Properties of Soils from Madhupur Rubber Plantation Area in Bangladesh

A. T. M. Emdad Hossain[1] and Z. H. Khan[2]
[1]Bangladesh Forest Research Institute, P. O. Box 273, Chittagong 4000, Bangladesh
[2]Department of Soil Science, University of Chittagong, Chittagong 4331, Bangladesh

Abstract

Physical and chemical properties of some soils from Madhupur rubber plantation area in Bangladesh have been studied. Results of particle-size distribution, oven dry/air dry ratio, field moisture capacity, pH, organic carbon, total nitrogen, cation exchange capacity (CEC) and exchangeable cations of the soils on depth basis have been presented. The nutrient contents of these soils have also been reported. With respect to nutrient status and physico-chemical properties, these soils are considered to have good potentiality and prospect for increased production of rubber, if proper attention and management practices are adopted.

সারসংক্ষেপ

বাংলাদেশের মধুপুর অঞ্চলে সৃষ্ট রাবার বাগানের কিছু মৃত্তিকা নমুনার ভৌত ও রাসায়নিক গুণাগুণ পর্যবেক্ষণ করা হয়েছে। মৃত্তিকা গভীরতার ভিত্তিতে মৃত্তিকা নমুনাসমূহের কণার বন্টন (বুনট), ওভেন ড্রাই/এয়ার ড্রাই অনুপাত, মাঠে পানি ধারণ ক্ষমতা, পি-এইচ, জৈব কার্বন, পূর্ণ নাইট্রোজেন, ক্যাটায়ন বিনিময় ক্ষমতা (সি. ই. সি.) এবং বিনিময়যোগ্য ক্যাটায়নসমূহ সম্পর্কিত ফলাফল উপস্থাপন করা হয়েছে। মৃত্তিকা নমুনাগুলোর পুষ্টি উপাদানের পরিমাণও উপস্থাপন করা হয়েছে। পুষ্টি উপাদানের অবস্থা এবং ভৌত ও রাসায়নিক গুণাগুণের ভিত্তিতে এ সকল মৃত্তিকা সফল রাবার উৎপাদনে সক্ষম বলে প্রতীয়মান হয়, যদি সঠিক ব্যবস্থাপনা পদ্ধতি এবং পরিচর্যা অবলম্বন করা যায়।

Key words : Madhupur tract, rubber plantation, soil properties

Introduction

Rubber (*Hevea brasiliensis*) is characteristically a tropical plant. The optimum ecological requirements for growing rubber are evenly distributed annual rainfall of 2000 mm over the year, temperature of 21-25^{0}C, and well drained loamy soil with high water holding capacity (ICAR 1980). Yew (1988) mentioned that soil profile free from iron pan/rock within 100 cm depth with gentle slope or rolling terrain between 4-20 percent slope gradient is desirable for the growth of rubber plants. From the above facts, it is evident that there is a good scope for raising rubber plantations in Madhupur area consisting of a complex relief covering an area of about 0.45 million ha of land in Bangladesh where the soils are considered to be of low natural fertility. In many places of this area, forests have been degraded and the soils have little or almost no potentials for field crop production. In fact rubber is presently growing on soils of these areas. Chan

et al. (1977) reported that the rate of growth of rubber varies according to soil characteristics. Since growth and yield of rubber can be improved by selective agro-management inputs, a sound knowledge of the distribution and properties of soils under rubber is an essential pre-requisite for proper and efficient agro-management for sustained production. Taking these facts into consideration the present study has been undertaken to gain detailed information about the physical and chemical properties of soils from Madhupur rubber plantation area in Bangladesh.

Materials and methods

Four pedons representing two topographic positions (two from top and two from middle of the slope) in Pirgacha block of Madhupur rubber plantation area within the Madhupur forest in Tangail District were selected for this investigation. The pedons were studied the in field, and samples were collected from variable depth of soil pits. All pits had a 1.5 x 1.5 x 1.0 m (length x breadth x depth) dimensions, and 1 kg samples representing each horizon were taken on the same day and kept in plastic bags. Soils were described by standard terminology (SSS 1993). Selected site characteristics for each pedon are presented in Table 1.

