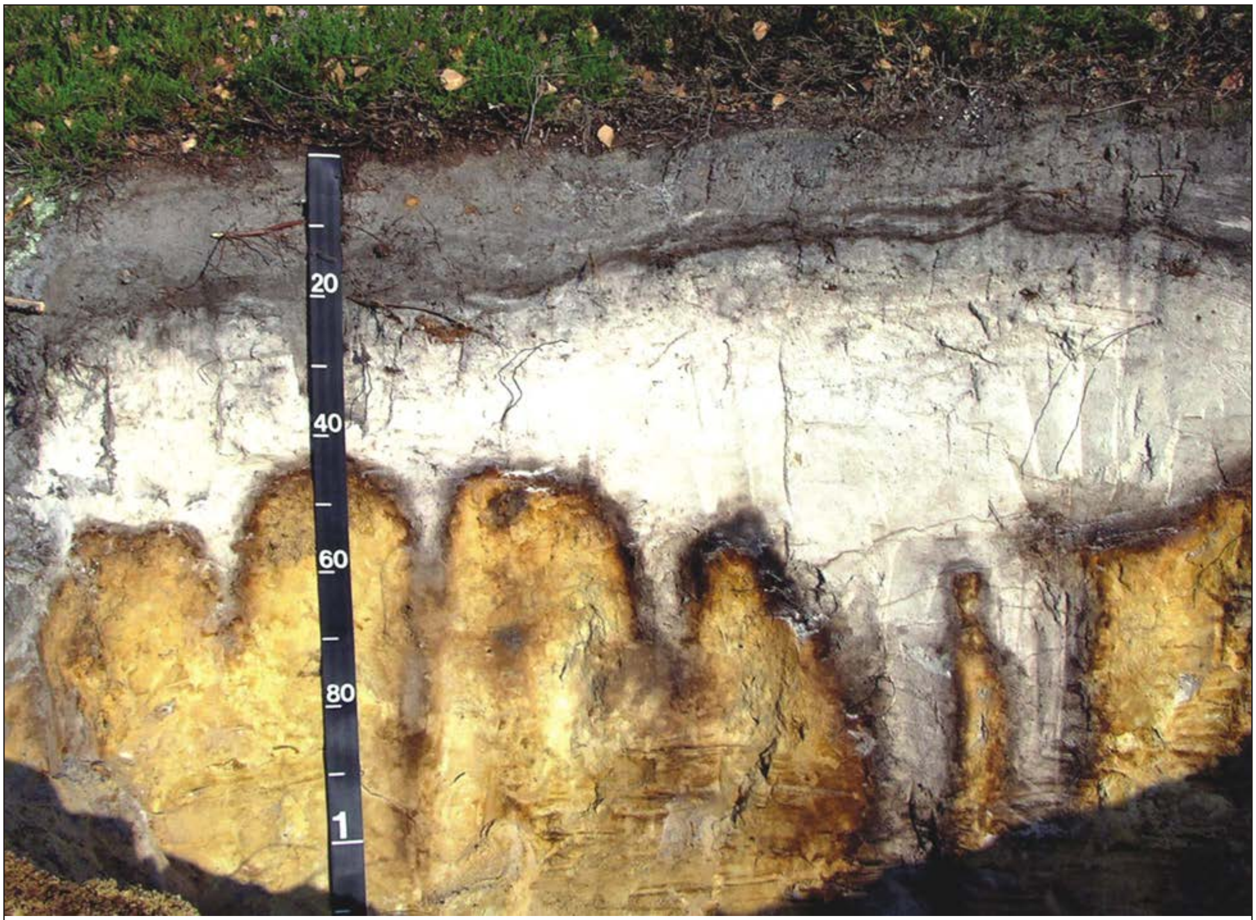

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Vertical Distribution of Magnesium in the Laterite Soils of South India

