https://doi.org/10.29321/MAJ.10.A02720

Madras agric. J. 67 (5) : 300—308, May, 1982

Magnesium as a Function of Pedogenic Factors

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Total magnesium obtained by summing up the four fractions of magnesium, namely, mineral magnesium, acid-soluble (reserve) magnesium, exchangeable magnesium and organic-complexed magnesium, was found to be as good as estimating total magnesium separately. The pattern of distribution of magnesium in the Nilgiris depended largely on rainfall which influenced indirectly through its manifested effect of pH, base saturation, exchangeable aluminium and total acidity which are interrelated among themselves. Wide variations may also be attributed to the parent materials which varied even within a small area, charnockite the parent rock of most Nilgiris soils which is known to very considerably from acid to ultra basic conditions. Increase in clay content of the soil was found to increase total Mg as well as magnesium fractions. Among other parameters, organic carbon, moisture, pH, total acidity, exchangeable H, E. C. and base saturation were also observed to influence the pattern of distributio.

The level of magnesium in soils depends to large extent on soil type. Highly leached and wethered soils are generally low in magnesium. Parent meterials, constituent minerals in the parent material and the climate of the region too play a in accounting for the vaiations in magnesium content in soils groups.

Kirkby and Mengel (1976) observed that soils formed in valleys, marsh soils, gleyed soils slightly leached solonchak and solonetz soils contained higher amounts of magnesium, while podzols and lateritic soils were low in magnesium. Mokwunye and Melsted (1972) stated that total magnesium content of the soil is a product of climate, especially rainfall and the stage of maturity of the soil. Metson and Gibson (1977) observed that silt and clay fractions in all cases contained more than 95 per cent of the total magnesium. Organic matter also contributes to the amount of magnesium in soils. Prince *et al.* (1947), Alston (1972) and Mokwunye and Melsted (1972) recorded different fractions of magnesium and observed the amount of various forms depended on the factor like clay, pH, rainfall, organic matter content, etc.

The Nilgiris are a lofty range of mountains in Tamil Nadu State. The altitude ranges between 1220 and 2637 metres above mean sea level. By virtue of its geographical position the Nilgiris come within the influence of both South - West and North - East monsoon. The mean annual rainfall

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recorded for all the localities ranged between 1300 and 2540 mm. The entire region is dotted with several steep and high hills separated invariably either by stream or a swampy valley.

Thus the area gives an excellent materials to study the influence of pedogenic factors on magnesium content and distribution of different discrete forms.

MATERIAL AND METHODS

A total of 147 horizon-wise soil samples from 29 profiles representing the agro-climatic regions of the Nilgiris, one profile from Kodaikanal and another from Yercaud were collected.

The processed samples were analysed for the various physico-chemical constituents (Jackson, 1973) and various forms of magnesium (Mokwunye and Melsted, 1972). Relationship between the forms of magnesium and the pedogenic factros were discussed with the help of block diagrams and simple correlation coefficients.

RESULTS AND DISCUSSION

The locations of the profiles studied and the morphological features of the profiles observed are presented in Table I. Within observable depths, all the profiles did not contain any identifiable unweathered rock fragments indicating that the parent rock and the parent material were far below the profile surfaces and that they belonged to age old formations.

The mean and range of values of physico-chemical properties of soils are furnished in Table II. The relationships between factors are furnished in Tables III and IV.

The total magnesium (Mg_t) content was estimated by two methods: (1) by summation of the four fractions namely, mineral magnesium (Mg_m), acid-soluble (reserve) magnesium (Mg_r), exchangeable magnesium (Mg_e) and organic-complexed magnesium (Mg_{oc}), and (2) by actual estimation (Metson, 1956). A very close correlation coefficient of $r = 0.973^{***}$ ($n = 147$) was obtained between the two indicating that both of them are equally reliable methods. Hence in the following discussions Mg_t by the former method is used.

Total magnesium content of the acid soils of the Nilgiris ranged very widely from as low as 2.5 me/100 g soil to as high as 13.3 me/100 g soil. Of the various parameters, moisture, pH total acidity, exchangeable H, exchangeable Al, EC, base saturation, organic carbon, clay content, rainfall and elevation were observed to influence the distribution pattern of Mg_t as well as the various fractions of magnesium.

