Influence of plantation crops on characteristics of soils (Typic Dystrochrepts) of Brahmaputra alluvium

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Abstract
The influence of plantation crops viz. tea, coffee and rubber on the characteristics of Typic Dystrochrepts was studied in a contiguous area. The bulk density was higher in the soils under tea, even in presence of organic matter enrichment. The pH of the soils was in acidic range (pH 4.3 – 5.8) with relatively higher (pH 5.2 – 5.8) in the subsurface horizons under rubber plantation. Exchange acidity and per cent Al-saturation were higher in the soils under tea and rubber. Exchangeable Mg^{2+} was higher in soils under rubber. Dithionite and oxalate extractable iron (Fe_d and Fe_o) forms were higher in the soils under tea. The surface horizons of all the soils contained higher amount of amorphous iron (Fe_o). The organically bound iron (Fe_p) was higher in the soils under rubber.

Additional keywords: Bulk density, forms of iron.

Introduction

Among the five soil forming factors (Jenny 1941), vegetation including both natural and man made plantation have a pronounced effect on soil properties (Cornforth 1970, Fisher and Eastburn 1974). Different plant species varying widely in canopy and rooting pattern influence the soil properties primarily through addition of organic matter and actions of roots in binding soil particles. Banerjee *et al.* (1980) observed that soil properties varied spatially primarily in response to rooting and litter fall, characteristics of a perennial vegetation, on more or less uniform parent material.

The tea plantation occupies a considerable area in the Brahmaputra valley of Assam. The soils of this valley are developed in alluvium. Recently other plantation crops like coffee and rubber have been introduced in these areas. But the influence of plantation crops on soil characteristics has not been studied. So the present investigation was undertaken to see the effect of tea, coffee and rubber plantations on the properties of a tropical Inceptisol (Typic Dystrochrept) of the Brahmaputra valley.

Materials and methods

The study area is situated in the Assam Agricultural University farm (26°44'N latitude and 94°12'E longitude) and is characterized by humid subtropical climate with mean annual rainfall of 2000 mm and mean annual temperature of 23.5°C. The moisture and temperature regimes of the area are udic and hyperthermic, respectively. The experimental farm (25.33 ha) was under different plantation crops viz. tea (9.00 ha), coffee (2.20 ha) and rubber (0.95 ha). The tea and coffee plantations were about 20 years old whereas the rubber plantation was 9 years old.

The contiguous area under tea (*Camellia sinensis* L. O., Kuntze), coffee (*Coffea canophora*) and rubber (*Hevea brasiliensis*) was selected and three representative soil profiles were excavated and horizonwise soil samples were collected. For comparison one soil profile from nonplantation adjacent area was also collected. Morphological characteristics of the soils were studied in the field (Anonymous 1971). Bulk density of the soil was determined by the clod method (Blake 1965). Air dried and processed soil samples (<2 mm) were analysed for mechanical composition and other physical and chemical properties of the soils were determined following standard procedures (Jackson 1973). Exchangeable acidity of the soil was determined by extracting the soil with1*N* KCl (McLean 1965). The soil was extracted for dithionite iron (Fe_d) (Mehra and Jackson 1960), oxalate iron (Fe_o) (McKeague and Dey 1966) and pyrophosphate iron (Fe_p) (Kononova 1966). Iron was determined by orthophenanthroline method (Krishna Murti *et al.* 1970).

Results and discussion

Morphological characteristics

Morphological characteristics of the soils are presented in table 1. The thickness of the Ap horizons was identical in case of soils under tea (P1), rubber (P3) and non plantation fallow (P4) and the soils under coffee (P2) had very thick surface horizon which could form a part of B horizon. The colour of the surface horizon varied from dark brown (10YR 4/3) to dark yellowish brown (10YR 4/4) and that of subsurface horizon from yellowish brown (10YR 5/6) to brownish yellow (10YR 6/6). An interesting observation