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ABSTRACT

High levels of exchangeable potassium or ammonium can interfere with the uptake of magnesium by crops. This antagonism is a major concern in some tea growing soils with low magnesium. Soil samples were collected from tea fields and a nearby forest, at various depths. The pH of tea soil ranged between 4.60 and 4.88 and the values were lower when compared to the forest soils. This could be due to the continuous application of nitrogen containing fertilisers. Water soluble magnesium content was higher in forest area when compared to the tea fields which could be attributed to the application of magnesium in the form of carbonate once in four year. Total magnesium was estimated in both cultivated and forest soils and the amount of total magnesium was higher in forest area when compared to the cultivated area. The total magnesium content in forest area ranged between 370 and 1550 mg kg^{-1}, while in tea soils it ranged between 228 and 968 mg kg^{-1}. The available magnesium content ranged between 10 and 40 mg kg^{-1} in tea soil and 20 and 70 mg kg^{-1} in forest soil. Water soluble magnesium had negative correlation with pH of the tea soils. There existed a linear relationship between water soluble magnesium and electrical conductivity of cultivated soils. The magnesium status of tea soils is generally low when compared to the forest area due to continuous exploitation of this nutrient by tea plants. This study confirmed that there is need for soil application of magnesium fertilizer in tea fields to preserve the magnesium status.

Key words: Cultivated area, forest area, magnesium, potassium, organic matter

INTRODUCTION

South Indian tea soils are classified as latosol and it contains kaolinite and gibbnite as predominant clay minerals with small amount of illite. In geological origin, the soils are mainly derived from gneissic rocks containing lot of mica. Tea is mono culture crop which had been planted in the forest soil and there is feeling that the fertility of the old forest soils is being depleted by tea cultivation. Soil magnesium is a moderately leachable nutrient. Compared to calcium, greater amounts are often found in the subsoil than in the upper parts of the soil profile, especially older, highly weathered soils. High levels of exchangeable potassium or ammonium can interfere with magnesium uptake by crop plants. This antagonism is a major concern in some tea growing areas with low magnesium soils. About 150 to 300 kg of K_2O is added every year to overcome potassium deficiency and to obtain sustainable yield (Verma and Palani, 1997; Venkatesan, 2006). The removal of magnesium through leaf harvesting is 6 to 8 times lesser than that of potassium, the higher potassium input strengthens the antagonism between magnesium and potassium leading to magnesium deficiency which is observed in many tea field in South India (Venkatesan, 2006). The correction is done through foliar application of magnesium sulphate along with zinc sulphate, manganese sulphate, boric acid and naphthalene acetic acid (Verma and Palani, 1997). This study is expected to provide the basic information as to what level the tea cultivation has influenced the magnesium nutrient present in soils, when compared to the forest soils. The information available on magnesium distribution is very much limited in tea, while there are many attempts under various other crops (Mathan, 1991; Garg *et al.*, 2003; Cornfield and Pollard, 2006). The data will be useful in understanding the magnesium fertiliser requirements. The present study attempts have also been made to study the distribution and interrelationship of different forms of soil magnesium influenced by tea cultivation practices in comparison to the nearby forest soils.

MATERIALS AND METHODS

Study site and soil sampling: In South India tea is grown in Latosols (Oxisols and Ultisols) in the humid regions of Western ghats, close to the west coast of peninsular India, at latitudes varied between 8° and 13° N elevation ranged between 600 and 2800 m above the mean sea level, the annual rain fall ranged between 900 and 7500 mm. The soil profile was excavated at three places in the tea fields at 500 m apart. The resulting trench was 2×2 m with depths of 2 m. Eight soil samples were taken by gently scratching each trench wall at the following depth intervals like 0-25, 25-50, 50-75, 75-100, 100-125, 125-150, 150-175 and 175-200 cm. Samples were collected at each depth at three places, pooled and mixed thoroughly by hand on a polythene sheet. At the same time the soil profiles were excavated at three places inside the forest situated nearer to the tea field. Soil samplings were done as in the case of tea fields. The bulk quantity of the sample was reduced by quartering method to make one composite sample. The samples were air dried and passed through 2 mm sieve. The experiment was conducted between 2007 and 2008 at UPASI Tea Research Foundation, Valparai.

Physicochemical properties: Soil pH was measured in 1:2 soil water mixture using Orion pH meter (Orion, 950) by Schofield and Taylor (1955), electrical conductivity was measured using conductivity meter (Systronics, 304) by Mason and Obenshain (1939) method, organic matter by Wakley and Black (1934) procedure, available phosphorus by Bray and Kurtz (1945) method, potassium by Hanway and Heidal (1952) Cation Exchange Capacity (CEC) and bulk density by Bhargava and Raghupathi (2001).