The area under study is situated at an altitude of about 15 metres above mean sea level and belongs to the Madhupur tract. This tract includes well drained dissected terraces and few

Table 1. Environmental conditions of the studied soils.

Pedons	Location	Topographic positions	Vegetation	Parent material	Drainage	Subsoil colour
Pirgacha-I	Near Pirgacha Rubber office, Kakraid, Madhupur, Tangail	Top of the slope	8 to 10 years old rubber plantations	Madhupur clay	Moderately well	Strong brown
Pirgacha-II	Near Pirgacha Rubber office, Kakraid, Madhupur, Tangail	Middle of the slope	8 to 10 years old rubber plantations	Madhupur clay	Moderately well	Yellowish brown
Chandpur-I	Chandpur garden spot (5 km apart from the old garden), Madhupur, Tangail	Top of the slope	2 to 3 years old rubber plantations	Madhupur clay	Moderately well	Yellowish brown
Chandpur-II	Chandpur garden spot (5 km apart from the old garden), Madhupur, Tangail	Middle of the slope	2 to 3 years old rubber plantations	Madhupur clay	Imperfectly well	Olive brown

narrow valleys. It comprises of diferent kinds of landscapes such as level top, moderately steep slope, gentle slope and valleys (FAO-UNDP 1988). The climate of the area is humid sub-tropical with a mean annual temperature of 25.5°C. The mean summer and winter temperatures are 30°C and 19°C respectively. The mean annual rainfall is around 2000 mm, the bulk of which is received between May and October (Manalo 1975).

The collected soil samples were processed and analysed in the laboratory for physical and chemical properties. Particle-size distribution was determined by hydrometer method (Day 1965). Hygroscopic moisture was calculated from the loss of moisture from the sample as described by Black (1965). Field capacity of the soils was determined following the procedure of Richards (1965).

Soil pH was measured in suspension at a soil : water ratio of 1:2.5 and at a soil : 1*N* KCl ratio of 1:2.5 with a Pye pH meter. Organic carbon content was determined by wet oxidation, total nitrogen by micro-Kjeldahl digestion and distillation, and cation exchange capacity (CEC) by neutral 1*N* ammonium acetate saturation. The exchangeable Na^+, K^+, Ca^{++} and Mg^{++} were also extracted with neutral 1*N* ammonium acetate. Available nitrogen was extracted with 1*N* KCl and available phosphorus with Truog's reagent. Total phosphorus and potassium were extracted phosphorus by fusion of soil with sodium carbonate. Available K, Fe, Mn and Zn were extracted with 1*N* NH_4OAc solution at pH 7.0. Gallenkamp flame photometer was used for determination of Na and K. On the other hand, Ca, Mg and micronutrients were determined by atomic absorption spectrophotometer. Phosphorus was determined by chlorostannous reduced molybdophosphoric blue colour method in sulphuric acid system (Jackson 1973).

Results and discussion

Physical properties of soils

Particle-size distribution : Clay is by far the dominant size fraction in all the pedons followed by silt and sand (Table 2). Percentage of sand in the soil ranged from 8 to 18 with a mean value of 11, of silt from 33 to 51 with an average of 44 and of clay from 32 to 58 with an average of 45. In all the studied pedons silt content showed a decreasing trend with depth. Conversely, there was a trend of increasing clay content with depth indicating its eluviation/illuviation. Particle-size class in surface horizon is silty clay loam where as it is silty clay to clay in lower horizons. However, these soils behave like loamy textured materials because of aggregation (FAO-UNDP 1988). Soils having more than 35% clay to retain sufficient moisture and preferably 30% sand to allow good aeration and drainage are considered suitable for rubber cultivation (Yew 1988).

