ASSESSMENT AND MAPPING OF SOME IMPORTANT SOIL PARAMETERS INCLUDING SOIL ACIDITY FOR THE STATE OF JHARKHAND (1:50,000 SCALE) TOWARDS RATIONAL LAND USE PLAN

GIRIDIH DISTRICT

National Bureau of Soil Survey and Land Use Planning (ICAR)
Regional Centre, Kolkata

In collaboration with :
Deptt. Of Soil Science & Agricultural Chemistry, BAU, Ranchi, Jharkhand

Sponsored by : Department of Agriculture & Cane Development, Govt. of Jharkhand

1. INTRODUCTION

Reliable information on the location, extent and quality of soil and land resources is the first requirement in planning for the sustainable management of land resources. The components of land i.e., soils, climate, water, nutrient and biota are organised into eco-system which provide a variety of services that are essential to the maintenance of the life support system and the productive capacity of the environment. Our land mass is fixed, but the competition among different kinds of uses for this land is increasing because of rapidly rising global population. Therefore, integrated land resource planning and management are required to resolve these conflicts and soil resource survey seems to be a viable means in this process and knowledge of soil fertility status and problems of soils like soil acidity/alkalinity become essential for sustainable land use plan.

Soil fertility is an aspect of the soil-plant relationship. Fertility status of the soils is primarily and importantly dependent upon both the macro and micronutrient reserve of that soil. Continued removal of nutrients by crops, with little or no replacement will increase the nutrient stress in plants and ultimately lowers the productivity. The fertility status of the soils mainly depends on the nature of vegetation, climate, topography, texture of soil and decomposition rate of organic matter. Optimum productivity of any cropping systems depends on adequate supply of plant nutrients. GIS is a versatile tool used for integration of soil database and production of a variety of users specific and user-friendly interpretative maps. This further leads to accurately and scientifically interpret and plan some of the aspects like conservation of organic matter, soil reaction (pH) control and fertilization.

Keeping in view NBSS & LUP, Regional Centre, Kolkata in collaboration with Department of Soil Science and Agricultural Chemistry, BAU, Ranchi, Jharkhand undertook a project entitled "Assessment and mapping of some important soil parameters including soil acidity for the state of Jharkhand (1:50,000 scale) towards rational land use plan" from Department of Agriculture, Govt. of Jharkhand. The major objectives of the project were

- Preparation of districtwise soil acidity maps
- Preparation of districtwise soil fertility maps (Organic carbon, available N, P, K, S and available Fe, Mn, Zn, Cu and B)

The above maps will provide information regarding soil nutrients and soil acidity status for the districts, which will be very useful in identification of site specific problems for planning purposes. The present report deals with the above mentioned objectives of the Giridih district, Jharkhand.

2. GENERAL DESCRIPTION OF THE AREA

2.1 Location and Extent

Giridih district is located in the northern part of the state. It is bounded by Jamui in the north, Bokaro and Dhanbad in the south, Deoghar and Jamtara in the east and Kodarma and Hazaribag in the west. The total geographical area of the district is 4941 sq. km and population of 19,01,584 persons (Census of India, 2001). The district comprises one subdivision (Giridih) and twelve development blocks viz. Gawan, Tisri, Deori, Raj Dhanwar, Jamua, Bengabad, Gande, Giridih, Birni, Bagodar, Dumri, Pirtanr.

2.2 Physiography, Geology and Drainage

This district has three types of topographical areas viz. central plateau having moderate elevation, lower plateau having lower elevation and the trough basin of Damodar. The lower plateau area have relatively rough terrain having an elevation of 390 metres. In the north and north west there is a table land having an elevation of 250 metres, where steep scarp is found. Areas of Damodar trough basin lies in the south. Geologically the area is comprised with Archean granites and gneisses with capping of laterites at some places. The area is drained by river Barakar, Sakri and Usri.

