of Saharsa district. The study of macro- and micro-nutrients of some soils of the district was carried out to assess the soil fertility and micro- nutrient status and their relationship with each other. Soils were analyzed for DTPA extractable Zn, Cu, Mn, Fe and hot water extractable B in relation to chemical properties of soils. The mean values for DTPA-extractable Zn, Cu, Mn, Fe and hot water extractable B were 2.36, 1.52, 113.93, 766.03 and 0.10 mg kg⁻¹, respectively. The mean values of available N, P₂O₅, K₂O and SO₄-S were 382.04, 38.31, 208.86 and 22.65 kg ha⁻¹, respectively. Distribution of micronutrients cations were influenced positively by pH, EC and organic carbon content of the soil. Results indicated that the micro- nutrient cations were significantly correlated with each other, suggesting about the dynamic equilibrium among them.

Key words : Soil fertility, Macro- and micro-nutrients, Soil reaction, DTPA

How to cite this article : Kumar, Ajeet (2015). Spatial distribution of macro- and micro- nutrients in soils of Saharsa district of Bihar. *Asian J. Soil Sci.*, **10**(2) : 276-282.

Introduction

Soil macronutrients are essential to plants growth; maintain ecosystems and high crop yields. However, imbalance fertilization, deteriorate the precious soil environment particularly N and P can be potentially hazardous to water resources when their available components in soils are excessive, because available macronutrients can be transported off site in runoff due to rain or irrigation (Phupaibul *et al.*, 2004 and Ju *et al.*, 2007) and subsequently degrades the soil and reduced the productivity. Several studies have documented that soil properties vary across agricultural fields, causing spatial variability in crop yields. Therefore, their proper management is necessary to avoid deteriorating the environment while meeting the requirement of high crop productivity and farmer must be advised to use balanced

fertilizers/manures, and accordingly adopt suitable cropping pattern. Hence it is necessary to evaluate the fertility status of the soil and promote the recommendations of soil test for balanced nutrition to maintain soil health.

Soil fertility is one of the important factors controlling the crop yield. Soil related limitations affecting the crop productivity including nutritional disorders can be determined by evaluating the fertility status of the soils. Soil testing provides the information about the nutrient availability of the soil upon which the fertilizer recommendation for maximizing crop yield is made. Zinc (Zn), copper (Cu), manganese (Mn), iron (Fe) and boron (B) are essential micro- nutrients for plant growth. Through their involvement in various enzymes and other physiologically active molecules, these micro-nutrients are important for gene expression, biosynthesis of

proteins, nucleic acids, growth substances, chlorophyll and secondary metabolites, metabolism of carbohydrates and lipids, stress tolerance, etc. (Singh, 2004; Rengel, 2007 and Gao *et al.*, 2008). Original geologic substrate and subsequent geochemical and pedogenic regimes determine the total amounts of micro-nutrients in soils. However, total amount is rarely indicative of the availability by plant, because availability depends on soil pH, organic matter content, adsorptive surfaces and other physical, chemical and biological conditions in the rhizosphere. Micro-nutrient availability to plants can be determined in direct uptake experiments or estimated with techniques that correlate the quantities of micro-nutrients extracted chemically from the soils (Kabata-Pendias, 2001). Micronutrient cycling is quite different among various terrestrial ecosystems (Han *et al.*, 2007). India is the second largest consumer of mineral fertilizers in the world after China, consuming about 26.5 million tons (Jaga and Patel, 2012). The application of mineral fertilizers is the most advantageous and the fastest way to increase crop yields and their deficiency leads to various types of disorders in crops (Duarah *et al.*, 2011). Stunted growth is a symptom for many deficiencies, especially stunted stems with nitrogen deficiency and stunted roots in phosphorus deficiency. Chlorosis, that is, decreased chlorophyll synthesis or increased chlorophyll degradation, is observed with magnesium, nitrogen, and iron deficiencies. Magnesium is the central atom for the electron cloud of chlorophyll from which electrons flow through the light reactions. Necrosis, dead spots or zones, is observed when magnesium, potassium or manganese deficiencies are present. Colour changes such as excessive anthocyanin production is observed in stems with phosphorus deficiency. They generally pick up an intense purple colour sometimes extending onto the leaves (Koning, 1994). Application of major nutrients (nitrogen, phosphorus, potassium) became common; therefore, the crops started responding to micronutrient fertilizers. At present about 48.1 per cent of Indian soils are deficient in diethylene-tri-amine penta acetate (DTPA) extractable zinc, 11.2 per cent in iron, 7 per cent in copper and 5.1 per cent in manganese. Apart from the deficiency of these micronutrients, deficiencies of boron and molybdenum have also been reported in some areas. Areas with multi-micronutrient deficiencies are limited, thus simple fertilizers are sufficient to exploit the potential of crops and cropping systems (Gupta, 2005). Concerted efforts have been made through the National