Different pattern of magnesium: The remaining soil samples were analysed for different forms of magnesium namely water soluble magnesium, 1 N ammonium acetate extractable magnesium (i.e., available magnesium) and extractable by 1 N boiling nitric acid. Exchangeable magnesium was determined by subtracting from water soluble magnesium (Jackson, 1977). Non exchangeable magnesium was determined by subtracting 1 N HNO_3 magnesium from available magnesium (Wood and de Turk, 1940). Total magnesium was determined by sodium carbonate fusion method (Jackson, 1977). Lattice magnesium was determined by subtracting total magnesium from non-exchangeable magnesium (Jackson, 1977). The amount of magnesium present in the soil solution was estimated by an Atomic Absorption Spectrophotometer (GBC Avanta 908 AA).

Statistical analysis was carried out by the standard method (Gomez and Gomez, 1984). The correlation coefficient was carried out using the software SPSS 12.1 for windows.

RESULTS

Physico chemical properties of tea and forest soils: The pH of the tea soils ranged between 4.60 and 4.88 and the values are lower when compared to the forest soils (Table 1, 2). The electrical conductivity of cultivated soil ranged between 0.02 and 0.05 dS m^{-1} which was greater than that of forest soils. Organic matter content was estimated in both cultivated and forest soils. The results showed that the forest soils are having slightly higher organic matter content when compared to the tea soils. Organic matter content decreased with increase in soil depth. Further the cation exchange capacity, an interrelated parameter to organic matter, showed a similar trend like organic matter. The bacteria and fungai count of tea soils are lower when compared to the forest soils. The microbial count generally decreased with increase in soil depth. The bulk density of forest soil ranged between 1.03 and 1.20 g cm^{-1} and the values were higher when compared to the tea soils. An irregular trend was observed in both the soils. The exchangeable potassium content of soils under tea plantations was significantly higher than that of forest soils up to 50 cm profile. The

Table 1: Physico-chemical characteristics of tea soils

Depth (cm)	pH	EC (dS m^{-1})	Bulk density (g cm^{-1})	Bacteria	Fungai (cfu g^{-1})	OM (g kg^{-1})	Ca (mg kg^{-1})	CEC (cmol kg^{-1})	P (mg kg^{-1})	K (mg kg^{-1})
0 to 25	4.66	0.05	0.88	7.01×10^5	6×10^4	18.4	73.00	5.50	22.06	200.00
25 to 50	4.60	0.05	0.98	2.20×10^4	4×10^3	15.8	65.00	4.30	12.01	125.00
50 to 75	4.58	0.03	0.94	1.14×10^4	2×10^3	12.9	57.00	3.90	6.25	75.00
75 to 100	4.67	0.03	1.09	1.10×10^4	1×10^3	6.7	57.00	3.60	9.21	50.00
100 to 125	4.75	0.03	0.93	1.00×10^4	1×10^3	4.0	65.00	3.40	4.20	45.00
125 to 150	4.77	0.02	0.92	-	-	2.7	65.00	3.20	2.83	25.00
150to 175	4.84	0.02	0.93	-	-	1.9	81.00	3.10	1.95	19.00
175 to 200	4.88	0.02	0.89	-	-	1.2	73.00	2.80	1.02	10.00
Statistical analysis										
SEm±	0.04	0.001	0.03	ND	ND	0.2	2.12	0.11	2.22	4.15
CD at p = 0.05	0.08	0.002	0.06	ND	ND	0.4	4.15	0.22	4.44	8.25
CD at p = 0.01	0.12	0.003	0.09	ND	ND	0.6	6.29	0.36	8.36	12.34

SEM±: Standard Error Mean; CD: Critical difference; EC: Electrical conductivity; CEC: Cation exchange capacity; OM: Organic matter; ND: non detectable