Table 1. Morphological characteristics of the soils*

Hori-zon	Depth (cm)	Soil colour (moist)	Mottles	Texture	Structure	Consistence
			P1 (Tea) : Typic Dystrochrepts			
Ap	0-35	Dark brown (10YR 4/3)	fld, strong brown (7.5YR 5/8) c3d, strong brown (7.5YR 5/8)	ls	f1 sbk	dsh, mvfr, wss, wps
B1	35-58	Yellowish brown (10YR 5/6)		sl	m2 sbk	dsh, mfr, wss, wps
B2	58-135	Brownish yellow (10YR 6/8)		sl	m1 sbk	dh, mfr, wss, wps
B3	125-225	Brownish yellow (10YR 6/8)		ls	m1 sbk	dsh, mfr, wss, wps
			P2 (Coffee) : Typic Dystrochrepts			
Ap	0-60	Dark brown (10YR 4/3)		sl	f1 sbk	dsh, mfr, wss, wps
B1	60-110	Brownish yellow (10YR 6/8)		sl	f1 sbk	dsh, mfr, wss, wps
B2	110-205	Brownish yellow (10YR 6/8)		sl	f1 sbk	dsh, mvfr, wss, wpo
			P3 (Rubber) : Typic Dystrochrepts			
Ap	0-30	Dark yellowish brown (10YR 4/4)	c1d, reddish yellow (7.5YR 6/8) c2d, strong brown (7.5YR 5/8) m2d, strong brown	ls	f1 sbk	dsh, mfr, wss, wps
B1	30-60	Yellowish brown (10YR 5/8)		sl	m1 sbk	dsh, mfr, wss, wps
B2	60-110	Yellowish brown (10YR 5/8)		sl	m1 sbk	dsh, mfr, wss, wps
B3	110-200	Brownish yellow (10YR 6/6)		sl	m1 sbk	dh, mfr, wss, wps
			P4 (Fallow) : Typic Dystrochrepts			
Ap	0-16	Yellowish brown (10YR 5/4)		sl	m1 sbk	ds, mfr, wss, wps
BA	16-44	Yellowish brown (10YR 5/4)	f1 d, reddish yellow (7.5YR 6/8)	sl	m2 sbk	ds, mfr, wss, wps
B1	44-97	Brownish yellow (10YR 6/6)		sl	m2 sbk	ds, mfr, wss, wps
B2	97-136	Brownish yellow (10YR 6/6)		scl	m2 sbk	dsh, mfr, wss, wps
B3	136-180	Brownish yellow (10YR 6/6)		scl	m3 sbk	dsh, mfr, wss, wps

* Symbols are as per Soil Survey Manual (Anonymous 1971).

was that strong brown (7.5YR 5/8) to reddish yellow (7.5YR 6.8) mottles were present in soils under tea (below 58 cm) and rubber (below 30 cm). This may be attributed to considerable oxidation-reduction cycles in the lower horizons that may be due to imperfect drainage condition. There was no abrupt variation in texture and consistence of the soils. Structural development was observed in the subsurface horizons of soils under tea and rubber.

Physical and chemical characteristics

The physical and chemical characteristics of the soils are presented in table 2. The mechanical composition of soils shows that the sand fraction constitutes bulk of the soil separates. The clay distribution pattern was identical in all the soils and it increased with soil depth, reached a maximum and then decreased thereafter. The bulk density was lower in the surface horizon as compared to other horizons of a profile. Among the soils under plantation crops, bulk density was higher (1.40 to 1.60 Mg m^{-3}) in the soils under tea (P1) as compared to the soils under coffee (P2) and rubber (P3). Among the surface horizons, bulk density was highest in the soils under non plantation fallow (P4) as compared to the soils under plantation crops. Organic matter content was higher (2.25 to 2.59%) in the surface horizons and it decreased regularly with soil depth. The difference in organic matter content of the surface horizons are evidently due to differences in vegetation. Although the surface horizon of soils under tea (P1) contained more organic matter, the bulk density was also higher as compared to the soils under coffee (P2) and rubber (P3). This suggests that besides organic matter content the rooting system of crops also influences the bulk density of soils. Higher bulk density of soils under tea may be due to more labour load (during inter-cultural operations) and close spacing in tea plantation as well as differences in rooting pattern of tea, coffee and rubber (Dutta and Saikia 1993, Krishna Kumar 1993).

