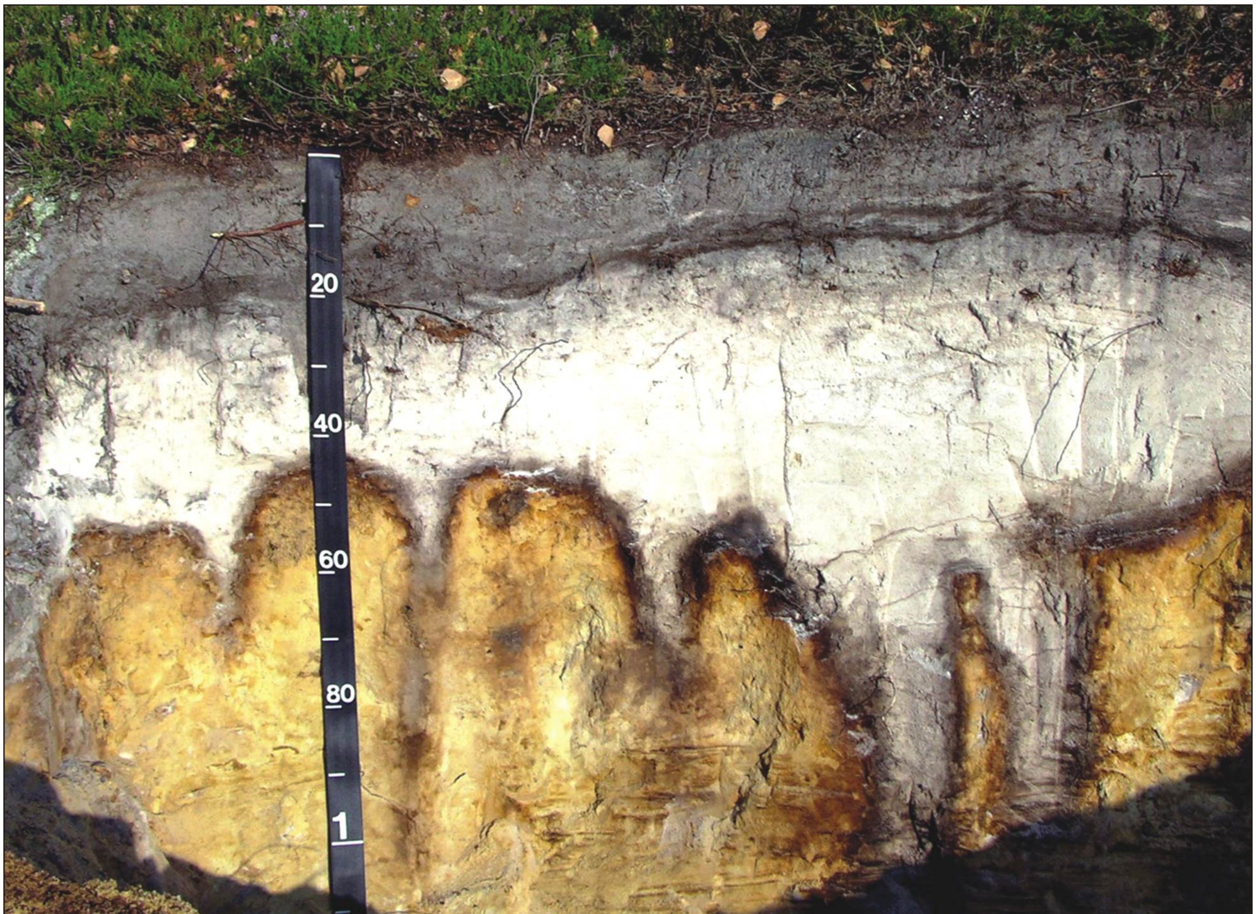

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Influence of Tea Cultivation on Soil Characteristics with Special Reference to Potassium

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Abstract: Soil samples were collected from tea a cultivated area and a nearby forest at various depths and analyzed for physico-chemical characteristics and different forms of Potassium (K) to find out the influence of cultivation practices on nutrient availability. The Organic Matter (OM) content decreased with an increase in soil depth. Nitrate nitrogen, Cation Exchange Capacity (CEC), water soluble, exchangeable and available K content estimated in cultivated soils decreased with an increase in soil depth. Ammonium nitrogen and organic matter content were higher in cultivated soils than in forest soils at any given depth. In the case of forest soils, lattice and total K increased with increase in depth up to 175 cm. Water soluble and exchangeable potassium of both soils had a positive and significant correlation with available K and cation exchange capacity, while forest soils had negative correlation with lattice, available and total K. There was a linear relationship for non-exchangeable and lattice K content with total K in the case of soils collected from cultivated area.

