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FORMS OF MAGNESIUM IN AEOLIAN AND ALLUVIAL PLAIN SOILS OF ARID RAJASTHAN

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ABSTRACT

Forms and occurrence of magnesium (Mg) in eight pedons on aeolian and alluvial plains of arid Rajasthan were studied. The contents of various forms were higher than in the soils of other regions. Quantities (mg/100 g soil) of different forms of Mg were : water soluble (9 to 40), exchangeable (3 to 38), ammonium acetate soluble (15 to 57), organic bound (0 to 43), reserve (120 to 519), and mineral (81 to 651), respectively representing 1 to 5, 0.5 to 3, 2 to 5, 0 to 3, 17 to 40 and 16 to 47 per cent of the total (0.597 to 2.648 g/100 g soil) content. Variations in Mg content were largely due to differences in the parent material. Type and proportion of 2:1 minerals influenced the exchangeable and reserve forms of Mg whereas mineralogy of fine sand influenced the content of mineral form of Mg. Free $CaCO_3$ contained 10 to 30% of the total Mg. Various forms of Mg were significantly inter-related.

INTRODUCTION

Tropical soils under low mean annual rainfall contain higher non-exchangeable Mg than other soils. (Kover and Riecken, 1976). Variable and comparatively higher Mg content in surface water flows of different catchments of Luni basin in Rajasthan (Choudhari and Sharma, 1984) suggested the arid soils to have varying status of Mg. Since precise information on this aspect was not available, the present, study was undertaken to find the content and occurrence of various forms of Mg in some aeolian and alluvial plain soils of western Rajasthan.

MATERIAL AND METHODS

Eight pedons of dominant soil series on aeolian and alluvial plains in the central part of arid zone (covering part of Jodhpur, Nagaur and Pali districts) were selected for the study. These were Dune (P. 1), Shergarh (P. 2), Chirai (P. 3), Palari pichkia (P. 4), Khajwana (P. 5), Gajsinghpura (P. 6), Pipar (P. 7) and Pali (P. 8). Air dried samples from each were analysed for important physico-chemical properties.

Fractionation of Mg was done by following procedure: One g of sample (crushed and passed through 80 mesh sieve) was taken into 50 ml polypropylene centrifuge tube. To remove water soluble and exchangeable Mg, it was shaken with 20 ml of 1 N neutral ammonium acetate for 40 minutes and then centrifuged for 10 minutes and supernatent decanted into a bottle. Additional treatments with 10-minute shakings were made until 100 ml extract was collected. To extract organic complexed Mg, the residue left from the above (ammonium acetate treatment) was oxidized with 10% H_2O_2 and washed with 1 N neutral ammonium acetate until 100 ml of the supernatent was obtained. Residue left from the H_2O_2 treatment was boiled for 30 minutes with 30 ml of 1 N HNO_3 to extract reserve Mg content. The digested mixture was filtered and washed with 0.2 N HNO_3 to obtain a total of 100 ml extract. The residue was then transferred to a 250 ml breaker and digested with tri-acid mixure ($H_3PO_4+HNO_3+HClO_4$) to extract Mg associated with primary minerals. The digested mixture was filtered and washed with distilled water until 100 ml of filterate was collected.

Total and exchangeable Mg contents were extracted by HF–$HClO_4$ and barium chloride triethanol amine procedures as described by Jackson (1958). Water soluble Mg was extracted from equilibrium extract obtained by shaking 1: 20 soil : deionized water mixture for 240 hours. HCl soluble Mg was extracted after Piper (1948). Magnesium associated with free lime was extracted by treating with normal cold HCl until 100 ml extract was collected.

Magnesium in all the extracts was determined with Atomic absorption spectrophotometer. Interference by other ions was suppressed by the addition of 2.5 ml of 7000 ppm Sr in 10 ml of aliquot.

RESULTS AND DISCUSSION

Soils of the study area were far from uniformity (Table 1). The pH (7.8 to 8.4) and conductivity values (127 to 1021 micromhos/cm) did not vary much as the soil components and their distribution in the profiles. In general $CaCO_3$ and clay contents increased with depth but maximum accumulation of clay was in B horizon whereas that of $CaCO_3$ in the C horizon.