A wide variation of the mean annual rainfall was recorded. Increasing amounts, of rainfall was observed to decrease the base saturation (r = — 0.842 **, n = 31). At lower base saturation, the Mg_e (r = 0.493 **; (n = 147) and Mg_{oc} (r = 0.347 **; n = 147) were seen to be lower while the mineral and acid-soluble Mg were observed to be comparatively higher. Further, Mg_m and Mg_r were observed to be directly proportional to the rainfall while Mg_e was indirectly proportional to the rainfall. Rains would have washed away the highly soluble Mg_e resulting in the increase of other fractions in the soil. This observation is in line with the report of Messing (1974) who observed lower Mg_e in high rainfall areas.

An increase in pH resulted in increased Mg_e with simultaneous decrease in Mg_m (r = — 0.163 **: n = 147) and Mg_{oc} (r = — 0.569 **; n = 147).

The interrelationships of rainfall, base saturation, pH and the magnesium fractions as observed in the present study suggest that the pattern of distribution of magnesium and its fractions was the manifestation of rainfall of the area acting directly by leaching and indirectly through pH, base saturation, etc. According to Mokwunye and Melsted (1972), the total magnesium content of the soil is a product of climate especially rainfall.

Further, total acidity was negatively correlated with Mg_e and positively correlated with Mg_r and Mg_m. Schuyjelen (1974) observed that Mg shortage was directly related to the acidity of the medium. Metson (1974) stated that total acidity, *per se* may reduced the Mg_e. Kamprats (1970) reported that aluminium contributed very much to the total acidity and it played an important role below pH 5.4. In the present investigation, 83.0 per cent of the soils recorded pH below 5.4 and exchangeable aluminium was observed to be negatively correlated with Mg_e but positively correlated with Mg_r and Mg_m. This might be due to the possibility of lattice magnesium substituting for aluminium in Octahedral position as reported by Chinttenden and Hodgson (1953). Exchangeable hydrogen was observed to exhibit positive relationships with Mg_r and Mg_m (Table II).

As the organic carbon content of the soil increased, the Mg_t Mg_r and Mg_m content also increased. This might be due to the fact that magnesium is a constituent of organic matter. Further, it may also be due to the release of magnesium by mineralisation to the pool of inorganic sources of magnesium.

As the clay content increased, Mg_t, Mg_{oc}, Mg_m and Mg_e content were also observed to increase. Other size fractions did not show any influence as the above. Beeson (1959), Salmon (1963 and Mokwunye and Melsted (1973) reported that soil texture has a profound influence on the level of Mg_e and the clay portion of the soil generally contained two-thirds of the soil magnesium.

Elevation also seem to play an important role in modifying the pattern of distribution of magnesium. Higher the elevation, higher was the Mg_m and Mg_r and lower was the Mg_e. Messing (1974) observed acute magnesium deficiency areas at higher elevations. It is of interest to note here that the moisture content of soil was positively correlated with Mg_e, Mg_r and negatively correlated with Mg_{oc}. The amount of soil moisture would have been well within the limits of providing favourable environment for mineralisation and release of magnesium from the Mg_{oc} fraction to the reserve and exchangeable pool.

As the cation exchange capacity of the soils increased, the Mg_t as well as Mg_e were observed to increase ($r = 0.206^{**}$; $n = 147$ and $r = 0.269^{**}$; $n = 147$ respectively), perhaps due to higher clay content which influences the cation exchange capacity largely.

ACKNOWLEDGEMENT

Sincere thanks are due to the Tamil Nadu Agricultural University, Coimbatore, for the facilities offered in carrying out this investigation as part of the Ph. D. thesis of the first author.