2.3 Climate

The district receives average annual rainfall of 1350 mm. and most of the rainfall occurs during the rainy season. The highest temperature goes upto 40^0C but the average temperature during winter season remains at 10^0C.

2.4 Agriculture and Land Use

The hilly portion are under thick forest cover. Important trees are sal, Khair, semal, mahua, palas, kusum, kend, ashar etc. Paddy is the main crop of the area. However maize, wheat, pulses are also grown. During recent year cultivation of vegetables and seasonal fruits are considerably increased. Only 8.46 percent area of agricultural use are net irrigated and major source of irrigations are well and tubewells.

Land Use in Giridih District (1997-98)

		Giridih	**Jharkhand**
1.	Forest	32.12 %	29.2 %
2.	Net sown area	17.41 %	22.7 %
3.	Barren and unculturable waste	7.83 %	7.2 %
4.	Non agricultural use	8.08 %	9.9 %
5.	Orchards	2.59 %	2.5 %
6.	Pasture	2.23 %	
7.	Culturable wasteland	3.65 %	3.5 %
8.	Current and other fallow	26.09 %	25.0 %

Source: Fertilizer and Agriculture Statistics, Eastern Region (2003-2004)

2.5 Soils

The soils occurring in different landforms have been characterised during soil resource mapping of the state on 1:250,000 scale (Haldar *et al.* 1996) and three soil orders namely Entisols, Inceptisols and Alfisols were observed in Giridih district (Fig.1 and table 1). Alfisols were the dominant soils covering 63.6 percent of TGA followed by Inceptisols (18.4 %) and Entisols (16.9 %).

Table 1. Soils of the district and their extent

Map unit	Taxonomy	Area ('00 ha)	% of TGA
15	Loamy-skeletal, mixed, hyperthermic Lithic Ustorthents Fine loamy, mixed, hyperthermic Ultic Haplustalfs	47	0.95
23	Fine-loamy, mixed, hyperthermic Typic Haplustepts Fine-loamy, mixed, hyperthermic Typic Haplustalfs	669	13.55
25	Fine, mixed, hyperthermic Typic Paleustalfs Fine, mixed, hyperthermic Rhodic Paleustalfs	930	18.82
26	Fine, mixed, hyperthermic Typic Haplustalfs Fine, mixed, hyperthermic Typic Paleustalfs	534	10.81
27	Fine-loamy, mixed, hyperthermic Typic Paleustalfs Fine-loamy, mixed, hyperthermic Typic Haplustalfs	90	1.82
30	Loamy-skeletal, mixed, Typic Haplustepts Fine-loamy, mixed, hyperthermic Typic Haplustalfs	128	2.60
32	Fine-loamy, mixed, hyperthermic Typic Haplustepts Coarse loamy, mixed,hyperthermic Typic Ustorthents	91	1.84
34	Fine loamy, mixed, hyperthermic Typic Paleustalfs Fine-loamy, mixed, hyperthermic Typic Rhodustalfs	384	7.77
35	Loamy-skeletal, mixed, hyperthermic Lithic Ustorthents Fine-loamy, mixed, hyperthermic Typic Haplustalfs	517	10.46
36	Fine, mixed, hyperthermic Typic Paleustalfs Fine loamy, mixed, hyperthermic Typic Rhodustalfs	78	1.58
40	Fine loamy, mixed, hyperthermic Typic Haplustepts Fine loamy, mixed, hyperthermic Typic Haplustalfs	186	3.76
41	Coarse loamy, mixed, hyperthermic Typic Ustorthents Fine loamy, mixed, hyperthermic Typic Paleustalfs	251	5.09
45	Fine, mixed, hyperthermic Aeric Endoaquepts Fine loamy, mixed, hyperthermic Typic Haplustepts	30	0.61
49	Fine loamy, mixed, hyperthermic Typic Haplustepts Coarse loamy, mixed, hyperthermic Typic Ustorthents	68	1.37
53	Fine loamy, mixed, hyperthermic Typic Haplustepts Fine, mixed, hyperthermic Typic Haplustalfs	11	0.22
64	Loamy, mixed, hyperthermic Lithic Ustorthents Fine, mixed, hyperthermic Typic Paleustalfs	32	0.65
65	Loamy, mixed, hyperthermic Lithic Ustorthents Fine loamy, mixed, hyperthermic Typic Haplustepts	142	2.87
66	Loamy-skeletal, mixed, hyperthermic Typic Haplustepts Coarse loamy, mixed, hyperthermic Typic Ustorthents	153	3.10
67	Coarse loamy, mixed, hyperthermic Typic Ustorthents Fine, mixed, hyperthermic Typic Haplustalfs	194	3.93
70	Fine loamy, mixed, hyperthermic Typic Haplustepts Fine, mixed, hyperthermic Aeric Endoaqualfs	60	1.21
75	Fine, mixed, hyperthermic Typic Rhodustalfs Fine, mixed, hyperthermic Rhodic Paleustalfs	9	0.19
76	Fine loamy, mixed, hyperthermic Typic Haplustalfs Fine loamy, mixed, hyperthermic Typic Paleustalfs	281	5.67
Miscellaneous		56	1.13
Total		4,941	100.00