Table 1. Range (%) of some important Physico-chemical parametres of arid soils.

Soil	Pedon No.	Organic Carbon	Fulvic acid	Silt	Clay	$CaCO_3$
Dune	P.1	0.110 - 0.133	.02 - .03	1 - 2	2 - 2	0 - 0.4
Shergarh	P.2	0.121 - 0.138	.04 - .05	5 - 7	4 - 5	0 - 3.5
Chirai	P.3	0.061 - 0.174	.03 - .06	5 - 11	4 - 10	0 - 7.7
Palari pichkia	P.4	0.191 - 0.348	.04 - .09	4 - 11	9 - 20	0 - 2 4
Khajwana	P.5	0.189 - 0.552	.07 - .11	10 - 17	14 - 24	0 - 16.1
Gajsinghpura	P.6	0.556 - 0.696	.11 - .15	15 - 21	18 - 33	6.7 - 42.2
Pipar	P.7	0.[illegible]87 - 0.560	.10 - .15	17 - 20	18 - 27	1.3 - 16.2
Pali	P.8	0.447 - 0 853	.15 - .21	37 - 40	29 - 43	2.0 - 8.8

Water soluble Mg in eqilibriated condition (9 to 33 mg/100 g soil) constituted 1 to 5.9% of the total Mg. Soils, in general, contained comparable amounts of water soluble Mg except Khajwana (P.5) sandy loam and Pali (P.8) soils which contained twice the amount. (Table 2) This is due to the lithology of the area which is, in the former case, limestone and, in the latter case, phyllite and slate.

The exchangeable Mg content varied between 4 to 38 mg/100 g soil, which saturated 4 to 17% of the CEC. The values were much higher than earlier reports for tropical soils (Mokwuny and Melsted, 1972). Further, sandy soils (P.1 to P.4) contained lower amounts but had higher saturation (10 to 17%) whereas reverse was true for medium to fine textured soils (P.5 to P.8). This may be due to higher amounts of amorphous material in sandy soils (Choudhari and Dhir, 1983). Preferential absorption of Mg by alluminosilicates with increasing pH was observed by Perrot (1981).

Organically bound Mg varied from 0 to 43 mg/100 g soil, much higher than normal for tropical soils. Further, the content in general increased with depth and maximum value was in upper part of calcic layer. This may possibly be due to precipitation of highly mobile Mg-fulvate, which has moved downwards. Increasing fulvic acid content (Table 1) in the soils and maximum in upper part of the calcic layer provides supporting evidences for accumulation in upper part of the C horizon or calcic layer.

Ammonium acetate soluble fraction of Mg was somewhat higher than aggregate of exchangeable and water soluble fraction (Table 2). Thus ammonium acetate, besides exracting water soluble and Mg on clay complex also extracted Mg adsorbed by organic matter. Salmon (1963), however, reported that soil organic matter held Mg in non-exchangeable form only.

Reserve Mg content (199 to 519 mg/100 g soil), in general, increased with the increase in finer fraction of soils (Tables 1 and 2). Finer material have influence on this fraction (Rice and Kamproth, 1968). Higher Mg content in clay fraction of some of the soils (Table 3) provides support to this report. Soils P.6 to P.8, containing same amount of clay showed varying contents of reserve Mg (Table 5). These soils also showed varying proportion of 2:1 lattice minerals (Choudhari and Dhir, 1981 and 1982). Soils having higher proportion of illite, smectite and chlorite were observed to have higher reserve of Mg. Thus reserve Mg appears to be a function of the type and proportion of clay minerals present in the soils.