Moisture properties : Table 2 presents the moisture properties of soils. Hygroscopic moisture increased with increasing depth in all soils. The higher amounts of hygroscopic moisture in lower horizons of the soil profiles may be attributed to their higher clay contents. A highly significant positive correlation (r = +0.72) was found between percent clay and hygroscopic moisture (Fig. 1). However, the oven dry/air dry (OD/AD) ratio had a significant negative relationship with the clay content of the soils (Fig. 2). The moisture at field capacity varied from 21 to 30 % with a mean of 25%. In all the cases, it increased with increasing depth. There was a significant positive correlation (r = + 0.90) between percent clay and field capacity (Fig. 3). Faiz *et al.* (1980) reported 19 to 31% moisture at field capacity in some soils of Madhupur tract. They also found highly significant correlation between field capacity and percent clay.

Chemical properties of soils

Chemical properties of the studied soils are shown in Table 3. The soils were strongly to moderately acidic in water, with pH varying from 4.9 to 5.9 and a decrease in pH in 1*N* KCl solution was observed. This corroborates well with the findings of Nayak *et al.* (1996) for some acidic soils of Monipur, India. The ΔpH [pH (KCl) - pH (H_2O)] values of the studied soils are negative and ranged

Table 2. Some selected physical properties of the studied soils.

Soils	Depth (cm)	Particle-size distribution (%)			Textural* class	Hygroscopic moisture (%)	OD/AD** ratio	Field capacity (%)
		Sand	Silt	Clay				
Pirgacha-I	0-12	15	51	34	Sicl	2.1	0.98	23
	12-35	13	50	37	Sicl	2.5	0.98	22
	35-58	14	40	46	Sic	3.0	0.97	25
	58-73	11	41	48	Sic	3.3	0.96	29
	73-100	11	39	50	C	3.3	0.96	28
Pirgacha-II	0-15	12	49	39	Sicl	2.1	0.98	24
	15-33	9	47	44	Sic	2.5	0.97	26
	33-48	9	38	53	C	3.0	0.96	28
	48-68	10	35	55	C	3.3	0.95	30
	68-100	9	33	58	C	3.3	0.95	29
Chandpur-I	0-17	18	49	33	Sicl	1.8	0.98	22
	17-40	15	50	36	Sicl	2.5	0.98	21
	40-63	10	49	41	Sic	3.2	0.97	23
	63-80	12	43	45	Sic	3.2	0.97	26
	80-100	8	44	48	Sic	3.3	0.96	27
Chandpur-II	0-14	17	51	32	Sicl	2.8	0.97	22
	14-44	16	50	34	Sicl	3.0	0.97	24
	44-65	12	42	46	Sic	3.2	0.97	25
	65-75	8	42	50	Sic	3.4	0.96	26
	75-100	9	42	49	Sic	3.3	0.96	29
Mean	—	11	44	45	Sic	2.9	0.97	25

* Sicl = Silty clay loam, Sic = Silty clay, C = Clay; ** = Oven dry/Air dry.

from -0.8 to -1.3 with a mean of -1.0. This indicates that the soils contain considerable reserve acidity. Chan (1978) emphasized that rubber plants grow well in Malaysia when soil pH (water) is around 5.0. With respect to pH, therefore, the studied soils appear to be suitable for growth of rubber plants.

The organic carbon content in the soils was low, ranging from 2.0 to 10.5 g kg^{-1} soil. The low organic carbon content may be due to its rapid decomposition at high rainfall and temperature. However, a gradual decrease in organic carbon content with depth is a usual phenomenon in these soils. Similar observations have been made in the Madhupur clay soils of Bangladesh by SRDI Staff (1984), Zaman *et al.* (1992) and BARC (1997).

Total nitrogen contents of the studied soils (0.20 to 0.97 g kg^{-1} with an average of 0.54 g kg^{-1}) fall within the ranges reported by Zaman *et al.* (1984), Shamsuddin *et al.* (1990) and Zaman *et al.* (1992) for some rubber producing soils of Bangladesh. Like organic carbon, total nitrogen content also showed a gradual decrease with depth of soil. A

Table 3. Results of some chemical analyses of the studied soils.