Table 2. Physical and chemical properties of the soils

Horizon	Sand	Silt	Clay	B.D. Mg m^{-3}	O.M. (%)	pH		Δ pH	Exchange acidity			Exchangeable bases				CEC	BS (%)
	------%------					H_2O	KCl		H^+	Al^{3+}	Total	Ca^{2+}	Mg^{2+}	Na^+	K^+		
									------cmol (p+) kg^{-1}------								
						P1 (Tea) : Typic Dystrochrepts											
Ap	77.5	6.8	15.6	1.42	2.2	4.3	3.6	0.7	0.1	0.6	0.7	1.60	0.3	0.02	0.40	7.5	31
B1	72.3	10.2	17.5	1.40	1.7	4.6	3.7	0.9	0.1	0.7	0.8	1.50	0.3	0.01	0.79	8.0	32
B2	70.8	10.1	19.1	1.63	1.4	4.7	3.8	0.9	0.1	0.8	0.9	1.80	1.2	0.01	0.17	8.2	39
B3	78.5	6.2	15.3	1.60	1.0	4.7	3.7	1.0	0.2	0.5	0.7	1.35	0.7	0.02	0.37	7.0	36
						P2 (Coffee) : Typic Dystrochrepts											
Ap	71.2	14.0	14.8	1.36	2.3	4.2	3.6	0.6	0.1	0.5	0.6	1.65	0.45	0.02	0.43	8.0	32
B1	61.5	19.0	19.5	1.27	1.4	4.6	3.7	0.9	0.2	0.3	0.5	1.50	1.40	0.01	0.73	8.5	43
B2	61.2	21.6	17.2	1.39	0.9	4.8	3.8	1.0	0.1	0.4	0.5	0.90	0.60	0.01	0.63	6.0	36
						P3 (Rubber) : Typic Dystrochrepts											
Ap	75.8	12.5	11.7	1.21	2,6	4.4	3.7	0.7	0.4	0.3	0.7	1.50	0.90	0.01	0.61	6.5	39
B1	68.4	16.6	15.0	1.22	1.4	4.8	3.9	0.9	0.1	0.6	0.7	1.65	0.85	0.02	0.11	7.0	38
B2	64.4	18.2	17.3	1.43	1.1	5.8	3.8	1.3	0.1	0.5	0.6	1.45	0.65	0.02	0.15	7.5	30
B3	61.6	22.8	15.5	1.58	1.1	5.2	3.8	1.4	0.1	0.7	0.8	1.50	0.65	0.02	0.32	7.1	35
						P4 (Fallow) : Typic Dystrochrepts											
Ap	70.2	14.4	15.4	1.46	1.2	4.6	3.9	0.7	0.1	0.3	0.4	2.60	0.75	0.01	0.19	7.6	47
BA	68.5	13.9	17.6	1.47	0.9	4.7	4.1	0.6	9.1	0.5	0.6	2.37	0.86	0.09	0.15	7.8	44
B1	65.9	16.1	18.0	1.51	0.6	4.8	4.1	0.7	0.1	0.5	0.6	2.01	1.12	0.07	0.12	8.2	40
B2	65.5	14.2	20.3	1.53	0.1	5.0	4.1	0.9	0.1	0.5	0.6	1.85	1.00	0.06	0.08	8.2	36
B3	78.3	5.5	16.2	1.58	0.1	5.2	4.2	1.0	0.1	0.4	0.5	1.65	0.95	0.06	0.11	7.9	35

The pH of the soils was, by and large, in the acidic range (pH 4.3 – 5.8). The subsurface horizons of the soils under rubber (P3) had relatively higher pH (5.2 – 5.8). The difference in pH values (ΔpH) determined in water and in 1*N* KCl ranges from 0.6 to 1.4. This indicates the presence of significant amount of exchangeable Al or complexed slowly exchangeable Al in these soils (Buol *et al.* 1978). However, the exchange acidity and per cent Al-saturation were higher in the soils under plantation crops and particularly so in the soils under tea (P1) and rubber (P3).