Table 2: Physico-chemical characteristics of forest soils

Depth (cm)	pH	EC (dS m^{-1})	Bulk density (g cm^{-1})	Bacteria	Fungai (cfu g^{-1})	OM (g kg^{-1})	Ca (mg kg^{-1})	CEC (cmol kg^{-1})	P (mg kg^{-1})	K (mg kg^{-1})
0 to 25	5.18	0.02	1.03	7.60×10^6	11.95×10^5	24.3	82.00	5.80	11.23	120.00
25 to 50	5.32	0.01	1.02	6.52×10^4	1.09×10^5	20.9	92.00	5.50	13.45	100.00
50 to 75	5.35	0.01	1.12	6.74×10^4	1.09×10^4	17.2	60.00	4.90	5.25	90.00
75 to 100	5.26	0.01	1.08	5.43×10^4	1.56×10^3	10.8	62.00	4.70	4.25	48.00
100 to 125	5.30	0.01	1.14	12.36×10^4	1.12×10^3	7.4	70.00	4.50	5.53	40.00
125 to 150	5.28	0.01	1.15	1.10×10^4	1.12×10^3	6.2	71.00	4.00	3.12	35.00
150 to 175	5.13	0.01	1.18	1.00×10^4	-	4.9	60.00	3.70	1.50	15.00
175 to 200	5.11	0.01	1.20	-	-	4.7	70.00	3.50	1.11	7.00
Statistical analysis										
SEm±	0.05	0.001	0.02	ND	ND	0.3	2.25	0.12	2.68	3.12
CD at p = 0.05	0.10	0.002	0.04	ND	ND	0.6	4.56	0.25	4.69	6.14
CD at p = 0.01	0.15	0.003	0.05	ND	ND	0.9	7.26	0.41	8.95	9.56

SEM±: Standard error mean; CD: Critical difference; EC: Electrical conductivity; CEC: Cation exchange capacity; OM: Organic matter; ND: non detectable

Table 3: Vertical distribution of different forms of magnesium distribution in tea and forest soils

	Water soluble Mg		Exchangeable Mg		Available Mg		Non exchangeable Mg		Lattice Mg		Total Mg	
	T	F	T	F	T	F	T	F	T	F	T	F
Depth (cm)	(mg kg^{-1})											
0 to 25	6.40	9.00	33.60	61.00	40.0	70.0	351.7	370.0	616.0	1180.0	967.7	1550.0
25 to 50	4.40	8.00	22.60	49.00	27.0	57.0	220.0	231.0	570.0	1079.0	790.0	1310.0
50 to 75	3.90	6.70	13.80	41.00	17.7	47.7	206.3	218.3	428.7	775.0	635.0	993.3
75 to 100	3.60	6.30	12.00	29.30	15.7	35.7	185.0	192.0	410.0	694.7	595.0	886.7
100 to 125	3.20	6.00	9.80	27.30	13.0	33.3	153.3	176.3	360.0	597.0	513.3	773.3
125 to 150	2.30	5.00	9.70	27.70	12.0	32.7	111.7	128.0	347.3	503.7	459.0	631.7
150 to 175	2.10	4.70	8.60	21.30	10.7	26.0	115.0	129.0	208.7	340.7	323.7	469.7
175 to 200	1.70	3.80	8.30	16.20	10.0	20.0	90.0	108.7	137.7	261.3	227.7	370.0
Statistical analysis												
SEM±	0.14	0.80	0.70	1.51	0.76	0.93	7.45	11.72	9.57	30.63	6.08	29.42
CD at p = 0.05	0.30	1.67	1.48	3.17	1.59	1.95	15.64	24.63	20.10	64.36	12.78	61.81
CD at p = 0.01	0.41	2.29	2.03	4.34	2.18	2.67	21.43	33.74	27.53	88.16	17.51	84.67

SEM±: Standard error mean; CD: Critical difference; Mg: Magnesium; T: Tea soils; F: Forest soils

available phosphorus was estimated in both cultivated and forest soils with respect to soil depth. Results showed that the tea soils were having comparatively higher P content. Available calcium content was higher in forest area when compared to tea fields. It ranged between 57 and 81 mg kg^{-1} in tea soils and between 60 and 92 mg kg^{-1} in forest soils.

Different pattern of magnesium in tea and forest soils: Water soluble magnesium content was higher in forest area when compared to the tea fields. It ranged between 1.7 and 6.4 mg kg^{-1} in tea soils and between 3.8 and 9.0 mg kg^{-1} in forest soils (Table 3). It decreased with increase in soil depth. The available magnesium content of tea soils ranged between 10 and 40 mg kg^{-1} and in forest soils it ranged between 20 and 70 mg kg^{-1}. It also decreased with increase in depth.

Both the soils were having comparable amount of non-exchangeable magnesium content. It varied between 90 and 352 mg kg^{-1} in tea soils (Table 3) and between 109 and 371 mg kg^{-1} in forest soils. The exchangeable magnesium content was lower in cultivated soils compared to the forest soils and varied between 8 and 34 mg kg^{-1} in tea soils and between 16 and 61 mg kg^{-1} in forest soils.