3. METHODOLOGY

The base map of the district was prepared on 1:50,000 scale using Survey of India toposheets (72H/12,13,14,15,16,72L/1,2,3,4,6,7,8,12,73E/13 and 73I/1,5) and all the maps were demarcated with grid points at 2.5 km interval.

Surface soil samples from demarcated grid points and other related informations were collected through field survey. Soil samples were air dried, processed and analysed for pH, organic carbon, available phosphorous and potassium (Page *et al.*, 1982), available nitrogen (Subbaiah and Asija, 1956), available sulphur by using 0.15 percent $CaCl_2$ as the extractant (William and Steinbergs, 1959), available (DTPA extractable) Fe, Mn, Zn and Cu (Lindsay and Norvell, 1978) and available B (hot water soluble) by Carmine method (Hatcher and Wilcox, 1950).

The soils are grouped under different soil reaction classess viz extreamely acidic (pH<4.5), very strongly acidic (pH 4.5 – 5.0), strongly acidic (pH 5.1 – 5.5), moderately acidic (pH 5.6-6.0), slightly acidic (pH 6.1-6.5), neutral (pH 6.6-7.3), slightly alkaline (pH 7.4-7.8), moderately alkaline (pH 7.9-8.4), strongly alkaline (pH 8.5-9.0) according to Soil Survey Manual (IARI, 1970).The soils are rated as low (below 0.50 %), medium (0.50-0.75 %) and high (above 0.75 %) in case of organic carbon, low (<280 kg ha^{-1}), medium (280 to 560 kg ha^{-1}) and high (>560 kg ha^{-1}) in case of available nitrogen, low (< 10 kg ha^{-1}), medium (10 to 25 kg ha^{-1}) and high (> 25 kg ha^{-1}) for available phosphorus, low (< 108 kg ha^{-1}), medium (108 to 280 kg ha^{-1}) and high (> 280 kg ha^{-1}) for available potassium and low (<10 mg kg^{-1}), medium (10-20 mg kg^{-1}) and high (> 20 mg kg^{-1}) for available sulphur (Singh *et. al.* 2004, Mehta *et. al.*1988). Critical limits of Fe, Mn, Zn, Cu and B, which separate deficient from non-deficient soils followed in India are 4.5, 2.0, 0.5, 0.2 and 0.5 mg kg^{-1} respectively. (Follet and Lindsay, 1970 and Berger and Truog, 1940).

The maps for the above mentioned parameters have been prepared using Geographic Information System (GIS) from data generated by analysis of grid soil samples.

4. SOIL ACIDITY AND FERTILITY STATUS

4.1 Soil Reaction

Soil pH is an important soil property, which affects the availability of several plant nutrients. It is a measure of acidity and alkalinity and reflects the status of base saturation. The soils of the district have been grouped under six soil reaction classes according to Soil Survey Manual (IARI, 1970).