Soil	Depth (cm)	pH		Δ pH[1]	Organic carbon (g kg^{-1})	Total nitrogen (g kg^{-1})	C/N ratio	CEC[2] (cmol kg^{-1})	Exchangeable cations (cmol kg^{-1})				BSP[3]
		(H_2O)	(KCl)						Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	
Pirgacha-I	0-12	5.9	4.7	-1.2	8.2	0.97	9	9.09	2.00	0.55	0.10	0.18	31.1
	12-35	5.6	4.5	-1.1	7.0	0.82	9	12.00	3.95	0.86	0.07	0.17	42.1
	35-58	5.4	4.5	-0.9	4.5	0.55	9	13.30	4.40	1.11	0.08	0.20	43.5
	58-73	5.5	4.4	-1.1	3.0	0.33	10	13.70	4.50	1.12	0.08	0.21	43.1
	73-100	5.5	4.4	-1.1	2.8	0.30	10	14.00	4.00	1.20	0.09	0.24	39.5
Pirgacha-II	0-15	4.9	4.0	-0.9	8.6	0.88	10	4.84	1.90	0.62	0.08	0.17	57.2
	15-33	5.0	4.1	-0.9	4.8	0.62	8	7.80	3.10	1.00	0.08	0.21	56.3
	33-48	5.3	4.1	-1.2	2.8	0.46	6	7.53	2.52	1.04	0.07	0.25	51.5
	48-68	5.5	4.2	-1.3	2.4	0.35	7	10.22	1.85	1.02	0.07	0.46	33.3
	68-100	5.6	4.4	-1.2	2.0	0.30	7	10.22	1.60	1.10	0.08	0.43	31.4
Chandpur-I	0-17	5.5	4.4	-1.1	10.5	0.95	11	7.86	2.10	0.80	0.03	0.28	40.8
	17-40	5.3	4.5	-0.8	8.5	0.80	11	7.67	2.17	0.85	0.06	0.20	42.7
	40-63	5.4	4.5	-0.9	4.6	0.44	10	9.36	2.44	0.67	0.03	0.23	38.9
	63-80	5.2	4.3	-0.9	3.3	0.30	9	12.12	3.01	0.53	0.05	0.41	33.0
	80-100	5.2	4.2	-1.0	3.2	0.28	9	12.20	2.88	0.49	0.05	0.45	31.7
Chandpur-II	0-14	5.4	4.3	-1.1	9.0	0.85	11	8.27	1.90	0.55	0.04	0.14	31.8
	14-44	5.6	4.4	-1.2	5.3	0.60	9	12.06	1.24	1.11	0.06	0.16	21.3
	44-65	5.7	4.6	-1.1	3.0	0.48	7	12.86	2.80	1.05	0.05	0.12	31.3
	65-75	5.6	4.4	-1.2	2.8	0.35	9	14.68	2.85	1.00	0.03	0.10	27.1
	75-100	5.6	4.5	-1.1	2.0	0.20	10	14.50	2.78	0.91	0.05	0.13	26.7
Mean	—	5.4	4.4	-1.0	4.9	0.54	9	10.21	2.70	0.88	0.06	0.24	40.0

[1] = $pH_{(KCl)} - pH_{(H_2O)}$, [2] = cation exchange capacity, [3] = base saturation percentage.

Table 4. Total and available nutrient contents of the soil.

Soils	Depth (cm)	Total nutrients ($g\ kg^{-1}$ soil)			Available nutrients ($mg\ kg^{-1}$ soil)					
		N	P	K	N	P	K	Fe	Mn	Zn
Pirgacha-I	0-12	0.97	0.59	19.5	60	4	70	65	123	1.8
	12-35	0.82	0.58	20.3	46	4	66	70	114	1.1
	35-58	0.55	0.54	18.3	38	2	78	71	118	1.3
	58-73	0.33	0.60	20.7	36	1	82	30	90	0.9
	73-100	0.30	0.61	20.8	30	2	94	35	96	1.4
Pirgacha-II	0-15	0.88	0.62	24.5	63	4	66	137	172	2.5
	15-33	0.62	0.59	19.7	53	5	82	81	105	2.1
	33-48	0.46	0.66	19.7	40	2	98	67	74	1.5
	48-68	0.35	0.55	21.8	29	2	179	32	89	1.7
	68-100	0.30	0.66	22.3	22	1	168	57	65	1.0
Chandpur-I	0-17	0.95	0.50	17.7	78	5	110	73	114	1.5
	17-40	0.80	0.48	20.8	65	3	78	73	97	2.1
	40-63	0.44	0.50	19.5	46	2	90	27	80	0.8
	63-80	0.30	0.51	20.1	30	2	160	17	84	1.0
	80-100	0.28	0.52	20.2	31	2	176	13	68	1.2
Chandpur-II	0-14	0.85	0.49	19.5	70	3	55	74	98	1.7
	14-44	0.60	0.46	18.1	51	2	63	74	105	1.8
	44-65	0.48	0.52	15.2	41	1	47	80	135	1.1
	65-75	0.35	0.48	18.5	28	1	40	52	118	1.4
	75-100	0.20	0.52	17.3	30	1	51	40	149	1.0
Mean	—	0.54	0.55	19.7	44	2.5	93	58	105	1.4