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TABLE I Locations and Morphological Features of Profiles

Location	Mean annual rainfall (mm)	Elevation in metres above MSL	Colour		Texture	Structure
			Dry	Moist		
Bembatty	1600	2057	7.5 YR 5/4	7.5 YR 4/2	cl	M
Emerald	1600	1881	7.5 YR 4/2	5.0 YR 3/2	cl	M
Yedakad	1403	1905	7.5 YR 4/2	5.0 YR 3/3	sel	M
Mulligur	1403	1945	7.5 YR 5/4	7.5 YR 4/2	cl	Bl
Melkundha	1403	1676	7.5 YR 5/4	7.5 YR 4/2	cl	Sbk
Titukkal	1330	2210	7.5 YR 5/2	7.5 YR 3/2	cl	Bl
Kavaratty	1600	2057	7.5 YR 5/4	5.0 YR 4/3	cl	Bl
Ward's gate	1330	2134	7.5 YR 5/4	5.0 YR 4/8	cl	Pr
Kadanad	1330	1981	10.0 YR 6/2	7.5 YR 4/2	cl	Pr
Maragal	1330	1829	7.5 YR 4/2	2.5 YR 2/4	cl	Bl
Ebbanad	1625	1783	7.5 YR 4/2	5.0 YR 4/6	cl	M
Thuneri	1625	1829	10.0 YR 4/3	7.5 YR 4/2	cl	Sbk
Doddabetta (top)	1330	2637	5.0 YR 3/1	7.5 YR 2/0	cl	Bl
Doddabetta (mid point)	1330	2515	5.0 YR 3/1	5.0 YR 3/1	cl	M
Doddabetta (bottom)	1330	2377	7.5 YR 4/2	5.0 YR 2/2	cl	M
Kambatty	1625	1981	7.5 YR 5/4	5.0 YR 4/4	cl	M
Thummanatty	1625	1625	5.0 YR 4/8	2.5 YR 3/4	cl	M
Balacola	1600	2054	7.5 YR 4/2	5.0 YR 3/3	cl	Bl
Melur	1600	1829	7.5 YR 5/2	5.0 YR 7/3	cl	Bl
Hulikkal	1625	1844	5.0 YR 4/8	2 5 YR 3/4	cl	Pr
Ketty	1220	1981	7.5 YR 4/2	5.0 YR 4/2	cl	Pr
Kengarai	1508	1600	7.5 YR 4/2	5.0 YR 3/2	cll	M
Nedugula	1508	1890	5.0 YR 5/4	2.5 YR 3/6	sl	Pr
Kodanad	1508	2042	10.0 YR 5/4	5.0 YR 3/3	sl	Pr
Kotagiri	1890	1920	7.5 YR 4/4	5.0 YR 4/3	cll	M
Sholur	2540	1859	7.5 YR 5/4	5.0 YR 3/3	cl	Sbk
Gudalur	2395	1143	10.0 YR 4/3	5.0 YR 3/3	cl	Sbk
Naduvattam	2540	1829	5.0 YR 4/4	2.5 YR 3/4	cl	Sbk
Nanjanad	1522	2134	7.5 YR 5/4	5.0 YR 4/4	cll	Sbk
Kodaikanal	1988	2200	5.0 YR 2/2	5.0 YR 2/2	cl	Sr
Yercaud	1300	1220	5.0 YR 6/4	5.0 YR 3/3	cl	Bl

cl : Clay
s : Sandy
l : Loam
Sbk : Subangular blocky
M : Massive
Bl : Blocky
Pr : Prismatic
Cr : Crumb

TABLE II Values of Mean of Ranges of Physico-Chemical Properties of 147 Samples Analysed

	Minimum	Maximum	Mean
Moisture (per cent)	1.2	12.6	5.1
pH	3.6	6.8	—
E. C. mmhos/cm	0.05	0.21	0.12
Base saturation (per cent)	7.4	98.0	47.07
Organic carbon (per cent)	0.1	25.2	3.8
Total acidity (me/100 g)	0.1	6.8	1.7
Mechanical analysis (per cent)			
Coarse sand	4.7	57.0	23.0
Fine sand	2.7	33.9	13.8
Silt	0.3	42.2	15.0
Clay	14.9	71.9	43.2
Cation exchange capacity (me/100 g)	4.5	41.8	13.9
Exchangeable aluminium (me/100 g)	0.05	5.00	1.44
Exchangeable hydrogen (me/100 g)	0.10	2.60	0.28
Total Mg (by summation) (me/100 g)	2.5	12.7	6.7
Total Mg (by estimation) (me/100 g)	2.0	12.7	6.7
Mineral Mg (me/100 g)	0.3	4.4	2.2
Acid - soluble Mg (me/100 g)	0.2	4.6	1.5
Exchangeable Mg (me/100 g)	0.2	7.9	1.4
Organic - complexed Mg (me/100 g)	0.2	4.3	1.6