The soil pH ranges from 4.5 to 7.2. The soil reaction classes with area are given in table 2 and figure 2. The data reveals that very strongly acid soils covers 28.6 percent area fallowed by strongly acid (27.5 %), moderately acid (22.4 %) and slightly acid (14.2 %) soils. Soils of 6.2 percent area of the district are neutral in reaction.

Table 2. Soils under different reaction classes

Soil reaction	Area ('00 ha)	% of the TGA
Very strongly acidic (pH 4.5 to 5.0)	1414	28.6
Strongly acidic (pH 5.1 to 5.5)	1357	27.5
Moderately acidic (pH 5.6 to 6.0)	1105	22.4
Slightly acidic (pH 6.1 to 6.5)	703	14.2
Neutral (pH 6.6 to 7.3)	306	6.2
Miscellaneous	56	1.1
Total	4941	100.0

4.2 Organic Carbon

The effect of soil organic matter on soil properties is well recognized. Soil organic matter plays a vital role in supplying plant nutrients, cation exchange capacity, improving soil aggregation and hence water retention and soil biological activity.

The organic carbon content in the district ranges from 0.07 to 3.75 %. They are mapped into three classes i.e., low (below 0.5 %), medium (0.5-0.75 %) and high (above 0.75 %) (Table 3 and Figure 3). From table 3 it is seen that

40.0 percent area shows high organic carbon content. Low and medium organic carbon content constitute 35.4 and 23.5 percent area respectively.

Table 3. Organic carbon status

Organic carbon (%)	Area ('00 ha)	% of the TGA
Low (below 0.50 %)	1748	35.4
Medium (0.50-0.75 %)	1162	23.5
High (above 0.75 %)	1975	40.0
Miscellaneous	56	1.1
Total	4941	100.0

4.3 Macronutrients

Nutrients like nitrogen (N), phosphorus (P) and potassium (K) are considered as primary nutrients and sulphur (S) as secondary nutrient. These nutrients help in proper growth, development and yield differentiation of plants and are generally required by plants in large quantity.

4.3.1 Available Nitrogen

Nitrogen is an integral component of many compounds including chlorophyll and enzyme essential for plant growth. It is an essential constituent for amino acids which is building blocks for plant tissue, cell nuclei and protoplasm. It encourage aboveground vegetative growth and deep green colour to leaves. Deficiency of nitrogen decreases rate and extent of protein synthesis and result into stunted growth and develop chlorosis.

Available nitrogen content in the surface soils of the Giridih district ranges between 95 and 825 kg/ha and details are given in table 4 and figure 4. Majority area (82.4 % of TGA) of the district have medium availability status of available nitrogen (280-560 kg ha^{-1}). Soils of 8.3 and 8.2 percent area are low and high in available nitrogen content respectively.

Table 4. Available nitrogen status in the surface soils

Available nitrogen (kg/ha)	Area ('00 ha)	% of the TGA
Low (below 280)	410	8.3
Medium (280-560)	4071	82.4
High (above 560)	404	8.2
Miscellaneous	56	1.1
Total	4941	100.0

4.3.2 Available Phosphorus

Phosphorus is important component of adenosine di-phosphate (ADP) and adenosine tri-phosphate (ATP), which involves in energy transformation in plant. It is essential component of deoxyribonucleic acid (DNA), the seat of genetic inheritance in plant and animal. Phosphorous take part in important functions like photosynthesis, nitrogen fixation, crop maturation, root development, strengthening straw in cereal crops etc. The availability of phosphorous is restricted under acidic and alkaline soil reaction mainly due to P-fixation. In acidic condition it get fixed with aluminum and iron and in alkaline condition with calcium.

Available phosphorus content in these soils ranges between 1.0 and 25.5 kg/ha and their distribution is given in table 5 and figure 5. Data reveals that soils of majority area are low (79.0 %) followed by medium (19.8 %) and high (0.1 %) in available phosphorous content.

