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Effect of Organic Matter on Different Forms of Manganese, Iron and Cobalt in Soils

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Abstract: Manganese moved from insoluble forms (CO_3, CFeOX, residual, MnOX) to more plant-available forms (exchangeable and organic). Manganese as percentage of total soil Mn in different fractions was in the order: residual > MnOX > AFeOX > CFeOX > OM > Ex+W > CO_3. Increasing organic matter moved iron from CFeOX and CO_3 fraction to residual fraction and less soluble and intermediately fractions. More than 50% of total Fe was associated in the mineral fraction (residual fraction) in all the soils. The results showed that native and added Co was mainly retained in soluble and intermediately soluble fraction of MnOX and AFeOX. Cobalt in various fractions was in the order: Residual > Ex+W > AFeOX > MnOX > OM > CO_3 > CFeOX.

Key words: OM levels, heavy metals, sequential fractionation, chemical forms.

Besides having several other beneficial effects on soil condition and plant growth, organic manures may also help in alleviating the deficiency of micronutrients. This is achieved through the liberation of carbon dioxide and organic acids during decomposition of organic matter which lowers the soil pH and increases the availability of micronutrients. Takker and Bhumbla (1968) reported that free and active forms of Mn did not depend on organic carbon content of the soil. Olomu *et al.* (1973) observed that all the Fe in soil solution was complexed with organic matter, whereas Mn was either not complexed or only weakly complexed. The available information regarding the effect of organic matter on the extractable Mn, Fe and Co content in the different fractions in soil is not only insufficient but also sometimes contradictory in nature. It was, therefore, considered worthwhile to investigate this aspect for further details.

Materials and Methods

Three soils, viz., loamy sand, sandy loam, and clay loam used in the experiments, were analyzed for physico-chemical characteristics (Table 1). The soils were air dried and sieved through a 2 mm stainless steel sieve. Soil pH and electrical conductivity (EC) were determined in 1:2 soil to water suspension; organic carbon by a modified Walkley-Black procedure (Nelson and Sommers, 1982); $CaCO_3$ by the acid-neutralization method (Allison and Moodie, 1965); carbon exchange capacity by the NaOAc method (Chapman, 1965); and particle size distribution by the pipette method (Day, 1965). The total amount of Mn, Fe and Co were estimated using the procedures of Tessier *et al.* (1979). In all the soils,

Table 1. Physical and chemical characteristics of the soils used

Soil characteristics	Soil texture		
	Loamy sand	Sandy loam	Clay loam
Field capacity (%)	14.00	20.00	24.00
Organic carbon (%)	0.03	0.65	0.84
$CaCO_3$ (%)	Nil	0.60	1.50
pH (1:2)	8.45	8.30	7.70
EC (dS m^{-1})	0.16	0.55	0.51
CEC [cmol (p^+) kg^{-1}]	8.90	14.30	16.20
Sand (%)	89.60	73.40	28.40
Silt (%)	1.40	6.60	37.20
Clay (%)	9.00	20.00	34.40
Total Mn (mg kg^{-1} soil)	342.80	458.70	426.50
Total Fe (mg kg^{-1} soil)	12875.00	18540.00	21680.00
Total Co (mg kg^{-1} soil)	28.60	35.70	42.60

the organic matter was added at the rate of 0, 5.0, 7.5 and 10.0 g kg^{-1} through starch in order to avoid any complication that might arise due to the release of mineral elements from the decomposition of organic matter if any conventional manure was used. Twenty milligram each of Mn, Fe and Co kg^{-1} soil were added in solution form in three soils varying in texture in triplicate at field capacity in all possible combinations

Table 2. Initial sequential fractionation of soils used

	Different fractions (μg g^{-1} soil)						
	Exch.	Carbonate	Mang. oxide	Organic	Am. Fe. oxide	Cry. Fe. oxide	Residual
Loamy sand							
Zn	0.82	1.13	0.80	1.00	0.72	1.53	44.30
Mn	2.63	1.41	52.10	4.00	15.64	27.22	229.90
Fe	3.00	5.00	73.00	69.00	690.0	4382.00	7278.00
Sandy loam							
Zn	1.13	1.90	1.34	1.61	1.51	2.31	67.00
Mn	3.80	1.52	62.43	7.51	22.34	37.30	311.90
Fe	3.64	6.00	165.00	80.00	710.00	6492.00	10543.26
Clay loam							
Zn	1.40	1.84	2.62	1.51	3.62	3.11	89.60
Mn	5.73	5.21	59.00	8.33	18.00	35.13	283.00
Fe	4.74	6.82	207.00	135.00	830.00	7364.00	12452.84

