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Study on Sesquioxide Content and Lime Requirement of Lateritic Soils

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Abstract

Laterite and lateritic soils of Andhra Pradesh are of found in patches. They were red to dark brown, sandy clay loam to clay, moderately acidic to neutral in reaction, non saline and high in sesquioxide (R_2O_3) contents. The soils of the study area except for Krishnapur series (Inceptisol) were Alfisols, interpreted by presence of illuvial-B horizons with higher base saturation. The sesquioxide content ranged from 13.77 to 30.06% in profiles and from 15.23 to 28.53% in surface samples. The lime requirement (LR) ranged from 1.7 to 3.1 t ha^{-1} in profile samples and from 1.2 to 6.4 t ha^{-1} of $CaCO_3$ in surface samples. There was a decrease in sesquioxide contents in most of the profiles and decrease in LR with increasing depth in some profiles. Lower pH directed towards higher LR. With the increase in clay content there was increase in LR in surface soil but trend did not followed with profile soils. Sesquioxide was not correlated significantly with LR. The DTPA extractable micronutrients like Zn, Fe, Cu and Mn content of profile samples ranged widely from 0.121-2.120, 4.77-41.78, 0.459-6.256 and 8.28-80.00 ppm respectively and 0.532-3.228, 12.00-75.46, 1.336-11.502 & 52.78-81.98 ppm respectively for surface samples. Significant positive correlation existed between DTPA extractable Fe and Mn with sesquioxides in top soils but not with profile soils.

1. Introduction

Laterite soils are typically formed under tropical climate experiencing alternate wet and dry seasons. They are generally acidic, have low CEC, low to moderate base saturation (Buol and Cook, 1998), dominated by kaolinite clay (80-97%) with few primary silicate minerals and rich in sesquioxides. Oxides, oxyhydroxides, or hydroxides of Fe, Al and Mn are termed as sesquioxides. Virtually all soils possess sesquioxide minerals, with few possible exceptions. Most amorphous sesquioxides possess no permanent charge, but develop surface charge dependent on the pH and ionic strength of the soil environment with substantial coulombic and specific adsorption of organic molecules, cations, and anions occur on sesquioxides (Shaw and West, 2006). They may form coatings and may block some exchange sites thus exhibit lower CEC (Bear, 1964). These oxide minerals largely affect soil chemical and physical properties, morphology, and classification (Shaw and West, 2006). Laterite soils show deficiency of primary nutrients, show toxicity of Fe & Al and nutrient imbalances (Bhaskar and Subbaiah, 1995). Weakly buffered soils include sandy textured soils, particularly with low organic carbon (Konyers, 2006) have greater lime potential (Ghosh et al., 2005). Application of lime increases soil pH, reduce exchangeable and total acidity, exchangeable Al^{3+}, H^+ & Fe^{3+}, total Fe and Al and improves fertility status of lateritic soils (Chatterjee et al., 2005). Determination of lime LR of acid soil is one of the most important parameter which determines the amount of lime required to ameliorate an acidic soil which otherwise unproductive. This is generally done for plough layer or topsoil. The soils in lateritic belt of Medak district have low fertility status (Basanta et al., 2011). Very limited information is available regarding the various soil properties of sesquioxide rich lateritic soils. The investigation was therefore, conducted with the view to assess the sesquioxide distribution, LR, micronutrient availability and their correlations with other soil properties in both profile and top soils of farmers' fields in the lateritic belt.

2. Materials and Methods

2.1. Study area

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The laterite and lateritic soils occur in the south-western and southern part in Medak district of Andhra Pradesh, covering about 84,652 ha (8.7%). They occur as caps (50-60 m thick) over Deccan Traps in Zaheerabad and Narayankhed areas. Six soil profiles-Rejental (Fine, Mixed, Iso-Hyperthermic, Typic Rhodustalf), Parvatapur (Fine, Mixed, Iso-Hyperthermic, Lithic Rhodustalf), Algol (Clay skeletal, Mixed, Iso-Hyperthermic, Kandic Rhodustalf), Bilalpur (Clay skeletal, Mixed, Iso-Hyperthermic, Typic Haplustalf), Zaheerabad (Fine, Loamy, Mixed, Iso-Hyperthermic, Typic Haplustalf) and Krishnapur (Loamy skeletal, Mixed, Iso-Hyperthermic, Typic Ustochrept) were selected from general cultivated area. Soil samples were collected in March, 2008 from each horizon of the six profiles. Sixty topsoil (0-20 cm) samples were randomly collected from the farmer's fields. The pH, EC and CEC were analyzed following standard procedure (Jackson 1973). The available N, P_2O_5 and K_2O content in profiles ranged from 25.08-225.79 kg ha^{-1}, 2.24-68.76 kg ha^{-1} and 82.00-182.56 kg ha^{-1} respectively.