Table 5. Available phosphorous status in the surface soils

Available phosphorous (kg/ha)	Area ('00 ha)	% of the TGA
Low (below 10)	3904	79.0
Medium (10-25)	977	19.8
High (above 25)	4	0.1
Miscellaneous	56	1.1
Total	4941	100.0

4.3.3 Available Potassium

Potassium is an activator of various enzymes responsible for plant processes like energy metabolism, starch synthesis, nitrate reduction and sugar degradation. It is extremely mobile in plant and help to regulate opening and closing of stomata in the leaves and uptake of water by root cells. It is important in grain formation and tuber development and encourages crop resistance for certain fungal and bacterial diseases.

Available potassium content in these soils ranges between 49 and 1344 kg/ha and details about area and distribution is given in table 6 and figure 6. The data reveals that most of soils (43.7 % of TGA) have medium available potassium content (108-280 kg ha^{-1}). Soils of 36.0 percent area are high (above 280 kg ha^{-1}) and 19.2 percent area are low (below 108) in available potassium content.

Table 6. Available potassium status in the surface soils

Available potassium (kg/ha)	Area ('00 ha)	% of the TGA
Low (below 108)	948	19.2
Medium (108-280)	2161	43.7
High (above 280)	1776	36.0
Miscellaneous	56	1.1
Total	4941	100.0

4.3.4 Available Sulphur

Sulphur is essential in synthesis of sulphur containing amino acids (cystine, cysteine and methionine), chlorophyll and metabolites including co-enzyme A, biotin, thiamine, or vitamin B1 and glutathione. It activates many proteolytic enzymes, increase root growth and nodule formation and stimulate seed formation.

The available sulphur content in the soils ranges from 0.36 to 85.38 mg kg^{-1} and details about area and distribution is given in table 7 and figure 7.

Majority of soils (50 % of TGA) are high (>20 mg kg^{-1}) in available sulphur. Soils of 23.7 and 25.2 percent area are medium (10-20 mg kg^{-1}) and low (<10 mg kg^{-1}) in available sulphur content respectively.

Table 7. Available sulphur status in the surface soils

Available Sulphur (mg kg^{-1})	Area ('00ha)	% of the TGA
Low (<10)	1244	25.2
Medium (10-20)	1169	23.7
High (>20)	2472	50.0
Miscellaneous	56	1.1
Total	4941	100.0

4.4 Micronutrients

Proper understanding of micronutrients availability in soils and extent of their deficiencies is the pre-requisite for efficient management of micronutrient fertilizer to sustain crop productivity. Therefore, it is essential to know the micronutrients status of soil before introducing any type of land use.

4.4.1 Available Iron

Iron is constituent of cytochromes, haems and nonhaem enzymes. It is capable of acting as electron carrier in many enzyme systems that bring about oxidation-reduction reactions in plants. It promotes starch formation and seed maturation.

The available iron content in the surface soils ranges between 4.64 and 84.0 mg kg^{-1}. As per the critical limit of available iron (> 4.5 mg kg^{-1}), all the soils are sufficient in available iron. They are grouped and mapped into four classes. Most of the soils (38.4 % of TGA) have available iron content between the range of 25 to 50 mg kg^{-1}. The details of area and distribution is presented in table 8 and figure 8.

Table 8. Available Iron status in the surface soils

Available iron (mg kg^{-1})	Area ('00ha)	% of the TGA	Rating
<15	1065	21.6	Sufficient
15-25	860	17.4	
25-50	1896	38.4	
50-100	1064	21.5	
Miscellaneous	56	1.1	
Total	4941	100.0	

4.4.2 Available Manganese

Manganese is essential in photosynthesis and nitrogen transformations in plants. It activates decarboxylase, dehydrogenase, and oxidase enzymes.