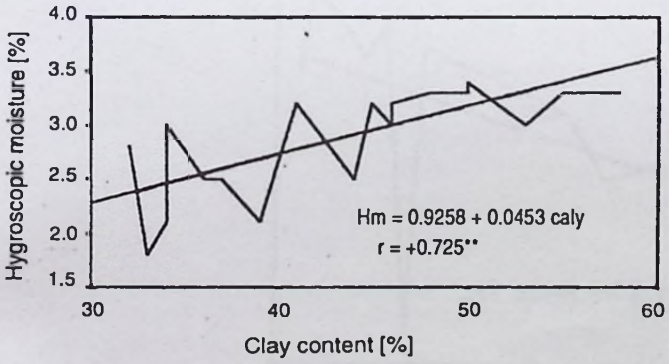

Figure 1. Relationship between hygroscopic moisture and clay content.

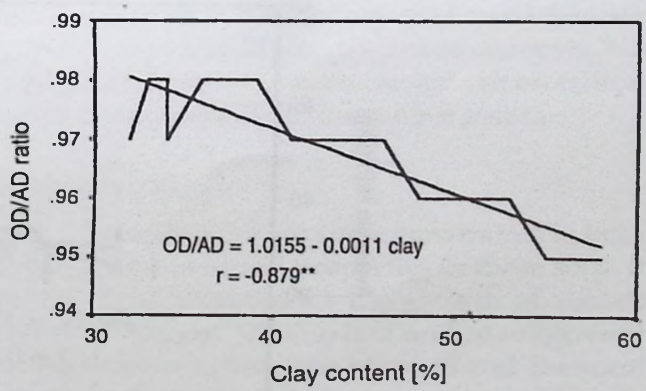

Figure 2. Relationship between oven dry/air dry (OD/AD) ratio and clay content.

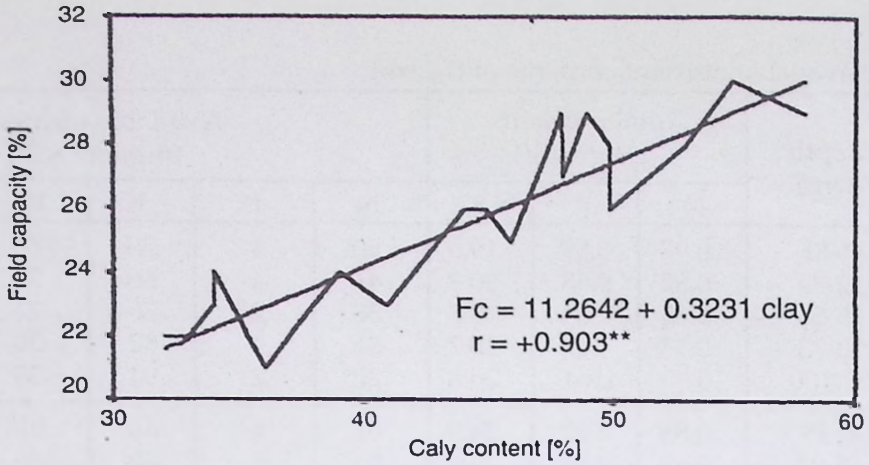

Figure 3. Relationship between field capacity and clay content.