Mineral form of Mg was nearly equal or, in some soils (P. 4 to P. 6), lower than reserve Mg. Mokwuny and Melsted (1972) reported that highest fraction of Mg in tropical soils was in mineral form. Further, in arid soils, mineral Mg (13 to 41 % of the total Mg) exists mostly as a part of the crystal structure of very resistant primary minerals, or is associated with free lime of soils, not dissolved by tri-acids. About 20

Table 2. Forms of magnesium (mg/100 g) in arid soils (range and mean values)

Soils	Water soluble	NH_4 OAC	Exchangeable	Organic bound	Reserve	Mineral	HCl soluble	Total	Carbonate bound
P.1	14 - 15 14.2	20 - 24 24.2	4 - 5 4.2	7 - 10 7.7	120 - 199 147	183 - 188 186	217 - 374 268	597 - 772 674	0 - 68 34
P.2	12 - 14 12.5	24 - 29 26	4 - 9 6.2	10 - 11 10.8	148 - 211 185	188 - 220 199	392 - 549 467	724 - 748 756	0 - 120 75
P.3	12 - 24 16 2	15 - 34 23.8	5 - 6 5.8	1 - 2 1.4	136 - 198 171	188 - 193 149	386-777 428	658 - 330 707	0 - 64 27
P.4	11 - 16 13.4	16 - 57 33	3 - 9 5.2	0 - 1 0.8	136 - 259 180	81 - 140 115	139 - 452 244	543-658 607	0 - 156 59
P.5	23 - 40 35	24 - 30 26	9 - 22 15	3 - 15 8	222 - 334 275	220 - 333 271	434 - 658 543	651 - 1019 803	36 - 236 146
P.6	9 - 24 16	23 - 38 30	7.23 13	4 - 15 12	210 - 346 294	107 - 220 168	664 - 1236 844	802 - 1260 960	148 - 320 198
P.7	15 - 18 16	27 - 37 32	16 -18 17	2 - 7 4	247 - 309 266	252 - 317 282	615 - 694 658	742 - 559 837	104 - 168 133
P.8	27 - 33 30	44 - 54 50	30 - 38 35	21 - 43 32	296 - 519 432	318 - 651 538	1050 - 1442 1289	1110 - 2648 1714	206 - 365 270
Mean	19.3	28.8	12.7	8.9	242.7	234.9	584	864	—

to 30 % more Mg was extracted by HCl than by the sequential treatments (sum of water soluble, exchangeable and reserve Mg form). This suggests that significant part of Mg was associated with free lime, as evidenced by Mg content (24 to 36 mg/100g soil) extracted by cold dilute HCl treatment (Table 2). Beside the lower mineral Mg content, the soils show wider variation in content (81 to 561 mg/100 g soil) and variation was further much more between coarse and fine textured soils. Soil in Gajsinghpura (P.4) contained lowest amount of mineral Mg, contained low amount of heavy minerals and lower proportion of Mg bearing minerals (chlorite, mica, ferro-magnesiun compared to other soils (P.3 and P.8) in their fine sand fraction (Table 3).

Table 3. Magnesium content (%) in various fractions of some arid soils

Soil	Coarse Sand	Fine Sand	Silt	Coarse Clay	Fine Clay
Chirai	0.19	1.61	0.98	3.04	1.38
Gajsinghpura	0.38	1.51	1.62	2.94	1.42
Pipar	0.14	1.46	1.62	2.12	1.43
Pipar	0.16	1.16	1.78	2.29	1.49

The data thus suggest that proportion and type of Mg bearing mineral influences the mineral Mg content of soils beside the heavy mineral content alone (Table 4).

Table 4. Mineral Mg content and minerals in some arid soils.

Soil and depth (cm)	Mineral Mg (mg/100g)	Heavy minerals (%)	Fractions of the heavy minerals			
			Mica	Chlorite	Tour-maline	Ferro-Mg
Chirai						
0-10	145	6	9	24	2	10
10-35	193	6	9	24	4	8
35-68	140	5	8	30	4	8
68-135	150	4	4	25	2	4
Gajsinghpura						
0-20	118	1	4	25	2	4
20-46	220	1	2	34	2	4
78-110	107	1	5	34	1	5
Pali						
0-10	381	4	4	37	–	16
10-20	629	2	3	30	–	15
20-35	651	2	1	33	–	17
35-50	491	2	1	32	–	16