The exchangeable bases were found to be influenced by the plantation crops. The soils under non-plantation fallow (P4) contained higher amount of basic cations as compared to soils under plantation crops. The exchangeable Ca^{2+} was the dominant basic cation in all the soils. Among the soils under plantation crops, the exchangeable Mg^{2-} was higher throughout the profile under rubber (P3) as compared to the other soils except in the B2 and B1 horizons of soils under tea (P1) and coffee (P2), respectively. The CEC of the soils was low (7.0 – 8.2 cmol (p+) kg^{-}) in all the soils. The per cent base saturation was also low (30.3 – 46.7%) indicating dystric nature of the soils.

Forms of iron

The data on different forms of iron in soils show that the dithionite extractable iron (Fe_d) was the most dominant form (Table 3). The Fe_d indicates the crystalline form of iron present in the primary and secondary minerals (Mehra and Jackson 1960). Higher amount of Fe_d in the soils under tea (P1) suggests more weathering of primary and secondary minerals and subsequent crystallization of amorphous iron in these soils. The amount of Fe_d increased with soil depth in all the soils and this may be partly due to co-migration of iron with clay (Blume and Schwertmann 1969) as indicated by narrow differences in the Fe_d/clay ratios within a profile.

Table 3. Forms of iron in soils

Horizon	Fe_d (%)	Fe_o (%)	Fe_d-Fe_o (%)	Fe_p (%)	Fe_o/Fe_d	Fe_d/Clay
			P1 (Tea) : Typic Dystrochrepts			
Ap	1.00	0.25	0.75	0.01	0.25	0.06
B1	1.37	0.12	1.25	0.09	0.09	0.08
B2	1.40	0.12	1.28	0.05	0.08	0.07
B3	1.45	0.11	1.34	0.03	0.07	0.09
			P2 (Coffee) : Typic Dystrochrepts			
Ap	0.75	0.13	0.62	0.15	0.17	0.05
B1	0.83	0.12	0.71	0.03	0.14	0.04
B2	1.43	0.06	1.37	0.02	0.04	0.09
			P3 (Rubber) : Typic Dystrochrepts			
Ap	0.73	0.19	0.54	0.13	0.26	0.07
B1	0.80	0.18	0.62	0.23	0.23	0.06
B2	0.83	0.07	0.76	0.06	0.08	0.05
B3	0.97	0.06	0.91	0.07	0.06	0.07
			P4 (Fallow) : Typic Dystrochrepts			
Ap	0.60	0.15	0.45	0.12	0.25	0.04
BA	0.81	0.11	0.70	0.06	0.13	0.05
B1	0.90	0.08	0.82	0.02	0.09	0.05
B2	0.95	0.08	0.87	0.04	0.08	0.05
B3	1.20	0.06	1.14	0.02	0.05	0.07

The oxalate extractable iron (Fe_o) is the most poorly crystallized (amorphous) iron form (Schwertmann 1973). The Fe_o was higher in the soil under tea (P1) and its amount decreased with soil depth in all the soils. In general, the surface horizons of all the soils contained higher amount of Fe_o as compared to other horizons of a profile. High organic matter content in the surface horizons of the soils may be responsible for higher amount of amorphous iron (Fe_o) as organic matter inhibits transformation of amorphous iron to crystalline form (Schwertmann and Taylor 1977). The ratio of Fe_o/Fe_d (activity ratio) was higher in the surface horizon indicating less crystallization of amorphous iron in the surface horizon.

The dithionite minus oxalate iron (Fe_d-Fe_o) provides an estimate of more or less crystalline iron oxide (McKeague *et al.* 1971). Higher amount of crystalline iron oxide (Fe_d-Fe_o) was found in the soils under tea (P1).

The pyrophosphate extractable iron (Fe_p) represents the organically bound iron (Tan 1978). The Fe_p was higher (0.07 – 0.23%) in the soils under rubber as compared to the soils under tea (0.01 – 0.09%) and coffee (0.02 – 0.15%). Although the surface horizons contained higher amount of organic matter, Fe_p was found to be higher in the B1 horizons of P1 (tea) and P3 (rubber). This may be due to more humified substances that formed complexes with iron compounds in the B1 horizons.

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