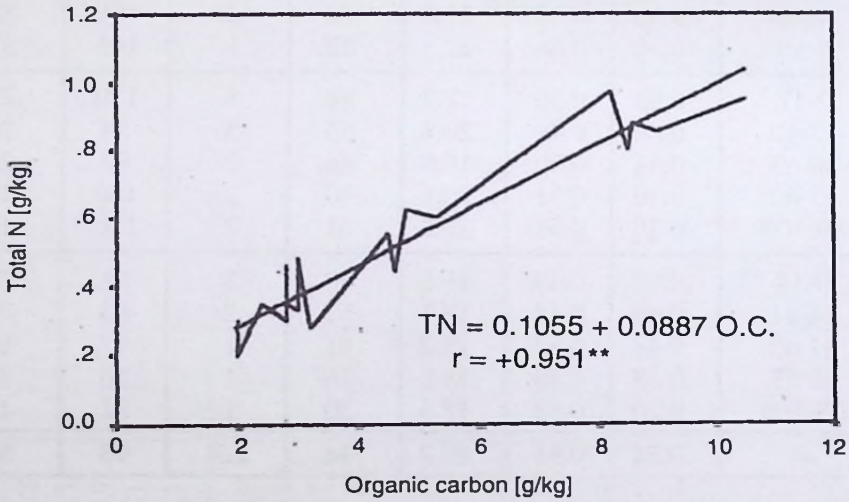

Figure 4. Relationship between total N and organic carbon.

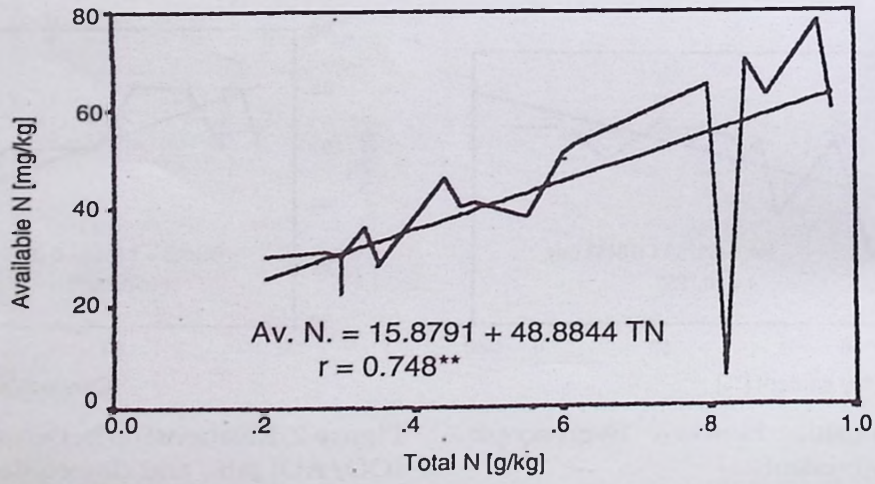

Figure 5. Relationship between available N and total N.

highly significant positive correlation (r = +0.95) between organic carbon and total nitrogen (Fig. 4) suggests that addition of organic matter may lead to higher nitrogen retention in the soils.

The C/N ratio varied from 6 to 11 with a mean value of 9. Such narrow C/N ratio is indicative of higly oxidized nature of organic matter in the soils. However, a decrease in C/N ratio with depth was noticeable in some of the pedons and similar distribution pattern was also observed in some rubber soils elsewhere (Anam *et al.* 1978, Zaman *et al.* 1984).

Cation exchange capacity varied widely in the studied soils. It ranged from 4.84 to 14.68 cmol kg^{-1} with a mean of 10.21 cmol kg^{-1}. These values were in accordance with ranges reported by Khan *et al.* (1997) in some soils of Madhupur tract. Among the exchangeable bases Ca^{++} is the dominamt cation followed by $Mg,^{++}$ K^{+} and Na^{+}. Percent base saturation ranged from 21.3 to 57.2 with a mean of 40.0. Leaching of bases caused by heavy rainfall is considered to be the reason for such base saturation in the soils.