In the top layer of soil profile the total magnesium content in forest soils was almost two fold higher when compared to the tea soils (Table 3). The top layer (0 to 25 cm) and the next profile (25 to 50 cm) had similar quantum of total magnesium, but beyond that depth the values gradually decreased. Total magnesium content varied between 228 and 968 mg kg^{-1} in tea soils and between 370 and 1550 mg kg^{-1} in forest soils. Lattice magnesium was determined by subtracting the total and non-exchangeable magnesium. It was higher in forest soils when compared to the tea soils. It varied between 138 and 616 mg kg^{-1} in tea soils and between 261 and 1180 mg kg^{-1} in forest soils.

Different forms of magnesium and their relationship with physical properties: Water soluble magnesium of cultivated soils showed positive and significant correlation coefficients with EC, organic matter, cation exchange capacity, exchangeable and non-exchangeable magnesium (Table 4), while the same parameter observed in forest soils had positive correlation with different forms of magnesium only and did not show any significant relationship with physical properties of the soil. Water soluble magnesium has negatively correlated with pH of the tea soils (Table 4), but in the case of forest soils no significant correlation (Table 5). Exchangeable magnesium content of cultivated soils showed positive correlation with available Mg, water soluble Mg, non-exchangeable Mg, total Mg, EC and OM content and negative correlation with soil pH. In the case of forest soils the available Mg has shown non-significant correlation with pH. Available magnesium content of cultivated soils had positive and significant relation with EC, CEC and OM. A negative correlation coefficient was obtained for available magnesium and pH. But in the forest soils have shown the positive correlation coefficients (Table 5). Lattice magnesium showed positive and significant correlation with other forms of magnesium and physical properties of cultivated soils and a negative correlation with soil pH. But the forest soils have shown positive correlation with soil pH (Table 5). Lattice magnesium had a positive and significant correlation with other forms of magnesium and poor correlation with pH and EC in the case of forest soils. Similar kind of trend was observed in exchangeable Mg, non-exchangeable Mg and total Mg (Table 4, 5).

Table 4: Correlation coefficients among soil properties and different forms of magnesium in tea soils

	Magnesium									
Parameters	Water soluble	Exchangeable	Available	Non-exchangeable	Lattice	Total	pH	EC	OM	CEC
Water soluble Mg	1.000									
Exchangeable Mg	0.940**	1.000								
Available Mg	0.957**	0.999**	1.000							
Non-exchangeable Mg	0.994**	0.948**	0.963**	1.000						
Lattice Mg	0.929**	0.859**	0.876**	0.893**	1.000					
Total Mg	0.975**	0.912**	0.928**	0.953**	0.988**	1.000				
pH	-0.749*	-0.584	-0.613	-0.707*	-0.861**	-0.828*	1.000			
EC	0.911**	0.914**	0.921**	0.883**	0.913**	0.925**	-0.723*	1.000		
OM	0.935**	0.909**	0.919**	0.926**	0.919**	0.944**	-0.846**	0.923**	1.000	
CEC	0.987**	0.976**	0.985**	0.990**	0.911**	0.961**	-0.690	0.905**	0.936**	1.000

*Significantly at 5% level; **Significantly at 1% level. EC: Electrical conductivity; OM: Organic matter; CEC: Cation exchange capacity

Table 5: Correlation coefficients among soil properties and different forms of magnesium in forest soils

	Magnesium									
Parameters	Water soluble	Exchangeable	Available	Non-exchangeable	Lattice	Total	pH	EC	OM	CEC
Water soluble Mg	1									
Exchangeable Mg	0.970**	1								
Available Mg	0.976**	1.000**	1							
Non-exchangeable Mg	0.946**	0.947**	0.950**	1						
Lattice Mg	0.991*	0.973**	0.978**	0.919**	1					
Total Mg	0.995**	0.981**	0.985**	0.948**	0.997**	1				
pH	0.414	0.349	0.357	0.181	0.449	0.400	1			
EC	0.659	0.722*	0.717*	0.848**	0.620	0.675	-0.275	1		
OM	0.954**	0.977**	0.977**	0.921**	0.965**	0.969**	0.358	0.641	1	
CEC	0.994**	0.957**	0.964**	0.923**	0.994**	0.993**	0.477	0.602	0.958**	1

*Significantly at 5% level; **Significantly at 1% level. OM: Organic matter; CEC: Cation exchange capacity; EC: Electrical conductivity