Key words: Forms of soil potassium, cultivated soils, forest soils, physico-chemical properties, correlation coefficients

Introduction

Geologically, the tea soils are mainly derived from genessic rocks containing lot of mica. During the early 1980s virgin forest areas of Western ghats receiving higher amounts of rain were cleared and planted with tea. Since then the area under tea cultivation was expanded from time to time. Cultivated areas therefore were only planted with tea without any inter cropping or multi cropping. There is a general feeling among farmers and scientists that the fertility of the old forest soils is being exploited by tea cultivation (Verma and Venkatesan, 2001). But if we critically look at the yield levels, a sustainable increase could be seen during the last few decades (from 1000 kg to 3500 kg made tea ha^{-1} yr^{-1}). Apart from high yielding varieties, the increase could also be due to improved soil fertility. Hence, the authors decided to examine the changes in soil characteristics due to cultivation practices with special reference to the soils of nearby virgin forest. This study is expected to yield the basic information as to what level the cultivation of tea has influenced the nutrient status of the soil in comparison to control (forest soils). A previous study of virgin and cultivated soils of Iowa indicated that cultivated soils had about one-third less total nitrogen than did the uncultivated soils (Anderson and Browning, 1950). It was also reported that cultivation was found to increase bulk density and soil pH. However, no such studies were carried out under tea cultivation, even though the

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cultivation practices are unique. Originally the soils of Western ghats are reported to be poor in potassium fertility (Verma, 1997). However, 75 years of tea research has helped the plantations to reduce or eliminate potassium deficiency by recommending appropriate K fertilizer applications corresponding to yield levels and nutrient removal (Verma and Palani, 1997). But the specific information available about the distribution and inter relationship of different forms of soil K influenced by cultivation of tea in comparison to forest soils is limited. Such information is necessary to have a better understanding of K fertilizer input requirements of tea. Hence, attempts have also been made to study the mentioned facts.

Materials and Methods

During May 2005, soil samples were collected from three different locations under tea cultivation at various depths (0-25, 25-50, 50-75, 75-100, 100-125, 125-150, 150-175 and 175-200 cm), where tea was planted during 1973. Similar soil samples were also collected from three different places in an undisturbed forest. The soils were air-dried and analysed for physico-chemical characteristics such as pH, Electrical Conductivity (EC), bulk density, Cation Exchange Capacity (CEC), ammoniacal nitrogen (NH_4^+- N), nitrate nitrogen (NO_3^-- N) (Subba Rao, 2001), organic matter (Walkley and Black, 1934) and available phosphorus (Bray and Kurtz, 1945). The remaining soil samples were analyzed for different forms of potassium namely water-soluble K, 1N ammonium acetate extractable K (available K) and K extractable by 1N boiling nitric acid. Exchangeable K was determined by subtracting available K from water soluble K (Jackson, 1977). Non-exchangeable K was determined by subtracting 1N HNO_3 K from available K (Wood and De Turk, 1940). Total K was determined by digesting the soil sample with nitric acid and perchloric acid mixture (Jackson, 1977). Lattice K was extracted following the method given by Piper (1966). The correlation analysis was carried out using the software "SPSS 7.5 for Windows". Statistical analysis was done using standard method (Gomez and Gomez, 1984). The data presented in this manuscript are the means of three replications.

