MOISTURE RETENTION CHARACTERISTICS OF RUBBER GROWING SOILS OF MEGHALAYA, INDIA

Ram Phool Singh, Mrinal Choudhury*, Mercykutty Joseph**
and Gitali Das*

Rubber Research Institute of India, Regional Research Station, Tura-794 001, Meghalaya, India
*Rubber Research Institute of India, Regional Research Station, Guwahati-781 006 Assam, India
** Rubber Research Institute of India, Kottayam-686 009, Kerala, India

Received: 17 March 2015 Accepted: 10 September 2015

Singh, R.P., Choudhury, M., Joseph, M., and Das, G. (2015). Moisture retention characteristics of rubber growing soils of Meghalaya, India. *Rubber Science*, **28**(3): 255-265.

A study on the moisture retention characteristics of the rubber growing soils of Meghalaya indicated wide variation among different locations of the major rubber growing areas. The moisture retention in the surface layers at -0.033 MPa ranged from 21.05 per cent in Rongara (South Garo Hill district) to 36.08 per cent in Mendipathar (North Garo Hill district). However, the available water storage capacity (AWSC) did not show any variation as a result of the concomitant increase in the moisture retained at Byrnihat, -1.5 MPa. The moisture retention at the two tension ranges was found to be influenced by an aggregate effect of clay, sesquioxides, silt and organic matter. The moisture retained at -1.5 MPa was more than 0.4 times clay, suggesting that clay is either not well dispersed or some water is held by the gels. Silt was found to play an active role in conjunction with clay in the moisture retention at -1.5 MPa suggesting the colloidally active nature of silt in sub tropical soils. In general, rubber growing soils in Meghalaya have high water retention potential and this is of high practical significance for a rainfed crop like rubber. The data revealed that, about 31.4 per cent of available moisture is desorbed at -0.033 MPa and about 20.6 per cent at -1.5 MPa indicating that, this tension range could be of relevance to the water availability to crops like rubber grown under rainfed conditions.

Keywords: Available water content, Available water storage capacity, Field capacity, *Hevea brasiliensis*, Rubber growing soils, Soil moisture

INTRODUCTION

Natural rubber cultivation is expanded to North Eastern states of India to meet the increasing demand of natural rubber for the industry. Meghalaya is the third largest state as per the area under rubber cultivation in North East India. Meghalaya state, comprising of three main Hills *viz.,* Khasi Hills (East, West Khasi Hills and Ribhoi districts), Garo Hills (East, West and South Hills districts) and Jaintia hills located in seven districts. Rubber cultivation is mostly confined to East (now North), West and South Garo Hills, Ribhoi and Jentia Hills, covering more than 11,875 ha. (Rubber Board, 2014). Rubber is mostly grown as a rainfed crop and the soils under rubber cultivation belong to the soil orders Inceptisol, Ultisol and Entisol (Bhattacharya *et al*., 1996).

Correspondence : R.P. Singh (Email: ramphoolsingh@rediffmail.com)

Retention of adequate soil moisture is very important in rubber plantations for sufficient latex production. The total amount of water which is generally received through rain in short spells, in high altitude areas like Meghalaya cannot be fully retained in the soil. Soil texture, structure, bulk density, organic matter and mineral make up of the clay complex are the major factors affecting soil moisture retention (Gupta *et al.*, 1983; Hillel, 1971). Soils under rubber in Malaysia retain available moisture to the tune of 80 to 200 mm within one meter soil depth (Soong and Lau, 1977). Though few studies (Thulasidharan and Nair, 1984, and Krishnakumar *et al.*, 1990b) on the moisture retention characteristics of lateritic soils under rubber in the traditional rubber growing belts in India, was reported, no attempt has been made yet to study the same of soils under rubber in Meghalaya. Hence, this study characterizes the moisture retention characteristics of the rubber growing soils in Meghalaya under the North Eastern region of India.

MATERIALS AND METHODS

A total of six locations representing the major rubber growing regions in Meghalaya *viz.* Khasi hills (East, West Khasi Hills and Ribhoi districts), Garo Hills (East, West and South Hills districts) and Jaintia Hills were selected and soil samples were collected from four depths *viz.*, 0-30 cm, 30-60 cm, 60-90 cm and 90-120 cm along with core samples. Details of the locations are provided in Table 1. The collected soil samples were air-dried, sieved through 2 mm sieve and used for the estimation of soil pH, organic carbon, available P and K as per the procedures outlined in Jackson (1973). The soil pH was measured using soil-water suspension in the ratio of 1:2.5. Organic carbon was estimated following Walkley and Black method (Jackson, 1973). Available P was determined colorimetrically using Bray-II extractant (Bray and Kurtz, 1945) and available K was determined flame photometrically using Morgan's reagent (Morgan, 1941) as the extractant. Bulk density, particle density and porosity of the core samples were measured as described by Baruah and Barthakur (1997). Total porosity was calculated from the equation S_t = 100 (1-db). where, S_t - Total porosity, P - Particle density and db - bulk density. Particle size distribution was determined by the International Pipette Method (Piper, 1966). Soil moisture at -0.033 MPa and -1.5 MPa were estimated by pressure plate apparatus and available water storage capacity (AWSC) from the formula as described by Krishnakumar *et al*. (1990a).