Am. Fe. oxide = Amorphous iron oxide bound.
Cry. Fe. oxide = Crystalline iron oxide bound.

in polythene bottles plugged with cotton wool. The bottles containing soil were placed in an incubator at 20 ± 2°C for 15 weeks to attain equilibrium. After the completion of each incubation period, the samples were prepared for sequential fractionation of Mn, Fe and Co in water soluble plus exchangeable (Ex+W), carbonates (CO_3), organic (OM), manganese oxide (MnOX), amorphous ferric oxide (AFeOX), crystalline ferric oxide (CFeOX), and residual (RES) fractions. The sequential extraction procedures for Mn, Fe and Co were used as modified by Kaushik *et al.* (1993). The data of initial sequential fraction of different metals in the soils are given in Table 2.

Results and Discussion

Distribution of manganese

Manganese in Ex+W fraction increased significantly in all the soils as a result of addition of organic matter (Fig. 1). Application of 10 g kg^{-1} O.M. enhanced Mn in Ex+W fraction by 19.9, 45.1 and 26.1% in loamy sand, sandy loam and clay loam soil, respectively, when compared with that

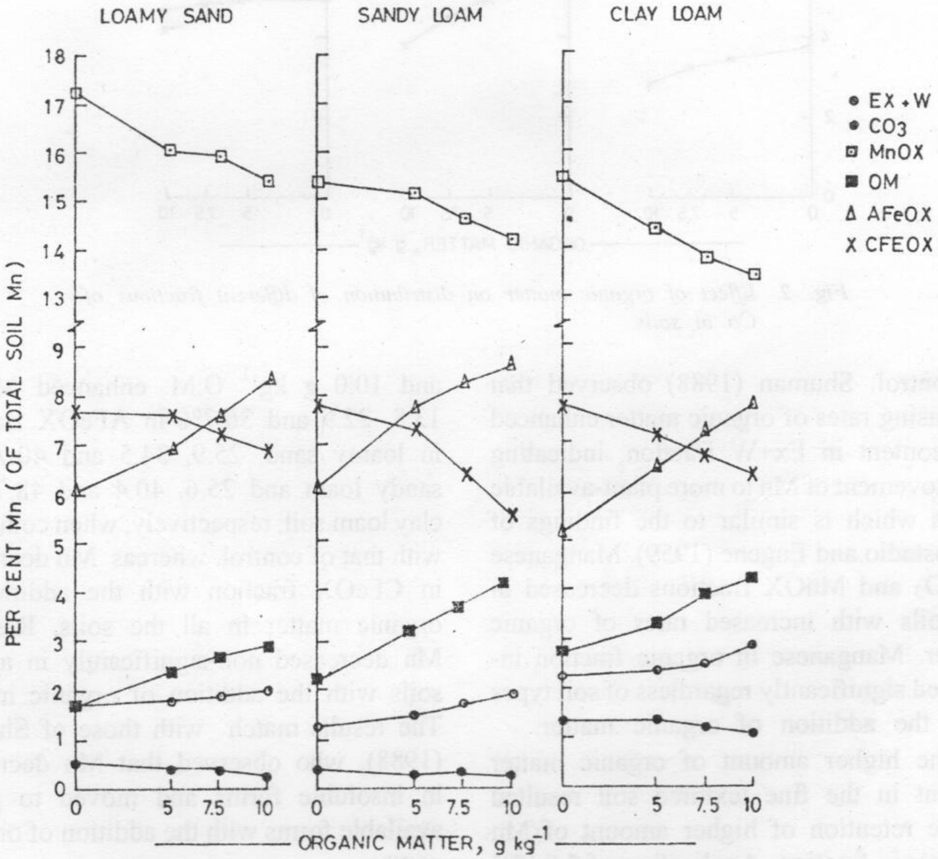

Fig. 1. Effect of organic matter on distribution of different fractions of Mn in soils.