Results and Discussion

Physico-Chemical Characteristics of Cultivated and Forest Soils

The physico-chemical characteristics of cultivated and forest soils are given in Table 1. The acidic nature of both the soils could be due to their high degree of weathering (Ranganathan and Natesan, 1985) and the intensity of rainfall received (Verma and Palani, 1997). The higher acidity expressed in the case of cultivated soil could be because of the continuous use of acid forming N fertilisers. It is customary to use 200 to 300 kg of nitrogen ha^{-1} yr^{-1} to maintain the yield level of tea gardens. Resultantly, EC of surface and bottom soils from cultivated land were marginally higher when compared to that of virgin soils. A decrease in EC of cultivated soils was noted up to 100 cm soil depth and beyond which it became static. On the other hand the EC of the forest soils was rather erratic. This might be due to many factors, one of which could be the canopy coverage over the soil surface. In the case of soils with tea cultivation, the canopy coverage is thicker and uniform. Contrary to the cultivated soils, canopy coverage over the forest soils was haphazard resulting in the varied intensity of rainfall reaching the soil surface. This could probably lead to the fluctuation in EC of the forest soils. But the reason for increase in EC with increase sampling depth beneath 75 cm is not clearly known. On contrary to the reports available under various cultivation systems (Anderson and Browning, 1950), the cultivated soils had lesser bulk density than that of the forest soils. The organic matter

Table 1: Physico-chemical characteristics of cultivated and forest soils

Depth (cm)	pH		EC ($dS\ m^{-1}$)		Bulk density ($g\ cm^{-3}$)		OM ($g\ kg^{-1}$)		NH_4^+-N ($mg\ kg^{-1}$)		NO_3^--N ($mg\ kg^{-1}$)		Avai. P ($mg\ kg^{-1}$)		CEC ($cmol\ kg^{-1}$)	
	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F
0-25	4.5	4.9	0.05	0.03	0.88	1.03	36.0	32.0	42	48	10.9	25.0	1.06	1.09	5.5	5.6
25-50	4.8	5.0	0.03	0.01	0.97	1.02	31.0	17.0	59	64	6.1	1.7	0.66	1.22	4.3	4.7
50-75	4.5	4.9	0.02	0.01	0.94	1.12	13.0	12.0	50	65	1.8	3.0	0.95	0.81	3.9	4.2
75-100	4.4	5.1	0.03	0.04	1.08	1.08	15.0	5.0	64	70	7.1	4.7	1.11	1.13	3.3	4.3
100-125	4.5	5.3	0.02	0.03	0.93	1.14	15.0	6.0	67	72	7.7	3.6	0.83	0.67	3.9	4.2
125-150	4.6	5.1	0.02	0.03	0.91	1.15	16.0	3.0	40	112	7.8	6.3	1.20	1.37	3.7	4.0
150-175	4.7	5.1	0.02	0.05	0.93	1.18	16.0	3.0	55	82	10.0	3.9	1.82	1.27	3.7	3.9
175-200	4.9	5.3	0.02	0.04	0.89	1.20	18.0	3.0	98	100	11.7	5.5	1.30	2.09	3.5	3.7
SEM	0.03	0.07	ND	ND	0.03	0.02	1.10	0.2	6.41	8.20	2.56	2.36	0.19	0.17	0.10	0.16
CD at p = 0.05	0.06	0.15	ND	ND	0.06	0.04	2.40	0.4	13.75	17.59	5.49	5.06	0.41	0.37	0.22	0.34
CD at p = 0.01	0.09	0.20	ND	ND	0.09	0.05	3.30	0.5	19.08	24.41	7.61	7.02	0.57	0.51	0.30	0.47

SEM: Standard Error Mean, CD: Critical Difference, C: Cultivated soil, F: Forest soil, ND-The values are too low to be reported

content of cultivated soils, at any given depth, was higher than that of forest soils. Higher organic matter in cultivated soils is likely due to the biomass recycled at the time of pruning (once in four years) which is a contributing factor for the higher organic matter content of the cultivated soils (Garg *et al*., 2003). Even though the OM content estimated at the surface of cultivated and forest soils were similar to each other, a sharp decline in OM status of forest soils was noted with sampling depth. The reduction in OM content of forest soils was as high as 90% at 125 cm beneath the soil surface whereas it was only around 50% in the case of cultivated soils. It is concluded, based on this observation, that the soils under tea cultivation practices accumulates higher organic matter than that of virgin forest soils and there will be no decline in the OM content due to tea cultivation practices as it was assumed (Verma and Venkatesan, 2001) so far. This fact remained as a guideline for assessing the impact of controlled cultural practices. The ammonium nitrogen content estimated in both the soils increased with increase in sampling depth. This is perhaps due to the negative charge of soil clay particles which increases with increase in depth. Since ammonium ions are positively charged they are retained more with increased soil depth. The nitrate nitrogen content was also higher in the cultivated soils when compared to forest soils except in the surface soil (0-25 cm). The forest soils are generally not disturbed and hence the percolation of nitrate ion by leaching process is little difficult which might have led to accumulation of more nitrate at the surface of forest soils. Since the cation exchange capacity is an interrelated parameter to organic matter it showed a similar trend like organic matter.