Project on Management of Soil Health and Fertility Project (NPMSHF) to delineate the soils of Saharsa district of Bihar, regarding the spatial variability of macro and micronutrients. Keeping in view, the above importance of mineral fertilizers for crop growth and yield, this study on the status of soil macro and micro nutrients was carried out with the objectives (i) to assess the macronutrients, that is, NH_4^+ , H_2PO_4^- , K^+ and $\text{SO}_4^{=}$ and micronutrients, that is, Zn^+ , Cu^+ , Mn^{++} , Fe^{++} and B^{+++} distribution on the surface soils and (ii) to explore the relationships among micro-nutrients with other soil properties.

The present study is mainly focused on testing of soil samples to determine their current fertility status and to provide information to the farmer regarding nutrient availability in soils. The baseline data so generated can form the basis for the fertilizer recommendations for maximizing crop yields and further to maintain the optimum fertility in soil year after year.

Resource and Research Methods

The present investigation was carried out to assess macro and micro-nutrient status of the soils of Saharsa district. The Saharsa district located between 25.88° N Latitude and 86.6° E Longitude over the globe. The total geographical area of the districts is 1661.30 Sq. km with 19 per cent of the total geographical area of the state. Soils of Saharsa district has, non-calcareous, non-saline, neutral, and light alluvial type of soil. Salinity and sodicity hazard appears in some patches in the zone, due to poor drainage. The Kusaha tragedy in, 2008 had changed soil scenario in some parts of the zone. The climate of the district is warm humid with average annual rain fall of 1450 mm, which is suitable for good cultivation of rice, jute and maize. The average temperature ranges from 5°C to 38°C . The forty representative soil samples (0 to 30cm) were collected from 40 villages of Saharsa districts. This district consists of ten blocks *viz.*, Banma itahri, Kahra, Mahishi, Nauhatta, Patarghat, Salkhua, Sattar katiya, Saur bazaar, Simri bakhtiyarpur, and Sonbarsa; in which total 40 villages (four villages from each block) were selected. Soil samples were collected with auger having six spots were selected for each composite sample. All the composite soil samples were air-dried, ground and passed through 2 mm sieve for chemical analysis. All the samples were stored in the polythene bags for further analysis. Soil pH and electrical conductivity (EC) were determined by potentiometry

and direct reading conductivity meter using 1: 2.5 soil water suspensions (Jackson, 1973). The composite soil samples were analyzed for available nitrogen (Subbiah and Asija, 1956), available P_2O_5 (Bray and Kurtz, 1945), neutral ammonium acetate extractable K_2O (Jackson, 1973), organic carbon (Walkley and Black, 1934), and available $SO_4=S$ (Chesnin and Yien, 1951). The available Zn, Cu, Mn and Fe extracted with DTPA (Lindsay and Norvell, 1978) were determined on an Atomic Absorption Spectrophotometer. The hot water soluble B was estimated by UV-VIS Spectrophotometer (Wear, 1965). The relationship between various soil properties and micro-nutrients distribution were established by using simple correlation co-efficient.