DISCUSSION

Continuous applications of fertilisers have impacted two important physico chemical properties of tea soils viz., pH and electrical conductivity. The decrease in pH could be due to the application of acid forming nitrogenous fertilisers, while the ions dissociated in soil moisture could have contributed for increase in conductivity. The results are confirmative to the reports available at TRI (Ranganathan and Natesan, 1985; Venkatesan *et al.*, 2003). The organic matter content of tea soil was slightly lower than forest soils due to continuous removal of nutrients by harvesting. On the other hand the forest systems accumulate organic matter at the top soils by littering process, while translocating nutrients from deeper horizons through deep root system (Hirekurabar *et al.*, 2000; Verma and Venkatesan, 2001). The removal in forest eco system is rather low. Due to the same reason, at any given depth organic matter content of tea soil was lower than the forest soils. Organic matter has been proved to be directly proportional to the microbial population of soil (Klose and Tabatabai, 2000). Due to this reason, same kind of trend was observed in microbial count also. Its decrease with increase in soil depth could be attributed to the addition of leaf litter on the surface soils (Subba-Rao, 1995). The higher levels of potassium content observed in cultivated soils could be because of application of potassium fertilisers to achieve commercial levels of production (Venkatesan and Murugesan, 2006). The exchangeable potassium content generally decreased with increase in soil depth. This could be due to the addition of leaf litter on the surface soil which releases liable K from organic residues and also due to upward translocation by capillary rise of ground water (Hirekurabar *et al.,* 2000). In many depths the phosphorus content of tea soils was higher than the forest soils, which could be due to addition of citric acid along with rock phosphate (Venkatesan and Murugesan, 2004; Venkatesan, 2006).

As mentioned earlier dolomitic lime is the main source of magnesium, which is applied in tea fields as liming materials. It contains 12.6% of Mg in the form of $MgCO_3$, which is not fully soluble in water. It normally takes a long time to become available form of Mg. This could be the main reason for obtaining low water soluble Mg in tea soils. Exchangeable Mg contents were lower in tea soils which indicates the fact of exhausted nature of cultivated soils due to continuous harvesting of tea shoots.

The same phenomenon could have affected the available Mg of tea soils which was lower than forest soils. Since the soil available Mg was proved to be directly proportional to the exchangeable and non-exchangeable form of Mg (Chu, 1985; Mathan, 1991; Berkowitz and Wu, 1993; Cofie and Pleysier, 2004; Cornfield and Pollard, 2006), the trend observed in available Mg was seen in other two forms also. Since, tea soils are proved to have higher total potassium than the forest soils (Jayaganesh and Venkatesan, 2006; Venkatesan and Murugesan, 2006) and since they are antagonistic to each other, the total magnesium content of forest soils was higher than tea soils. Similar kind of observations were reported by Garg *et al.* (2003), Komosa *et al.* (1999), Khan *et al.* (1997) and Ashraf and Biddappa (1994) in various soils. The decrease in all forms of magnesium distribution in both the soil with increase in depth was probably due to variation in degree of leaching of magnesium and fluvial characteristics of soils (Ashraf and Biddappa, 1994; Mathan, 1991).

As mentioned elsewhere, 2000 to 3000 kg of dolomite lime was applied once in pruning cycle to enhance the soil pH. Such a higher quantity could have increased the conductivity behaviour in combination with fertiliser applications. Because of this, different forms of Mg content positively correlated with Electrical Conductivity (EC) of cultivated soils (Table 4). The insignificant correlation coefficients revealed by forest soils could be due to lack of external addition of Mg in any form. Similar trend was observed by Komosa *et al.* (1999) and Khan *et al.* (1997). Same kind of trend observed in non-exchangeable and total magnesium in both the soils. This could be because of the fact that the distribution pattern of total magnesium at different depths is mostly governed by parent materials and physiographic characteristics of the soils.

CONCLUSION

Intensive applications of potassium can increase the leaching of Mg by displacing it from cation exchange sites so that the amount in the root zone is reduced. Calcium and potassium can also interfere with the root uptake of Mg by competition at the root surface even when available Mg is not reduced by application of these essential elements. Hence, the mining of magnesium might have been severe for several decades. Resultantly, the reservoir is appearing to be exhausted. In nutshell, different form of magnesium content in tea soils were lower when compared to the forest soils which shows that continuous cultivation of tea without magnesium fertiliser led to serious depletion of soil magnesium pool. Therefore the study advocates to enrich the soil Mg status.

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