2.2. *Analysis for sesquioxides (R_2O_3)*

Sesquioxides (Fe_2O_3+Al_2O_3) in the soil samples were determined in the 8N HCl digested soil extract gravimetrically as described by A.O.A.C. (1950). In the extract, Fe is first oxidized to $Fe^{3+}$by adding nitric acid and then boiling it for a minute. Then Fe & Al is precipitated by making the solution distinctly alkaline with concentrated NH_4OH. The contents were then boiled on a hot sand bath, and the precipitate was collected after settling on a filter paper. The precipitate was then washed with distilled water to make it free from chloride. The residue was dried, ignited, weighed and expressed in percentage.

2.3. *Analysis for lime requirement (LR)*

The LR of the soils was determined by measuring the pH of the soil buffer suspension as described by Shoemaker et al. (1961). A buffer solution (pH 7.5 adjusted with NaOH) was prepared by dissolving P-nitrophenol, triethanolamine, potassium chromate, calcium acetate and calcium chloride in distilled water. The soil was equilibrated with buffer solution and the pH of soil buffer suspension is determined by a pH meter. The LR was noted from a table giving pH of soil buffer suspension with the corresponding LR.

2.4. *Micronutrient analysis*

Soil samples were analysed for available micro-nutrient cations of Zn, Cu, Fe and Mn by extracting them with diethylene triamine penta acetic acid (DTPA) following standard procedure (Lindsay and Norvell, 1978). They were estimated using atomic adsorption spectrophotometer (AAS). The LR, sesquioxide content, DTPA extractable micronutrient cations were correlated at 1% and 5% levels of probability with physico-chemical properties of the soils using SPSS-16.0 software.

3. Results and Discussion

3.1. *Soil physical and physico-chemical properties*

The soil depths varied from 45 to 95 cm. The Rejental, Bilalpur and Zaheerabad profiles were moderately deep (Figure 1). The soils were red to dark brown, gravely, sandy clay loam to clay in texture with low water holding capacity. It was seen that clay content increased with depth in the profiles.

Important soil properties relevant to the study are presented in Table 1 for profile samples and Table 2 for surface samples (mean of 10 samples). The soils were moderately acidic to neutral pH (5.4-7.0). Similarly pH of surface samples (average) ranged from 6.1 to 6.5). The pH increased gradually with depth making subsoil making near neutrality in almost all profiles due to leaching of bases from the topsoil. The EC ranged from 0.012 to 0.275 dS m^{-1} in profile and from 0.051 to 0.570 dS m^{-1} in surface soils. The CEC of the soils ranged from 12.0 to 29.8 c mol (p^{+}) kg^{-1} profile soil and from 13.93 to 23.2 cmol (p^{+}) kg^{-1} in surface soils. Low to moderate CEC in these soils was due to mixed type of kaolinitic, illitic and other clays. The percentage base saturation (BS) ranged from 30.2 to 78.6 in the profiles and in top soils it ranged from 41.1 to 86.1% with mean value of 69.86%. The organic carbon content of the profiles ranged from 0.045 to 0.570%. Most of the profile samples recorded low (<0.5%) organic carbon content whereas, most of surface samples recorded medium. Here, only mean data on soil properties of topsoil samples are presented due to large volume. The pH of topsoil showed significant positive correlation with CEC (r=0.952**). This may be attributed to more exchangeable bases due to increase in free negative charges on mineral and organic clay surfaces with increasing pH. The distributions of clay, sesquioxides and lime requirement with depths for profiles are illustrated in Figure 2.