Research Findings and Discussion

The results obtained from the present investigation as well as relevant discussion have been summarized under following heads :

Chemical characteristics of soil :

Forty surface soils (0 to 30 cm) of Saharsa district were analyzed. The results of soil pH, and EC represented in Table 1 and 2, respectively. Chemical properties of the soils were positively and significantly correlated with each other except S which was significantly correlated with pH, EC and available P_2O_5 .

pH :

Result shows that pH of the soils ranged from 6.5 to 8.1. Out of forty soil samples, majority of soil samples (35%) fall in the range of 7.5 to 8.0 followed by 32.5 per cent samples in the range of 7.11 to 7.5. Very little number

of soil samples, about 10 per cent fell in the category of alkaline range. The measure of soil pH is an important parameter which helps in identification of chemical nature of the soil (Shalini *et al.*, 2003) as it measures hydrogen ion concentration in the soil to indicate the acidity or alkalinity nature of the soil. Soil acidity (pH) in the range 5.5-7.5 though rarely affects the growth of most crops directly, but can influence the availability of other nutrients. The soil samples have favourable pH, with pH varying from 6.5 to 8.1, indicating neutral to slightly alkaline nature. The lowest pH value of 6.5 was found in sample number 13, while a maximum pH of 8.1 was found in sample number 22 and 34 (Table 1). The alkaline nature in the soil samples may be due to high amount of leaching of exchangeable anions as observed in the field. In Satarkataiya and Kahra block of Saharsa district, the pH of soil was slightly acidic in reaction which might be due to the high rainfall leading to the leaching losses of bases from the surface soils. Application of nitrogenous fertilizers and decomposition of organic residues hastened the soil acidity.

Electrical conductivity :

Conductivity, as a measure of current carrying capacity, gives a clear idea of the soluble salts present in the soil. It plays a major role in the salinity of soils. Lesser the EC value, low will be the salinity value of soil and vice versa. Even though, soil conductivity is influenced by many factors, high conductivities are usually associated with clay-rich soil and low conductivities are associated with sandy and gravelly soils. This is a result of the shape and physical properties of the particles which make up the soil. A salt affected soil is defined as soil that has been adversely affected the growth of most

Sr. No.	pH values	Range	No. of samples	(% of samples)
1.	6.5 to 7.00	6.5-6.9	9	(22.5)
2.	7.00 to 7.5	7.11-7.5	13	(32.5)
3.	7.5 to 8.0	7.51-7.94	14	(35)
4.	8.0 to 8.5	8.02-8.1	4	(10)

EC (dS/m)	Category	Range	No. of samples	(% of samples)
< 0.7	All crops	0.014-0.310	35	(87.5)
0.7 – 2.0	Most crops	0.75-0.82	5	(12.5)
2.0 – 10.0	Salt tolerant crops	----		
10.0 – 32.0	Most halophytes	----		
33.0 >	No crops (sea water)	----		

crops by the presence of anion or cation of soluble salts. This type of soil is commonly seen in arid and semi-arid regions; in irrigation command areas; in regions with poor drainage and in areas where poor quality water is used for irrigation, because there is insufficient rainfall to flush them from the upper soil layers, which include both sodic and saline soils. The soluble salts concentration above 4 dS/m in soil moisture inhibits the seed germination and growth of most commercial crops, which adversely affects the biomass production and economic yield. In the present study, it is very much clear from the results that the salinity problem is not critical as the saline criterion was < 0.7 , indicating the good quality of soil and considered suitable for agriculture purposes (Table 2).

Available micronutrients status and their influence in soil :

The soil organic carbon (OC), available N, P_2O_5 , K_2O , $SO_4^{=}$ S and DTPA- extractable Zn, Cu, Mn, Fe and hot water extractable B are presented in Table 3. Result shows that organic carbon content ranged from 6.0 to 25.2 g kg^{-1} with a mean value of 14.74 g kg^{-1} . The available N, P_2O_5 , K_2O and $SO_4^{=}$ S varied from 290.20 to 893.17 (mean 382.04), 24.62 to 64.37 (mean 38.31), 55.60 to 359.11 (mean 208.86) and 6.20 to 95.10 (mean 22.65) $kg\ ha^{-1}$, respectively. The high organic carbon content in the soil is due the luxuriant grasses growth along with the seasonal decomposition of vegetative parts and roots.