TABLE III Coefficients of correlations between magnesium fractions and factors like rainfall, elevation and soil properties (No. of pairs: 31 upto 11 and remaining 147)

Relationship between X	Y	'r'	Regression equation
Rainfall (mm)	Base saturation (%)	—0.842**	Y = 149.04 — 0.061X
Rainfall (mm)	Mineral Mg	0.220**	Y = 0.503 + 0.001X
Rainfall (mm)	Acid—soluble Mg	0.202*	Y = 0.003 + 0.001X
Rainfall (mm)	Exchangeable Mg	—0.213**	Y = 0.3397 + 0.001X
Elevation (meters)	Base saturation (%)	—0.174NS	Y = ...
Elevation (meters)	Total Mg (summation)	0.211**	Y = 3.402 + 0.002X
Elevation (meters)	Total Mg (estimation)	0.240**	Y = 3.362 + 0.002X
Elevation (meters)	Mineral Mg	0.310**	Y = 0.231 + 0.001X
Elevation (meters)	Acid soluble Mg	0.271**	Y = 0.001X + 0.239
Elevation (meters)	Organic - complexed Mg	0.307**	Y = 0.001X + 0.249
Elevation (meters)	Exchangeable Mg	—0.198*	Y = 3.669 — 0.001X
Moisture content (%)	Exchangeable Mg	0.159*	Y = 0.888 + 0.093X
Moisture content (%)	Acid—soluble Mg	0.274*	Y = 0.977 + 0.099X
Moisture content (%)	Organic — complex Mg	0.534**	Y = 0.494 — 0.172X
pH	Exchangeable Mg	0.225*	Y = 0.473X — 0.830
pH	Organic complexed Mg	—0.569**	Y = 4.63 — 0.66X
pH	Mineral Mg	—0.163*	Y = 3.21 — 0.22X
Electrical conductivity (mmhes/cm)	Organic complexed Mg	0.208*	Y = 0.208* — 5.64X
Base saturation (%)	Exchangeable Mg	0.493**	Y = 0.029X — 0.01
Base saturation (%)	Organic complexed Mg	0.347**	Y = 1.06 + 0.012X
Base saturation (%)	Acid soluble Mg	—0.172*	Y = 1.76 — 0.006X
Base saturation (%)	Mineral Mg	—0.213**	Y = 2.57 — 0.008X

Mg expresed as me / 100g

TABLE IV Coefficients of Correlations Between soil Magnesium Fractions and Physico-Chemical Properties (No of pairs = 147)

Relationship between X	Y	'r'	Regression equation
Organic carbon (%)	Acid-soluble Mg	0.175*	Y = 1.316 + 0.042X
Organic carbon (%)	Mineral Mg	0.278**	Y = 1.911 + 0.073X
Organic carbon (%)	Total Mg (summation)	0.271**	Y = 6.043 + 0.159X
Organic carbon (%)	Total Mg (estimation)	0.245**	Y = 6.201 + 0.141X
Total acidity (me/100 g)	Mineral Mg	0.404**	Y = 1.706 + 0.285X
Total acidity (me/100 g)	Acid - soluble Mg	0.227**	Y = 1.227 + 0.151X
Total acidity (me/100 g)	Exchangeable Mg	—0.325	Y = 1.956 + 0.351X
Clay content (%)	Eachangeable Mg	0.196*	Y = 0.237 + 0.026X
Clay content (%)	Organic complexed Mg	0.167*	Y = 0.102 + 0.012X
Clay content (%)	Mineral Mg	0.297*	Y = 1.110 + 0.025X
Clay content (%)	Total Mg (summation)	0.170*	Y = 5.224 + 0.033X

* Significant at P = 0.05 Mg expressed as me/100 g

** Significant at P = 0.01