Nutrient status of the soils : Table 4 shows the nutrient status of the soils. Total nitrogen contents in the soils were discussed before. Total phosphorus content ranged from 0.48 to 0.66 g kg^{-1} with a mean of 0.55 g kg^{-1}. These results are in agreement with those of Islam and Mandal (1978). The soils of Pirgacha rubber plantation area contain higher amount of total P. This may be due to the application of phosphatic fertilizer in these soils. The total potassium contents were high, varying from 15.2 to 24.5 g kg^{-1} with a mean of 19.7 g kg^{-1} soil. These results are comparable with the findings of Karim and Khan (1956). Higher amount of K may be due to the presence of K bearing minerals in these soils (Alam *et al.* 1993).

Available nitrogen ranged from 22 to 78 mg kg^{-1} with a mean of 44 mg kg^{-1} soil. A highly significant correlation between available N and total N (Fig. 5) in the soils implies that the variation in the available nitrogen content follows closely the pattern of total N. The available N is high in Chandpur soil and low in Pirgacha soil. The higher amount of available N in Chandpur soils may be due to removal of a small fraction of available N by newly planted rubber trees.

Available phosphorus in soils ranged from 1 to 5 mg kg^{-1} with an average of 2.5 mg kg^{-1}. This falls in the deficient range (BARC 1997). Like available nitrogen, available phosphorus was also higher at the surface and decreased downward in the soil profile. The available phosphorus is low due to fixation in these acidic soils. Islam and Islam (1956) found available P deficiency in soils of Madhupur tract due to high phosphate fixing capacity. Available potassium ranged from 40 to 179 mg kg^{-1} with a mean of 93 mg kg^{-1} soil. The less available potassium may be due to the presence of sesquioxides and mica in clay which fix most of the available K.

Among the micronutrients, zinc has received maximum attention in Bangladesh soils. Available Zn, Fe and Mn contents varies from 1.0 to 2.5, 13 to 137 and 65 to 172 mg kg^{-1} soil respectively. The mean values of the corresponding nutrients were 1.4, 58 and 105 mg kg^{-1} soil. Available Zn content seems to be higher than that reported by Rahman *et al.* (1997) for a number of rubber producing soils of Madhupur. Katyal and Sharma (1979) proposed 0.8, 3.1, 4.5 mg kg^{-1} DTPA extractable Zn, Mn, and Fe respectively as critical limits for field crops. Taking these limits into consideration the studied soils have adequate quantity of available micronutrient elements. No works have, however, been carried out on critical limits of micronutrients for rubber plants.

Conclusion

Though there are some constraints in both physical and chemical properties of these soils, it has good potentialities for the growth of rubber plants if proper fertilization and management practices are adopted. The physical and chemical properties as well as environmental condition of these soils are conducive to favourable growth of rubber plants through their good internal drainage,

level to gently slopping terrain, deep soil profile, clayey textures with more than 15% sand and acidic reaction. However, high P fixation capacities and lower K availabilities in these soils require special consideration for fertilizer management. Similarly, these soils have low water holding capacity, which may need improvement through mulching or manuring.

References

Alam, M. L.; Miyauchi, N.; Shinagawa, A. 1993. Studies on clay mineralogical characteristics of hill and terrace soils of Bangladesh. *Clay Science* 9 : 109-121.

Anam, K.; Huq, S. M. I.; Aziz, A. and Ahmed, M. 1978. A study on two rubber producing soils of Chittagong. *Bangladesh Journal of Soil Science* 14 : 161-168.

BARC 1997. *Fertilizer Recommendation Guide*. Bangladesh Agricultural Research Council, Dhaka. 196 pp.

Black, C. A. 1965. *Methods of Soil Analysis*. American Society of Agronomy, Madison, Wisconsin. 1022 pp.

Chan, H. Y. 1978. Soil survey interpretation for improved rubber production in peninsular Malaysia. *In*: Swindale, L. D. (ed.). *Soil Resource Data for Agricultural Development*. Hawaii Agriculture Experimental Station. Honolulu, Hawaii. pp. 41.

Chan, H. Y.; Pushparajah, E.; Yew, F. K. and Zainol Eusof 1977. A soil suitability technical grouping system for *Hevea*. *Proceedings of the Third ASEAN Soils Conference*. Kuala Lumpur, Malaysia on 1st-5th Dec. 1975. pp. 277-286.