Nutrient removal per tonne of economic produce was of the following order (Aulakh, 1985): Groundnut - Fe 2284 g, Zn 109 g, Mn 93 g, and Cu 36 g ha^{-1} ; Pigeonpea- Fe 1440 g, Zn 38 g, Mn 128 g and Cu 31 g; Chickpea- Fe 1302 g, Zn 57g, Mn 105 g and Cu 17 g.

Nutrient removal for major cereals in this region was as follows : Maize- Fe 2130 g, Zn 380 g, Mn 340 g, B 240 g, Cu 110 g, Mo 9 g and also 81 kg Cl (IFA, 1992); Rice- Fe 150 g, Zn 40 g, Mn 675 g, Cu 18 g, B 15 g (Yoshida, 1981).

Iron :

Available Fe contents in the surface soils ranged from 11.00 to 1045.00 $mg\ kg^{-1}$ with a mean value of 766.03 $mg\ kg^{-1}$ (Table 3). All the soils had significant amount of Fe considering 4.5 $mg\ kg^{-1}$ as critical limit as suggested by Lindsay and Norvell (1978). It showed positive and significant correlations with pH ($r = 0.8623^{**}$), OC ($r = 0.8355^{**}$), available N ($r = 0.8302^{**}$), available P_2O_5 ($r = 0.7812^{**}$), and also positive and significant correlations with other micro- nutrient cations. Similar results were also reported by Verma *et al.* (2005), Jiang *et al.* (2009) and Bassirani *et al.* (2011).

Manganese :

Available Mn in the surface soils varied from 45.00 to 150.00 $mg\ kg^{-1}$ with a mean value of 113.93 $mg\ kg^{-1}$. Considering 1.0 $mg\ kg^{-1}$ as critical limit for Mn deficiency (Lindsay and Norvell, 1978), all the soils had sufficient amounts of available Mn. In simple correlation co-efficient studies (Table 4), available Mn showed significant and positive correlation co-efficients with pH ($r = 0.8938^{**}$), EC ($r = 0.5166^*$), OC ($r = 0.7882^{**}$), available N ($r = 0.7994^{**}$), available P_2O_5 ($r = 0.8364^{**}$), and available K_2O ($r = 0.5402^*$). Available Mn also had positive significant correlations with other micronutrient cations content in the soils. Soil micro- nutrient cations like Fe, Cu and Zn have significant correlation with available Mn, suggesting variation in their distribution dependent upon common soil factors (Follet and Lindsay,

Soil characteristics	Mean	Range
Organic carbon (g kg^{-1})	14.74	6.0 – 25.2
Available N (kg ha^{-1})	382.04	290.20 – 893.17
Available P_2O_5 (kg ha^{-1})	38.31	24.62 – 64.37
Available K_2O (kg ha^{-1})	208.86	55.60 – 359.11
Available $SO_4^{=}$ S (kg ha^{-1})	22.65	6.20 – 95.10
Fe (mg kg^{-1})	766.03	11.00 – 1045.00
Mn (mg kg^{-1})	113.93	45.00 – 150.00
Cu (mg kg^{-1})	1.52	0.65 – 2.60
Zn (mg kg^{-1})	2.36	1.30 – 4.90
B (mg kg^{-1})	0.10	0.046 – 1.004

1970).

Copper :

Available copper content in the surface soils ranged from 0.65 to 2.60 mg kg⁻¹ with a mean value of 1.52 mg kg⁻¹. Considering 0.2 mg kg⁻¹ as critical limit for Cu deficiency (Lindsay and Norvell, 1978), all the soils were found to be in adequate range. The micro- nutrient cation showed significant and positive correlation co-efficient with pH (r = 0.8220**), OC (r = 0.7422**), available N (r = 0.7590**), available P₂O₅ (r = 0.7840**) and available K₂O (r = 0.5161*). This finding is in conformity with those of Singh *et al.* (2006); Verma *et al.* (2007); Jiang *et al.* (2009) and Bassirani *et al.* (2011).