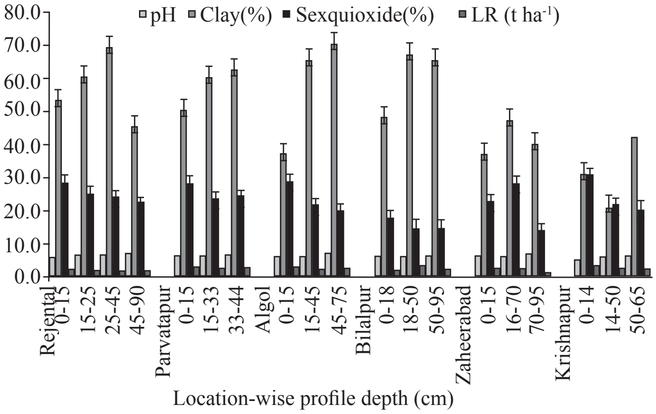

Figure 1: The distribution of clay, sesquioxides, lime requirement with depth for profiles

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Table 1: Depth wise distribution of important physical and chemical properties of profiles

Location	Depth (cm)	pH	OC (%)	Clay (%)	CEC#	BS (%)	Sesq. (%)	LR (t ha^{-1})	Fe (ppm)	Mn (ppm)	Cu (ppm)	Zn (ppm)
Rejental (Typic Rhodustalf)	0-15	6.0	0.57	53	18.3	55.9	28.51	2.2	26.92	80.00	6.26	0.98
	15-25	6.2	0.49	60	22.4	59.2	25.11	1.9	22.59	76.90	4.05	1.02
	25-45	6.6	0.27	69	25.5	46.3	24.08	1.9	24.54	50.60	4.24	1.18
	45-90	6.8	0.21	45	16.3	36.5	22.52	1.7	20.26	45.30	2.17	0.65
	Mean	6.4	0.39	56.7	20.6	49.48	25.06	1.9	23.58	63.20	4.18	0.96
Parvatapur (Lithic Rhodustalf)	0-15	6.2	0.45	50	23.1	64.4	28.45	2.9	41.78	77.34	2.37	0.77
	15-33	6.4	0.30	60	25.2	54.4	23.65	2.5	35.80	73.42	3.97	0.80
	33-44	6.3	0.27	62	24.3	53.2	24.53	2.5	13.77	37.37	2.18	0.85
	Mean	6.3	0.34	57.3	24.2	57.33	25.54	2.6	30.45	62.71	2.84	0.81
Algol (Kandic Rhodustalf)	0-15	5.9	0.49	37	15	76.2	29.05	3.1	11.29	64.32	2.54	1.02
	15-45	6.3	0.27	65	14.7	43.8	21.61	2.5	7.69	49.74	1.93	1.24
	45-75	7.0	0.15	70	17	31.7	20.02	2.5	22.66	57.98	1.42	0.62
	Mean	6.4	0.31	59.3	15.5	50.57	23.56	2.7	13.88	57.35	1.96	0.96
Bilalpur (Typic Haplustalf)	0-18	6.2	0.33	48	17.1	87.5	18.05	2.4	19.60	73.72	5.94	2.12
	18-50	5.9	0.36	67	26.8	54	14.55	3.1	19.56	74.00	3.35	1.06
	50-95	6.4	0.22	65	24.8	49	15.12	1.9	23.24	59.18	2.76	0.70
	Mean	6.2	0.31	60	22.9	63.5	15.91	2.5	20.80	68.97	4.01	1.29
Zaheerabad (Typic Haplustalf)	0-16	6.4	0.41	37	27.2	47	28.33	2.7	26.22	73.34	5.80	1.77
	16-70	6.1	0.30	47	28.7	50.2	23.17	2.5	15.58	48.64	2.14	0.52
	70-95	7.0	0.05	40	29.8	34.8	13.77	1.5	20.26	64.88	1.94	0.12
	Mean	6.5	0.25	41.3	28.6	44	21.85	2.2	20.69	62.29	3.32	0.80
Krishnapur (Typic Ustochrept)	0-14	5.4	0.33	31	12	78.6	30.06	3.1	34.94	78.86	3.64	0.78
	14-50	5.9	0.21	21	15.3	68.8	22.26	2.8	4.77	10.28	5.04	0.39
	50-65	6.1	0.15	42	20.1	53.7	20.09	2.1	4.80	8.28	0.46	0.37
	Mean	5.8	0.23	31.3	15.80	67.03	24.37	2.7	14.84	32.47	3.04	0.51
Grand Mean		6.3	0.31	51.32	21.24	55.01	22.84	2.4	20.86	58.11	3.28	0.89