Distribution of Various Forms of Potassium and Their Relationship

The distribution of different forms of potassium in cultivated and forest soils are given in Table 2. The correlation coefficients determined between different forms of potassium and physico-chemical characteristics of cultivated and forest soils are given in Table 3 and 4, respectively. Water-soluble K of cultivated soils decreased with increase in soil depth, while the forest soils had no significant difference in the water soluble K content due to variation in sampling depth (Table 2). It appears that the cultural operations like application of potassium fertilizers resulted in a build up of water soluble K in the surface area. The water soluble K estimated in cultivated soils had a positive and significant correlation with available K and organic matter content. Similar kinds of observations were reported by Ahmed and Walia (1999), Singh *et al*. (1999) and Pal and Mukhopadhyay (1992) in various soils. A positive and significant correlation was obtained for water soluble K with EC,

Table 2: Different forms of potassium in cultivated and forest soils

Depth (cm)	Water soluble K (mg kg^{-1})		Exch. K (mg kg^{-1})		Avai. K (mg kg^{-1})		Non-Exch. K (mg kg^{-1})		Lattice K (mg kg^{-1})		Total K (mg kg^{-1})	
	C	F	C	F	C	F	C	F	C	F	C	F
0-25	19	6	162	52	180	58	619	679	1816	1153	2615	1889
25-50	15	3	84	33	99	36	510	649	1391	1376	2000	2061
50-75	12	7	23	43	39	49	1831	704	6558	1432	8423	2185
75-100	10	5	30	34	35	39	901	680	1138	2406	2078	3125
100-125	3	7	19	24	33	70	376	734	893	2563	1302	3367
125-150	4	5	15	19	19	23	54	612	250	3639	322	4274
150-175	3	4	12	23	17	27	395	1291	501	3011	910	4329
175-200	4	4	14	30	15	33	592	823	497	2491	1106	3346
SEM	0.84	0.61	2.87	1.45	3.07	1.21	9.77	14.46	69.76	96.15	69.26	88.77
CD at p = 0.05	1.80	1.32	6.15	3.10	6.58	2.61	20.96	31.03	149.63	206.25	148.56	190.42
CD at p = 0.01	2.49	1.83	8.53	4.31	9.13	3.62	29.09	43.06	207.66	286.24	206.18	264.27

SEM: Standard Error Mean, CD: Critical Difference, C: Cultivated soil, F: Forest soil, ND-The values are too low to be reported

Table 3: Correlation coefficients between soil properties and different forms of potassium of cultivated soils

	Avai. K	CEC	EC	Exch.K	Lattice K	Non-Exch.K	OM	pH	Total K
Avai. K	1.000								
CEC	0.880**	1.000							
EC	0.937**	0.818**	1.000						
Exch.K	0.995**	0.916**	0.921**	1.000					
Lattice K	0.091	0.035	0.038	0.054	1.000				
Non-Exch.K	0.009	-0.153	-0.024	-0.049	0.927**	1.000			
OM	0.917**	0.850**	0.845**	0.928**	-0.142	-0.221	1.000		
pH	0.713**	0.828**	0.667**	0.753**	-0.344	-0.399	0.824**	1.000	
Total K	0.097	0.016	0.047	0.056	0.997**	0.952**	-0.139	-0.343	1.000
Water soluble K	0.673**	0.303	0.705**	0.592**	0.350	0.420*	0.502*	0.176	0.359

* - Significant at 5% level; ** - Significant at 1% level

Table 4: Correlation coefficients between soil properties and different forms of potassium of forest soils