Zinc :

Available Zn in the studied surface soils varied from 1.30 to 4.90 mg kg⁻¹ with a mean value of 2.36 mg kg⁻¹. Similar finding was also reported by Raina *et al.* (2003) in apple growing soils of Himachal Pradesh, India. Considering 0.6 mg kg⁻¹ as critical limit of available Zn as suggested by Takkar and Mann (1975), the entire representative soils were under sufficient categories. Available Zn showed significant and positive correlation co-efficient with pH (r = 0.7500**), OC (r = 0.7075**), available N (r = 0.6897**), and available P₂O₅ (r = 0.6874*). This finding is in agreement with the earlier findings of Venkatesh *et al.* (2003); Verma *et al.* (2005) and Sharma and Chaudhary (2007). It also showed positive and significant correlation with other micronutrient cations. This result is also supported by the finding of Bassirani *et al.* (2011). Amount of zinc required for alleviating zinc deficiency varied with severity of deficiency, soil types, nature of crops and

cultivars. In majority of instances 5.5 kg zinc ha⁻¹ was found to be ideal dose. Zinc deficiency can be best alleviated with the use of 11 kg Zn ha⁻¹ to wheat, rice and maize; 5.5 kg Zn ha⁻¹ to soybean, mustard, raya, sunflower and sugarcane and with 2.5kg Zn ha⁻¹ to groundnut, ragi, gram, linseed, green gram, lentil etc.

Boron :

Hot water soluble B content in soils ranged from 0.046 to 1.004 mg kg⁻¹ with a mean value of 1.00 mg kg⁻¹. The range of available B in soils of different states of India varied from traces to 12.2 mg kg⁻¹ (Das, 2000). The chemical properties of the soils did not influence the B content in the soils as evident by the correlation studies. The relationship between the soil properties and water soluble B was positive but statistically non-significant (Table 4). The B had non-significant correlation with organic carbon of the soil due to complexing with them. Iron, Mn, Cu and Zn are most soluble under acid conditions. Organic matter and manure applications affect the immediate and potential availability of micronutrient cations (Rengel, 2007). The micronutrient cations react with organic molecules to form organo-metallic complexes as chelates which increase the availability of the micro- nutrient. These chelates may be synthesized by the plant roots and released to the surrounding soil. The chelate may also be present in the soil humus or may be synthetic compound added to the soil to enhance micronutrient availability (Brady and Weil, 2002). The soil organic matter related to chemical indices, were positively and significantly correlated with DTPA-extractable micro-nutrient, however, S content of the soils do not show the significant correlation with DTPA-extractable micro-

Table 4 : Correlation amongst the different soil parameters under study

Parameters	EC	OC	Available macronutrients				Available micronutrients				
			N	P	K	S	Fe	Mn	Cu	Zn	B
pH	0.6445*	0.8528**	0.8536**	0.8832**	0.5884*	0.5955*	0.8623**	0.8938**	0.8220**	0.7500**	0.2830
EC		0.5444*	0.5430*	0.5974*	0.6678**	0.5330*	0.4519	0.5166*	0.4861	0.3873	0.1760
OC			0.9100**	0.7742**	0.5281*	0.4879	0.8355**	0.7882**	0.7422**	0.7075**	0.1982
Available N				0.7821**	0.5545*	0.4845	0.8302**	0.7994**	0.7590**	0.6897*	0.2088
Available P					0.6562*	0.6083*	0.7813**	0.8364**	0.7840**	0.6874*	0.2414
Available K						0.4683	0.4563	0.5402*	0.5161*	0.3995	0.2386
Available S							0.4860	0.4976	0.4784	0.4102	0.1820
Available Fe								0.8491**	0.7675**	0.7201**	0.2050
Available Mn									0.8260**	0.7594**	0.2657
Available Cu										0.7798**	0.3918
Available Zn											0.2689

nutrients, indicating the role of organic matter enhancing available micro-nutrients. Again, DTPA-extractable micro-nutrient cations were positively and significantly correlated with soil pH. This might be due to leaching losses of micronutrients with the high rainfall leading to the low content of micro-nutrients in the soils even though these micro-nutrients are most soluble and readily available.