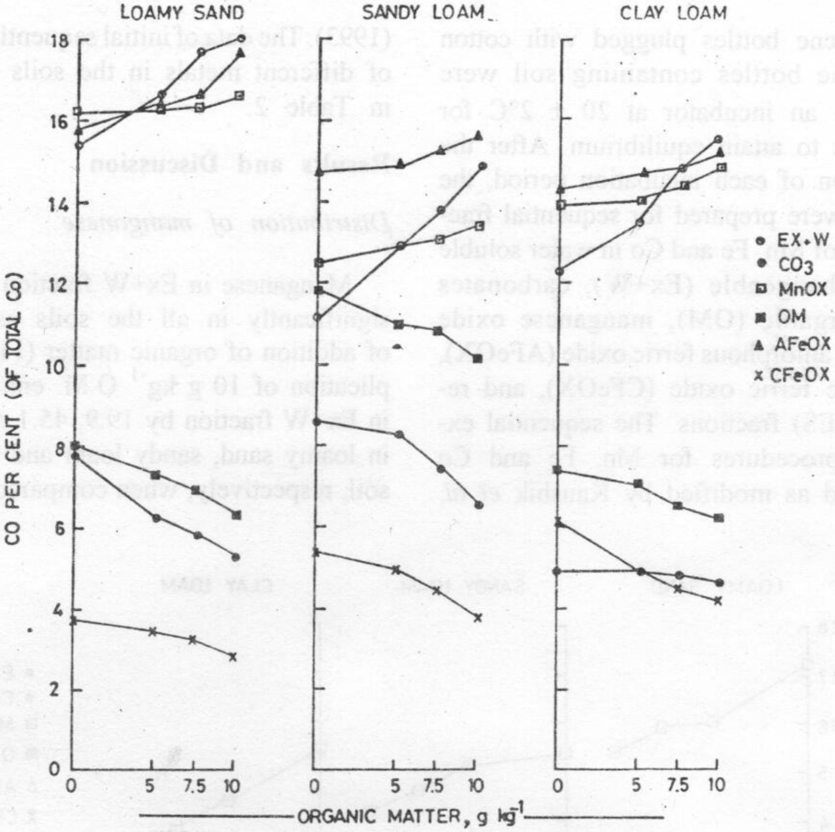

Fig. 2. Effect of organic matter on distribution of different fractions of Co in soils.

of control. Shuman (1988) observed that increasing rates of organic matter enhanced Mn content in Ex+W fraction, indicating the movement of Mn to more plant-available forms which is similar to the findings of Carlostadio and Eugene (1959). Manganese in CO_3 and MnOX fractions decreased in all soils with increased rates of organic matter. Manganese in organic fraction increased significantly regardless of soil types with the addition of organic matter.

The higher amount of organic matter present in the fine textured soil resulted in the retention of higher amount of Mn in organic fraction. Application of 5.0, 7.5 and 10.0 g kg^{-1} O.M. enhanced Mn by 13.8, 22.9 and 36.7% in AFeOX fraction in loamy sand, 25.9, 34.5 and 40.7% in sandy loam and 25.6, 40.4 and 48.7% in clay loam soil, respectively, when compared with that of control, whereas Mn decreased in CFeOX fraction with the addition of organic matter in all the soils. Residual Mn decreased non-significantly in all the soils with the addition of organic matter. The results match with those of Shuman (1988), who observed that Mn decreased in insoluble forms and moved to plant-available forms with the addition of organic matter.

Distribution of iron

Iron in Ex+W fraction increased regardless of soil texture due to the addition of organic matter (Table 3). Application of 10 g kg^{-1}O.M. increased Fe in Ex+W fraction by 14.1, 20.0 and 11.4% when compared with that of control in loamy sand, sandy loam and clay loam soil, respectively. Shuman (1988) also reported that increase in organic matter moved Fe into more plant-available form from the crystalline form. A decreasing trend was observed in CO_3 fraction with addition of organic matter regardless of soil texture. Amount of Fe in MnOX and OM fractions increased in all soils as a result of addition of organic matter. Application of 10 g kg^{-1} caused 52.0, 50.0 and 111.9% increase in Fe in AFeOX fraction when compared with that of control in loamy sand, sandy loam and clay loam soil, respectively. Shuman (1988) also observed that increasing the organic matter levels increased Fe in AFeOX fraction. Lu *et al.* (1981) reported that reduction and oxidation were probably accelerated by the presence of higher amount of organic matter and microbial activity, resulting in higher content of Fe. Iron in

Table 3. Effect of organic matter on the iron distribution among soil fractions

Soil	O.M. (g/kg)	Different fractions						
		Ex+W	CO_3	MnOX	OM	AFeOX	CFeOX	Residual
		mg kg^{-1}						
Loamy sand	0.0	7.82	6.61	62.54	60.00	500.00	5383.13	6500.00
	5.0	8.10	6.23	80.03	75.02	700.00	4380.62	7271.00
	7.5	8.41	6.02	82.01	81.03	720.00	4080.23	7542.50
	10.0	8.90	5.21	87.00	82.02	760.04	3920.13	7656.70
LSD (P=0.05)		0.16	0.20	1.91	1.04	9.18	14.69	15.32
Sandy loam	0.0	8.51	6.74	175.00	88.55	720.00	6487.10	10534.10
	5.0	9.20	6.00	180.04	99.04	980.02	5100.00	11651.70
	7.5	10.20	5.80	183.02	96.00	1000.08	4960.00	11764.00
	10.0	10.81	5.21	182.02	99.03	1080.03	4743.00	11899.90
LSD (P=0.05)		0.21	0.41	3.02	1.21	7.10	10.78	14.53
Clay loamy	0.0	12.34	8.51	214.00	140.00	840.85	7357.00	12447.30
	5.0	12.91	7.30	215.00	145.02	1400.04	4500.03	14739.90
	7.5	13.40	6.40	217.01	146.03	1650.05	4180.01	14808.10
	10.0	13.71	5.71	218.02	147.51	1780.04	3890.01	14964.90
LSD (P=0.05)		0.44	0.16	0.21	1.82	16.30	19.98	17.42