#[cmol (p+)kg^{-1}]; Sesq: Sesquioxide

3.2. Sesquioxide content

The data on depth-wise distribution of sesquioxides are presented in the Table 2 and Figure 2. The sesquioxide content in profile samples ranged from 13.77% of third layer of Zaheerabad profile to 30.06% first layer of Krishnapur of profile. The sesquioxide content of surface samples ranged from 15.23 to 28.53% with mean value 23.52%, exceeding the content of free sesquioxide (Fe_2O_3+Al_2O_3) in laterite soils of Orissa (2.9-18.2%) as reported by Das et al. (1992). Generally, sesquioxide content decreased with the depth in the Rejental, Algol, Zaheerabad and Krishnapur soil profiles. In the Parvatapur and Bilalpur profiles, their content decreased in their second layers and again increased slightly at the profile bottoms with narrow range. The highest range of distribution was in Zaheerabad profile (13.77-28.33%) with very sharp decrease with depth. The un-uniform distribution of sesquioxide with the depth in Parvatapur and Bilalpur may be due to their deposition in the lower layers. The mean sesquioxide content of profiles were in the order, Parvatapur>Rejental>Algol>Krishnapur>Zaheerabad>Bilalpur. The pH was negatively significantly correlated (r=-0.973**) with sesquioxide (Table 3). This may be due to hydrolysis of more Al-hydroxides from sesquioxides under aqueous condition releasing protons which ultimately makes soil solution acidic. The sesquioxide content did not have any correlation with LR. This might be due to the fact that, sesquioxide is not only the factor contributing soil reaction.

3.3. Lime requirement

The LR of the profiles studied ranged from 1.7 to 3.1 t ha^{-1} of $CaCO_3$ and it ranged from 1.2 to 6.4 (few samples) in surface samples. The LR of the area was lower than that of acidic red and lateritic soils (Typic Haplustalf, pH=5.6) of Kashipur, West Bengal, having LR=4.25 t ha^{-1} reported by Banerjee and Das (2001). The mean LRs of profiles was in the order Algol, Krishnapur (2.7 t ha^{-1})>Parvatapur (2.6 t ha^{-1})>Bilalpur (2.5 t ha^{-1})>Rejental (1.9 t ha^{-1}). The lime requirement decreased with the depth in almost all the profiles. But, un-uniform LR with depth was evidenced form data of red laterite soils of Midinapore district as reported by Rahaman and Karak (2001). LR of top soils did not have any correlation with organic matter content or CEC. The result was in line with the findings of Dolui and Datta (2001) in acid soils of Orissa. The OC in these soils were low which limits its influence on LR, might be the reason for this and influence of organic matter might be significant only when the exchangeable Al is low (Dolui and Dutta, 2001). Estimation of LR for top soils and correlating them with soil properties will give significant importance regarding plant growth and soil productivity. The LR showed significant positive correlation (r=0.947**) with clay percent (Table 3). Since clay being most important colloidal constituent contributing buffering capacity (Dolui and Dutta, 2001), the relation is not surprising. But it was not applicable to profile clay content in which LR decreased with increasing clay along with depth.

3.4. Micronutrients

The DTPA extractable micronutrients (Zn, Fe, Cu and Mn) content of profile were in the ranged from 0.121-2.120, 4.77-41.78, 0.459-6.256 and 8.28-80.00 ppm. The average contents of Zn, Fe, Cu and Mn in surface samples were 1.305, 37.10, 5.80 and 75.01 ppm respectively. It was interesting to note that, in top soil samples (0-20 cm), with increasing the sesquioxide content there was gradual increase of DTPA extractable Mn and Fe as illustrated in the Figure 3. The increase was more pronounce for iron than that of manganese. This might be due to influence of sesquioxide on decreasing pH which increased solubility of Fe and Mn and association of more Fe and Mn as integral part of sesquioxides. Except for Zn, all samples were high in Fe, Cu and Mn due to moderately low pH. There was significant positive correlation between sesquioxide with Fe (r=0.937**) and Mn (r=0.885*) but not with Zn and Cu. Significant positive correlation existed between Fe and Mn (r=0.703**). But, there was close association of Cu and Zn contents. Significant negative correlation was

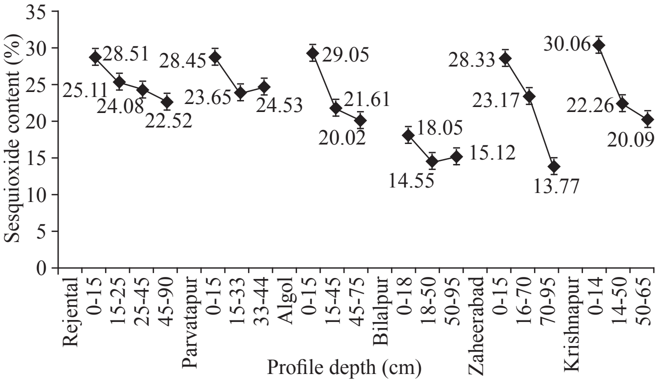

Figure 2: Depth-wise distribution of sesquioxides is lateritic soil profiles

Table 2: Important physico-chemical, physical and chemical properties of topsoil (mean of ten samples for each location)