Conclusion :

It is concluded from these insights, that there is wide variation in fertility of soils, developed on various land forms in the study area, but, by and large, the soils are low in available N, low in available P, medium in organic carbon and high in available K contents. The deficient nutrients have to be restored through chemical fertilizers and/or organic manures to maintain soil health.

Acknowledgement :

The author is highly thankful to Dr. Umesh Singh, Associate Dean -cum- Principal, MBAC, Agwanpur, Saharsa, for providing financial support to run the NPMSHF Project. The author is also thankful to Sri Bachan Jha, Senior Research Fellow of "NPMSHF project" for the finishing of all assigned duties, well in time, related with soil analysis and their compilation.

Literature Cited

- Aulakh, M.S. (1985).** Content and uptake of nutrients by pulses and oilseed crops. *Indian J. Ecol.*, **12** (2):238-242.
- Bassirani, N., Abolhassani, M. and Galavi, M. (2011).** Distribution of available micro-nutrients as related to the soil characteristics of Hissar; Haryana (India). *African J. Agric. Res.*, **6** : 4239-4242.
- Brady, A.C. and Weil, R.R. (2002).** *The nature and properties of soils*. 13th Ed., Prentice Hall, New Jersey, U.S.A.
- Bray, R.H. and Kurtz, L.T. (1945).** Determination of total, organic and available forms of phosphorus in soils. *Soil Sci.*, **59** : 39-45.
- Chesnin, L. and Yien, C.H. (1951).** Turbidimetric determination of available phosphate. *Proc. Soil Sci. Soc. Am.*, **15** :149-151.
- Das, D.K. (2000).** Boron. In: *Micro-nutrients: Their behaviour in soils and plants*. Kalyani Publishers, Ludhiana. pp. 127-161.
- Duarah, I., Deka, M., Saikia, N. and Deka Boruah, H.P. (2011).** Phosphate solubilizers enhance NPK fertilizer use efficiency in rice and legume cultivation. *Biotechnology*, **1** (4):227-238.

Follett, R. H. and Lindsay, W.L. (1970). Profile distribution of Zn, Fe, Mn and Cu in Colorado soil. *Tech. Bullet. Colorado*, **110** : 79.

Gao, S., Yan, R., Cao, M., Yang, W., Wang, S. and Chen, F. (2008). Effect of copper on growth, antioxidant enzymes and phenylalanine ammonia-lyase activities in *Jatropha curcas* L. seedling. *Plant Soil Environ.*, **54** : 117-122.

Gupta, A.P. (2005). Micronutrient status and fertilizer use scenario in India. *J. Trace Elem. Med. Biol.*, **18** (4):325-31.

Han, F.X., Kingery, W.L., Hargreaves, J.E. and Walkard, T.W. (2007). Effect of land uses on solid-phase distribution of micro-nutrients in selected vertisols of the Mississippi River Delta. *Geoderma*, **142**:96-103.

International Fertilizer Industry Association (IFA) (1992). *World fertilizer use manual*. Paris P. 632.

Jackson, M.L. (1973). *Soil chemical analysis*. Prentice Hall of India Pvt. Ltd., New Delhi (INDIA).

Jaga, P.K. and Patel, Y. (2012). An overview of fertilizers consumption in India: Determinants and Outlook for 2020-A Review. *Internat. J. Scientif. Engg. Technol.*, **1** (6):285-291.

Jiang, Y., Zhang, Y.G., Zhou, D., Qin, Y. and Liang, W.J. (2009). Profile distribution of micro-nutrients in an aquic brown soil as affected by land use. *Plant Soil Environ.*, **55** : 468-476.

Ju, X.T., Kou, C.L., Christie, P., Dou, Z.X. and Zhang, F.S. (2007). Changes in the soil environment from excessive application of fertilizers and manures to two contrasting intensive cropping systems on the North China Plain. *Environ. Poll.*, **145** (2) : 497-506.