Inspite of wide variations in the content of different forms, total Mg content was nearly the same in the aeolian (P.1 and P.2) and the coarse textured alluvial plain soils (Chirai P. 3 and P. 4). This is possibly due to origin of aeolian sands (90 to 95 % fine sand) by breakdown of alluvial plain (Dhir et al., 1977). The fine sand fraction contained higher amounts of Mg than other size fractions (Table 3). Accordingly, higher Mg content of fine textured Pali (P. 8) and Gajsinghpura (P. 6) soils was due to higher finer fraction (clay and silt) which contributed maximum to the total Mg compared to sand fraction.

Table 5. Relation between reserve magnesium and clay mineralogy of soils

Soil & Depth Cm.	Clay	Reserve mg 100 g	Dominant minerals (%) Illite	Smectite	Chlorite	Vermiculite
Gajsinghpura	18	3335	30-40	30-40	10-15	5-10
Pipar	18	2718	40-50	20-30	5-10	10-15
Gajsinghpura	29	2718	30-40	30-40	5-10	10-15
Pali	29	2965	30-40	20-40	5-10	5
Pali	33	5168	40-50	30-50	5	5

Correlation coefficient values between different Mg forms (Table 6) show that the water soluble, ammonium acetate soluble, exchangeable, and organically bound were positively and significantly correlated with reserve and total Mg. The reserve and HCl forms also showed significant positive relationship with total Mg thereby indicate that their is an equilibrium between the forms of Mg.

Table 6. Correlation coefficient beween the forms of magnesium.

	Ammonium acetate soluble	Exchangeable	Organic bound	Reserve	Mineral	Total	HCI Soluble
Water soluble	0.276	.495	.572	.673	.164	.341	.411
Ammonium acetate soluble		.675	.569	.661	.582	.636	.149
Exchangeable			.701	.887	.872	.773	.848
Organic bound				.631	.228	.784	.763
Reserve					.768	.775	.867
Mineral						.813	.773
Total							.846

CD at 1%=0.4182, CD at 0.1%=0.5182.

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REFERENCES

Choudhari, J. S. and Dhir, R. P. 1981. Clay mineralogy of medium to fine textured alluvial plain soils of western Rajasthan. Proceedings of the Indian National Science Academy. 47 A (6) : 695-704.

Choudhari, J.S. and Dhir, R.P. 1982. Clay mineralogy of dune and associated sandy plain soils of western Rajasthan. Journal of the Indian Society of Soil Science. 30 : 342-347.

Choudhari, J.S. and Dhir, R.P. 1983. Nature and distribution of amorphous alumino-silicates in arid soils of western Rajasthan. Journal of the Indian Society of Soil Science. 31: 94-98.

Choudhari, J.S. and Sharma, K.D. 1984. Stream salinity in Indian arid zone. Journal of Hydrology. 71 : 149-163.

Dhir, R. P., Singh, N. and Sharma, B. K. 1977. Some observations on the behavour of soils and sediments under the late quaternary environment and humen settlement in western Rajasthan. Man and Environment. 1 : 21-24.

Jackson, M. L. 1958. Soil Chemical Analysis. Constable & Co. Ltd, London.

Kover, J. A. and Riecken, F. F. 1976. Relation of non-exchangeable K and Mg to development in some mid- western Nigerian soils. Soil Science Society of America Journal. 40 : 547-552.

Mokwuny, A. U. and Melsted, S. W. 1972. Magnesium forms in selected temperate and tropical soils. Soil Science Society of America Proceedings. 36 : 762-766.

Piper, C. S. 1948. Soil and Plant Analysis. Academic Press, New York.

Rice, H. B. and Kamproth, E. J. 1968. Availability of exchangeable and non-exchangeable Mg in sandy coastal plain soils. Soil Science Society of America Proceedings. 32 : 386-388.

Salmon, R. C. 1963. Magnesium relationships in soils and plants. Journal of the Science of Food and Agriculture. 14 : 605-610.