Day, P. R. 1965. Particle fractionation and particle size analysis. *In* : Black, C. A. (ed.). *Methods of Soil Analysis*. American Society of Agronomy, Madison, Wisconsin. pp. 545-567.

Faiz, S. M. A; Khan, M. S. and Khan, T. H. 1980. Moisture properties of some soils under Madhupur tract and their pertinence to soil physical characteristics. *Bangladesh Journal of Soil Science* 16 : 75-81.

FAO-UNDP 1988. *Land Resources Appraisal of Bangladesh for Agricultural Development. Agroecological Regions of Bangladesh*. Report 2, FAO, Rome. 570 pp.

ICAR 1980. *A Handbook of Agriculture (3rd edition)*. Indian Council for Agriculture Research, New Delhi, India. 1303 pp.

Islam, A. and Mandal, R. 1978. Vertical distribution of phosphate in some humid tropical soils. *Dhaka University Studies* (*Part E*) 26 : 39-51.

Islam, M. A. and Islam, W. 1956. *Nutrient Status of East Pakistan Soils*. Bulletin No. 1, Directorate of Agriculture, Govt. of East Pakistan, Dhaka. 52 pp.

Jackson, M. L. 1973. *Soil Chemical Analysis*. Prentice Hall of India Pvt. Ltd., New Delhi. 498 pp.

Karim, A. and Khan, D. H. 1956. Vertical distribution of nitrogen, phosphorus and potassium in some East Pakistan soil. *Soil Science* 81 : 47-56.

Katyal, J. C. and Sharma, B. D. 1979. Micronutrient research in soils and plants in India. *Fertilizer News* 24 (9) : 35-50.

Khan, Z. H.; Mazumder, A. R. and Hussain, M. S. 1997. Extraction of aluminium from the soils of Madhupur tract. *Journal of the Asiatic Society of Bangladesh, Science* 23 (1) : 157-161.

Manalo, E. B. 1975. *Agroclimatic Survey of Bangladesh, Vol. 1.* IRRI-Publications, Los Banos, The Philippines. 361 pp.

Nayak, D. C.; Sen, T. K.; Chamuah, G. S. and Schgal, J. L. 1996. Nature of acidity in some soils of Manipur. *Journal of the Indian Society of Soil Science* 44 : 209-214.

Rahman, M. K.; Mandal, R.; Khurshid, A. A.; Mohsin, G. M. and Zaman, M. A. 1997. Micronutrient status of rubber growing soils of Madhupur. *Journal of the Asiatic Society of Bangladesh, Science* 23 (1) : 95-100.

Richards, L. A. 1965. Sample retainers for measuring water retention by soil. *Soil Science Society of America Proceedings* 20 : 301-303.

Shamsuddin; Alam, D.; Rahman, S. and Anam, K. 1990. A study on the soils of Satgaon and Shahzibazar rubber gardens having plantations of different ages. *Nuclear Science and Applications* 2 (2) : 32-36.

SRDI Staff 1984. *Reconnaissance Soil Survey Report of Dhaka District*. Soil Resources Development Institute, Dhaka. 256 pp.

SSS (Soil Survey Staff) 1993. *Soil Survey Manual*. U. S. Dept. Agriculture Handbook 18. 437 pp.

Yew, F. K. 1988. Soil suitability for rubber cultivation. In : *RRIM Training Manual on Management of Soils and Nutrition of* Hevea. Rubber Research Institute Malaysia. pp. 52-75.

Zaman, M. A.; Mohiuddin, A. S. M.; Mazumder, A. R. and Hussain, M. S. 1992. Fertility status of soils from the rubber plantations of Madhupur tract. *Bangladesh Journal of Soil Science* 23 : 15-22.

Zaman, M. B.; Mazumder, A. R.; Ahmed, N.; Hussain, M. S. and Rahman, S. 1984. Properties of soils from the major rubber plantations in Chittagong and Chittagong Hill Tracts. *Bangladesh Journal of Soil Science* 20 : 7-20.