Ex+W, exchangeable + water soluble; CO_3, carbonates bound; MnOX, Mn-oxide bound; OM, organically bound; AFeOX, amorphous Fe-oxide bound; CFeOX, crystalline Fe-oxide bound; OM, organic matter.

CFeOX fraction decreased in all soils with the addition of organic matter.

Distribution of cobalt

Cobalt in Ex+W soluble fraction increased regardless of soil texture as a result of increasing levels of organic matter (Fig. 2). Badhe and Zende (1962) also recorded highly significant relationship between organic matter and exchangeable cobalt. A decreasing trend was observed in CO_3 fraction with addition of organic matter in all soils while cobalt increased in MnOX fraction. In OM fraction, cobalt decreased with the addition of organic matter in all soils. It is observed that 6.3 to 8.0%, 10.1 to 11.6% and 6.2 to 7.4% of total cobalt was associated with OM fraction in loamy sand, sandy loam and clay loam soil, respectively. Cobalt exhibited a similar pattern of distribution in AFeOX fraction as in Ex+W and MnOX fraction in the soil studied. Depression of Co with the highest level of O.M. over control was 23.7, 32.7 and 32.2% in loamy sand, sandy loam and clay loam soil, respectively. In residual fraction, no effect of Co content was observed with increased levels of O.M. in loamy sand, sandy loam and clay loam soils.

References

Allison, L.E. and Moodie, C.D. 1965. Carbonate. In *Methods of Soil Analysis* (Ed. C.A. Black), Part 2, pp. 1379-1396. American Society of Agronomy, Madison, Wisconsin, U.S.A.

Badhe, M.N. and Zende, G.K. 1962. Cobalt status of Konkan soils in relation to organic carbon, lime and iron. *Indian Journal of Agronomy* 6: 304-310.

Carlostadio, S. and Eugene, K.J. 1959. Effect of liming and organic matter content on the availability of native and applied manganese. *Soil Science Society of America Proceedings* 23: 302-304.

Chapman, H.D. 1965. Cation exchange capacity. In *Methods of Soil Analysis* (Ed. C.A. Black), Part 2, pp. 891-903. American Society of Agronomy, Madison, Wisconsin, U.S.A.

Day, P.R. 1965. Particle fractionation and particle size analysis. In *Methods of Soil Analysis* (Ed. C.A. Black), Part 2, pp. 545-566. American Society of Agronomy, Madison, Wisconsin, U.S.A.

Kaushik, R.D., Gupta, V.K. and Singh, J.P. 1993. Distribution of zinc, cadmium and copper forms in soils as influenced by phosphorus application. *Arid Soil Research & Rehabilitation* 7: 163-171.

Lu, K.L., Pulford, I.D. and Duncan, H.J. 1981. Influence of waterlogging and lime on organic matter additions on the distribution of trace metals in an arid soil 2. Zinc and copper. *Plant and Soil* 59: 327-333.

Nelson, D.W. and Sommers, L.E. 1982. Total carbon, organic carbon and organic matter. In *Methods of Soil Analysis* (Ed. A.L. Page), Part 2, pp. 539-577. American Society of Agronomy, Madison, Wisconsin, U.S.A.

Olomu, M.O., Racz, G.L. and Cho, C.M. 1973. Effect of flooding on the Eh, pH and concentration of Fe and Mn in several Manitoba soils. *Soil Science Society of America Proceedings* 37: 220-224.

Shuman, L.M. 1988. Effect of organic matter on the distribution of manganese, copper, iron and zinc in soil fractions. *Soil Science* 146(3): 192-198.

Takker, P.N. and Bhumbla, D.R. 1968. Distribution of iron and manganese forms in acidic and neutral soils of the Himachal 1. *Agrochimica* 12: 412-421.

Tessier, A.P., Campbell, G.C. and Bisson, M. 1979. Sequential extraction procedure for the speciation of particulate trace metal. *Analytical Chemistry* 51: 844-851.