The available manganese content in surface soils ranges between 9.0 and 70.0 mg kg^{-1}. As per the critical limit of available manganese (> 2 mg kg^{-1}), all the soils are sufficient in available manganese. They are grouped and mapped into four classes. Soils of 59.1 % area of district have available Mn content between 25 and 50 mg kg^{-1}. The details of area and distribution are presented in table 9 and figure 9.

Table 9. Available manganese status in the surface soils

Available manganese (mg kg^{-1})	Area ('00ha)	% of the TGA	Rating
<10	218	4.4	Sufficient
10-25	650	13.2	
25-50	2922	59.1	
50-100	1095	22.2	
Miscellaneous	56	1.1	
Total	4941	100.0	

4.4.3 Available Zinc

Zinc plays role in protein synthesis, reproductive process of certain plants and in the formation starch and some growth hormones. It promotes seed maturation and production.

The available zinc in surface soils ranges between 0.04 and 9.70 mg kg^{-1}. They are grouped and mapped into six classes. Soils of Majority of soils (84.2 % of TGA) are sufficient (>0.5 mg kg^{-1}) whereas soils of 14.7 percent area are deficient (<0.5 mg kg^{-1}) in available zinc. The details of area and distribution are presented in table 10 and figure 10.

Table 10. Available zinc status in the surface soils

Available zinc (mg kg^{-1})	Area ('00ha)	% of the TGA	Rating
<0.5	727	14.7	Deficient
0.5-1.0	924	18.7	Sufficient
1.0-2.0	1733	35.1	
2.0-3.0	880	17.8	
3.0-5.0	502	10.2	
5.0-10.0	119	2.4	
Miscellaneous	56	1.1	
Total	4941	100.0	

4.4.4 Available Copper

Copper involves in photosynthesis, respiration, protein and carbohydrate metabolism and in the use of iron. It stimulates lignifications of all the plant cell wall and is capable of acting as electron carrier in many enzyme systems that bring about oxidation-reduction reactions in plants.

The available copper status in surface soils ranges between 0.18 and 5.40 mg kg^{-1}. They are grouped and mapped into six classes. Majority of soils (89.0 % of TGA) have sufficient amount of available copper (>0.2 mg kg^{-1}) and soils of

9.9 % area are deficient in available copper (<0.2 mg kg^{-1}). The details of area and distribution are presented in table 11 and figure 11.

Table 11. Available copper status in the surface soils

Available copper (mg kg^{-1})	Area ('00ha)	% of the TGA	Rating
<0.2	491	9.9	Deficient
0.2-0.5	439	8.9	Sufficient
0.5-1.0	829	16.8	
1.0-2.0	1511	30.6	
2.0-4.0	1452	29.4	
4.0-6.0	163	3.3	
Miscellaneous	56	1.1	
Total	4941	100.0	

4.4.5 Available Boron

Boron increases solubility and mobility of calcium in the plant and it act as regulator of K/Ca ratio in the plant. It is required for development of new meristematic tissue and also necessary for proper pollination, fruit and seed setting and translocation of sugar, starch and phosphorous etc. It has role in synthesis of amino acid and protein and regulates carbohydrate metabolism.

The available boron content in the soils ranges from 0.03 to 5.23 $mgkg^{-1}$ and details about area and distribution is given in table 12 and figure 12. The critical limit for deficiency of the available boron is <0.5. Soils of 46.6 percent area of district are deficient (<0.50 $mgkg^{-1}$) whereas 52.3 percent area are sufficient (>0.50 $mgkg^{-1}$) in available boron content.

Table 12. Available boron status in the surface soils

Available Boron (mg kg^{-1})	Area ('00ha)	% of the TGA	Rating
<0.25	1082	21.9	Deficient
0.25-0.50	1221	24.7	
0.50-0.75	696	14.1	Sufficient
>0.75	1886	38.2	
Miscellaneous	56	1.1	
Total	4941	100.0	

5. SUMMARY

The soil pH ranges from 4.5 to 7.2. Very strongly acid soils covers 28.6 percent area fallowed by strongly acid (27.5 %), moderately acid (22.4 %) and slightly acid (14.2 %) soils. Soils of 6.2 percent area of the district are neutral in reaction. The organic carbon content in the district ranges from 0.07 to 3.75 %. Soils of 40.0 percent area shows high organic carbon content. Low and medium organic carbon content constitute 35.4 and 23.5 percent area respectively.