Location	pH	EC (1:2.5)	O.C (%)	CEC	BS (%)	clay (%)	Sesq. (%)	LR (t ha^{-1})	Fe (ppm)	Mn (ppm)	Cu (ppm)	Zn (ppm)
Typic Rhodustalf	6.5	0.083	0.570	23.20	79.80	42	19.52	2.00	24.50	66.60	7.362	2.54
Lithic Rhodustalf	6.1	0.089	0.507	22.03	69.94	53	20.91	2.49	26.60	70.38	6.937	1.53
Kandic Rhodustalf	6.2	0.055	0.410	16.94	57.74	51	24.39	2.49	36.04	80.57	4.827	1.22
Typic Haplustalf	6.2	0.152	0.473	15.58	59.30	58	25.20	2.85	42.03	80.88	6.665	1.31
Typic Haplustalf	6.3	0.317	0.448	13.93	74.63	48	27.72	2.04	60.49	81.43	5.280	1.10
Typic Ustochrept	6.1	0.051	0.510	18.40	77.73	47	23.38	1.89	31.31	78.93	6.351	1.54
Mean	6.2	0.125	0.486	18.34	69.86	49.8	23.52	2.29	36.83	76.46	6.237	1.54

Table 3: Correlation coefficients of lime requirement and sesquioxide with important properties of topsoil

	pH (w)	Clay (%)	LR (t ha^{-1})	CEC$^{\#}$	OC (%)	Sesq. (%)	Zn	Fe	Cu
Clay (%)	.066	-							
LR (t ha^{-1})	.083	.947**	-						
CEC [cmol(p+) kg^{-1}]	.952**	.086	.101	-					
O.C. (%)	.127	-.148	-.151	.195	-				
Sesq. (%)	-.973**	-.086	-.096	-.970**	-.199	-			
Zn (ppm)	.049	.029	.033	.036	.176	-.084	-		
Fe (ppm)	-.920**	-.117	-.119	-.878**	-.176	.937**	-.153	-	
Cu (ppm)	-.119	.194	.185	-.178	-.987**	.188	-.183	.175	-
Mn (ppm)	-.861**	-.085	-.099	-.938**	-.206	.885**	.019	.703**	.179

**Significant at the 0.01 level; $^{\#}$ [cmol(p+) kg^{-1}]

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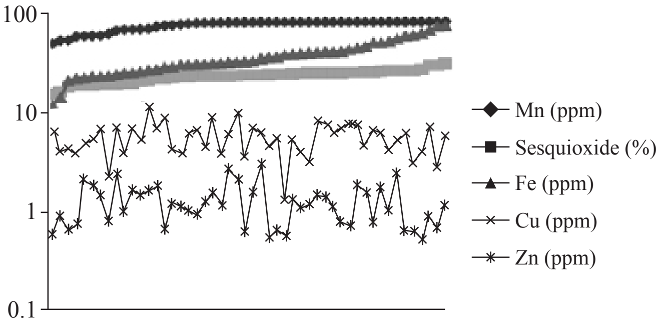

Figure 3: Sesquioxide (%) and micronutrient contents (ppm) in top soil

established for OC with Cu (r=-0.987**). This might be due to strong adsorption of Cu ion on the organic surfaces making it unavailable for extraction as reported by many workers. Significant negative correlation was established for CEC with Fe (r=-0.878**) and Mn (r=-0.938**). This might be due to decrease of CEC with decreasing pH affecting solubility of Fe and Mn. The significance was due to similarity of Fe and Mn in their chemical behaviour in the soil. High Fe concentration in soils also reduces copper absorption by plants (Das, 2000).

4. Conclusion

Higher sesquioxide content, especially in surface soils and higher subsoil pH in profiles necessitate for amelioration of surface only. Application of basic cation rich organic matter may be one alternative under scarcity of mineral lime or higher cost. Deep-rooted species that are able to bring cations from subsoil and deposit them at the surface as litter may be one remedy for reducing surface acidity and increasing micronutrient availability. There is significant positive correlation between DTPA extractable Fe and Mn with sesquioxide percentage in the lateritic soils. Higher subsoil pH may reduce availability of micronutrients if excessive liming materials are leached.

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