	Avai. K	CEC	EC	Exch.K	Lattice K	Non-Exch.K	OM	pH	Total K
Avai. K	1.000								
CEC	0.447*	1.000							
EC	-0.257	-0.573**							
Exch.K	0.997**	0.458*	-0.254	1.000					
Lattice K	-0.488*	-0.619**	0.596**	-0.498*	1.000				
Non-Exch.K	-0.301	-0.700**	0.545**	-0.290	0.305	1.000			
OM	0.463*	0.720**	-0.432*	0.467*	-0.814**	-0.349	1.000		
PH	-0.041	-0.441*	0.728**	-0.054	0.780**	0.206	-0.738**	1.000	
Total K	-0.498*	-0.718**	0.665**	-0.505*	0.977**	0.502*	-0.817**	0.760**	1.000
Water soluble K	0.705**	0.462*	-0.197	0.656**	-0.197	-0.314	0.247	0.133	-0.237

* - Significant at 5% level; ** - Significant at 1% level

exchangeable K and non-exchangeable K while water-soluble K of forest soils were positively correlated with available K, exchangeable K and CEC (Table 3 and 4). The linear relationship between water soluble K and EC of cultivated soils seems to be unique for tea soils. In cultural operations, potassium is applied in the form of potassium chloride (about 250 to 400 kg MOP ha^{-1} yr^{-1}). Such huge quantity of chloride could possibly be the reason for obtaining a positive correlation for EC with water soluble K determined in cultivated soils (Table 3).

Exchangeable K content was generally higher in surface soils than in sub soils under cultivated and non-cultivated conditions. This could be because of the continuous application of potassium fertilizers, addition of leaf litter, release of labile K from organic residues and upward translocation of K from lower depths with capillary rise of ground water. Similar types of results were reported by Srinivasa Rao *et al*. (1997) and Hirekurabar *et al*. (2000) under various cultivation practices. Exchangeable K content in cultivated soils was positively correlated with available and water-soluble K, organic matter, pH, EC and CEC. This is in line with the study done by Ahmed and Walia (1999). Singh *et al*. (1992) and Boruah and Nath (1992). This is perhaps due to the fact that clay and organic matter content are the main reservoirs of exchangeable K in these soils. Exchangeable K content of forest soils had positive and significant correlation with available K, water soluble K, OM, CEC and had a negative correlation with lattice K and total K.

The distribution of available K for cultivated soils follows a definite pattern with sampling depth; the concentration decreased with increase in depth. This could be probably due to variation in degree of leaching of potassium and fluvial characteristics of soils (Ahmed and Walia, 1999) Forest soils did not show any regular pattern with depth. Available K content of cultivated soils had positive relation with pH, EC, CEC and organic matter content. Similar to cultivated soils, available K content of forest soils also had a positive and significant correlation with CEC and OM and had a negative correlation with lattice and total K.

Non-exchangeable K content showed an irregular trend with sampling depth, which reflected on the insignificant relationship with OM and CEC. This is contrary to the findings of Boruah and Nath (1992) and Basumatary and Bordoloi (1992). This could be due to the dominance of clay minerals such as kaolinite in these soils developed under high rainfall conditions. As observed by various scientists, non-exchangeable K had a positive correlation with lattice and total K (Pal and Mukhopadhyay, 1992). Non-exchangeable K content of forest soil positively correlated with EC and total K and had a negative correlation with CEC.

Lattice K had a positive and significant correlation with the other forms of potassium like non exchangeable and total K. The poor relationship with soil properties is due to the inertness of lattice K (Basumatary and Bordoloi, 1992). Lattice K content of forest soils increased with an increase in depth of the soil up to 175cm and then decreased. Positive and significant correlation was obtained for lattice K content of forest soil with pH, EC, total K and negative correlation with CEC.

No specific trend was observed for total K with the sampling depth for cultivated soils. This may be because of their fulvial characteristics. The distribution of total K at different depths is mostly governed by parent material and physiographic characteristics of the soils. In forest soils, the total K content increased with increase in depth up to 175 cm and then decreased. It had a positive correlation with pH, EC and negative correlation with CEC and OM.

Conclusions

The cultivation practices adopted in tea fields has helped to increase the fertility of soils rather than exploiting the naturally available fertility. Since the surface soils are very much valuable in terms of its fertility, methods of soil preservation should be adopted effectively.

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