Available nitrogen content in the surface soils of the Giridih district ranges between 95 and 825 kg/ha. Majority area (82.4 % of TGA) of the district have medium availability status of available nitrogen (280-560 kg ha^{-1}). Soils of 8.3 and 8.2 percent area are low and high in available nitrogen content respectively. Available phosphorus content in these soils ranges between 1.0 and 25.5 kg/ha. Majority of the soils (79.0 % of TGA) are low followed by medium (19.8 %) and high (0.1 %) in available phosphorous content. Available potassium content in these soils ranges between 49 and 1344 kg/ha/. Most of soils (43.7 % of TGA) have medium available potassium content (108-280 kg ha^{-1}). Soils of 36.0 percent area are high (above 280 kg ha^{-1}) and 19.2 percent area are low (below 108) in available potassium content. The available sulphur content in the soils ranges from 0.36 to 85.38 mg kg^{-1}. Majority of soils (50 % of TGA) are high (>20 mg kg^{-1}) in available sulphur. Soils of 25.2 percent area are low (<10 mg kg^{-1}) in available sulphur content respectively.

Soils are analysed for available (DTPA extractable) micronutrients and seen that all the soils are sufficient in available iron and manganese whereas soils of 14.7 and 9.9 percent area are deficient in available zinc and copper respectively. Available boron content in the soils ranges between 0.03 to 5.23 $mgkg^{-1}$ and 46.6 percent area of district is deficient (<0.50 mg kg^{-1}) in it.

REFERENCES

Berger, K. C. and Truog, E.(1940) J. Am. Soc. Agron. 32,297

Census of India (2001) Primary Census Abstract.

FAI (2003 – 2004) Fertiliser and agriculture statistics, Eastern Region.

Follet, R. H. and Lindsay , W. L.(1970) Tech. Bull. Colo. Agric. Exp. Station 110.

Haldar, A. K., Srivastava, R., Thampi, C. J., Sarkar, D., Singh, D. S., Sehgal, J and Velayutham, M. (1996) Soils of Bihar for optimizing land use. **NBSS Publ. 50b**. (Soils of India Series), National Bureau of Soil Survey and Land Use Planning, Nagpur, India, pp. 70+4 sheets soil Map (1:500,000 scale).

Hatcher, J. T. and Wilcox, L. V. (1950) Analyt. Chem. **22**, 567

I.A.R.I. (1970). Soil survey manual, All India Soil and Land Use Organization, Indian Agricultural Research Institute, New Delhi.

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

Mehta, V. S. , Singh, V and Singh, R. P. (1988) J. Indian Society of Soil Science, 36, 743

Mishra, R. K. (2004) Planning for Food and Nutritional Security in Jharkhand, *Published by* Agricultural Data Bank, BAU, Ranchi, Jharkhand, p. 275

Page, A. L., Miller, R. H. and Keeney, D. R.(1982) Method of Soil Analysis, Part-II, Chemical and Microbiological Properties, Soil Sci. Soc. Am. And Am. Soc. Agron. Madison, Wisconsin, USA.

Singh Dhyan, Chhonkar, P. K. and Pandey, R. N.(2004) Soil Plant and Water Analysis, A Manual, IARI, New Delhi.

Subbaiah, B.V. and Asija, G.L. (1956). A rapid procedure for determination of available nitrogen in soil. Current Science 25, 259-260

Tandon, H. L. S. (Ed) (1999) Methods *of analysis of soils, plants, waters and fertilizers*. Fertilizer Development and Consultation Organisation, New Delhi, India.

William, C. H. and Stainbergs, A. (1959) Aust. J. Agric. Res. **10,** 342