Kabata-Pandias, A. (2001). *Soils and plants*. 3rd Ed., CRC Press, Boca Raton, Florida.

Lindsay, W.L. and Norvell, W.A. (1978). Development of DTPA soil test for Zn, Fe, Mn and Cu. *Soil Sci. Soc. Am. J.*, **42**:421-428.

Phupaibul, P., Chitbuntanorm, C., Chinoim, N., Kangyawongha, P. and Matoh, T. (2004). Phosphorus accumulation in soils and nitrate contamination in underground water under export-oriented asparagus farming in Nong Ngu Lauem Village, Nakhon Pathom Province, Thailand. *Soil Sci. & Plant Nutri.*, **50** (3) : 385-393.

Raina, J.N., Choudhary, S.K. and Bhandari, A.R. (2003). Status and chemical fractions of zinc in apple orchard soils of Himachal Pradesh. *J. Indian Soc. Soil Sci.*, **51** : 161-168.

Rengel, Z. (2007). Cycling of micro-nutrients in terrestrial ecosystems. In: Marschner, P, Rengel Z. (Ed.): *Nutrient cycling in terrestrial ecosystem*. Springer-Verlag, Berlin, Heidelberg, pp. 93-121.

- Shalini, K., Devenda, H.S. and Dhindsa, S.S. (2003).** Studies on causes and possible remedies of water and soil pollution in Sanganer town of Pink City. *Indian J. Environ. Sci.*, **7** (1): 47-52.
- Sharma, J.C. and Chaudhary, S.K. (2007).** Vertical distribution of micronutrient cations in relation to soil characteristics in lower Shiwaliks of Solan district of north-west Himalayas. *J. Indian Soc. Soil Sci.*, **55**:40- 44.
- Singh, M.V. (2004).** Micronutrient deficiencies in Indian soils and field usable practices for their correction. IFA International Conference on Micronutrients, Feb. 23-24, 2004, at New Delhi.
- Singh, R.D., Kumar, S. and Panse, H. (2006).** Micro-nutrient status of soils under different vegetations in Uttaranchal Hills. *J. Indian Soc. Soil Sci.*, **54**:115-116.
- Subbiah, B.V. and Asija, G.L. (1956).** A rapid procedure for estimation of available N in Soil. *Curr. Sci.*, **25** : 259-260.
- Takkar, P.N. and Mann, M.S. (1975).** Evaluation of analytical methods of estimation of available zinc and response of applied zinc in major soil series of Ludhiana, Punjab. *Agrochemica*, **19** : 420-430.
- Venkatesh, M.S., Majumdar, B., Kailash, K. and Patiram, H. (2003).** Status of micro-nutrient cations under land use system of Meghalaya. *J. Indian Soc. Soil Sci.*, **51** : 60-64.
- Verma, V.K., Setia, R.K., Sharma, P.K., Khurana, M.P.S. and Kang, S. (2007).** Pedospheric distribution of micronutrient cations in soil developed on various landforms in north-east Punjab. *J. Indian Soc. Soil Sci.*, **55** : 515-520.
- Verma, V.K., Setia, R.K., Sharma, P.K., Singh, C. and Kumar, A. (2005).** Pedospheric variations in distribution of DTPA-extractable micronutrients in soils developed on different physiographic units in central parts of Punjab, India. *Internat. J. Agri. Biol.*, **7** : 243-246.
- Walkley, A.J. and Black, I.A. (1934).** Estimation of soil organic carbon by chromic acid titration method. *Soil Sci.*, **37** : 29-38.
- Wear, J.I. (1965).** Boron. In: *Methods of soil analysis* (C.A. Black *et al.*, Eds.), Part II. American Society of Agronomy, Madison, Winconsin, USA.
- Yoshida, S. (1981).** *Fundamentals of rice crop science*. Los Banos, Philippines, IRRI. 269 p.

Webliography

- Koning, R.E. (1994).** Mineral requirements. Plant physiology information Website. http://plantphys.info/plant_physiology/minerals.shtml.

★ ★ ★ ★ ★ ^{10th} Year of Excellence ★ ★ ★ ★ ★