$$\text{AWSC (mm m}^{-1}) = \frac{(\%\text{ moisture at -0.033 MPa}) - (\%\text{ moisture at -1.5 MPa}) \times db \times 10}{100}$$

$$\text{Available water content (AWC) (mm mm}^{-1}) = (\%\text{ moisture at -0.033MPa}) - (\%\text{moisture at -1.5MPa}) \times db \times 10$$

where, db refers to the bulk density (Mg m^{-3})

RESULTS AND DISCUSSION

Soil physico-chemical properties are presented in Tables 2 and 3. Soil moisture retention characteristics of soil samples at four depths from different locations (Table 4)

Table 1. **Details of the profile sampling sites**

Location No.	Name of locations and distance from RRS, Tura	Rainfall (mm)	Soil sub group	Number of years of rubber cultivation
1.	**Jengichekgre** West Garo Hills (WGH-1),District Development Centre, 17 km from RRS, Tura Latitude: 25^0 27.565′ N, Longitude: 90^0 13.0312′ E Elevation: 154 m above MSL	2435	Typic Dystrudepts	About 24 years under rubber grown with natural cover. Mainly red soils occurring in catenary sequence along with laterite
2.	**Ganolgre** West Garo Hills (WGH-2) Regional Research Station, 17 km from RRS, Tura Latitude: 25^0 34.578′ N, Longitude: 90^0 14.141′ E Elevation: 410 m above MSL	2456	Typic Dystrudepts	About 27 years under rubber grown in association with leguminous ground cover. Mainly red soils occurring in catenary sequence along with laterite
3.	**Chhebragre** West Garo Hills (WGH-3), 25 km from RRS, Tura Latitude: 25^0 35.158′ N, Longitude: 90^0 13.248′ E Elevation: 430 m above MSL	2468	Typic Dystrudepts	About 20 years under rubber grown with natural cover. Mainly red soils occurring in catenary sequence along with laterite
4.	**Mendipathar** North Garo Hills (NGH), 102 km from RRS, Tura Latitude: 25^0 65.438′ N, Longitude: 90^0 38.312′ E Elevation: 80 m above MSL	2434	Typic Dystrudepts	About 28 years under rubber grown with natural cover. Mainly red soils occurring in catenary sequence along with laterite
5.	**Rongara** South Garo Hills (SGH), 160 km from RRS, Tura Latitude: 25^0 32.545′ N, Longitude: 90^0 16.012′ E Elevation: 160 m above MSL	2443	Typic Dystrudepts	About 17 years under rubber grown with natural ground cover. Mainly red soil occurring in catenary sequence along with laterite
6.	**Byrnihat** Ribhoi, Kiling village,260 km from RRS, Tura Latitude: 26^0 36.12′ N, Longitude: 90^0 50.0312′ E Elevation: 51 m above MSL	2100	Typic Dystrudepts	About 28 years under rubber grown with natural cover. Mainly red soils occurring in catenary sequence along with laterite

and the detailed illustration of the same are given in Figs. 1 and 2. The results showed a wide variation in gravimetric moisture at -0.033 and -1.5 MPa (Table 4). For the surface layer, the value ranged from 21.05 per cent (South Garo Hills) to as high as 36.08 per cent (North Garo Hills district). At -1.5 MPa, it ranged from 11.21 to 26.79 per cent among the different locations. Variation in the available water content of the profiles at -0.033 and -0.15 MPa was observed among the soil profiles (Table 4). However, the variation narrowed down, when the water content was expressed volumetrically. Though a low retention value at -0.033 MPa and -0.15 MPa in Rongara profile was observed, it showed a higher available water content than the Jengichekgre, Brynihat and Mendipathar profiles. The mean available water content was highest (192.52 mm mm^{-1})

Table 2. **Physico-chemical properties of soil**

Location	Depth (cm)	pH	Organic C ($g\ kg^{-1}$)	Available P ($kg\ ha^{-1}$)	Available K ($kg\ ha^{-1}$)
Jengitchekgre	0-30	5.03	12.4	14.6	91.8
	30-60	5.05	11.5	13.0	94.1
	60-90	5.06	10.6	9.4	100.8
	90-120	5.09	9.8	7.8	121.0
Ganolgre	0-30	4.92	13.0	12.5	91.8
	30-60	4.96	12.2	10.8	99.5
	60-90	4.99	11.1	9.4	107.5
	90-120	5.03	10.1	7.8	125.4
Chhebragre	0-30	4.75	12.0	13.9	183.9
	30-60	4.70	11.6	9.4	197.2
	60-90	4.76	10.6	4.7	217.3
	90-120	4.61	10.2	2.0	230.7
Mendipathar	0-30	5.10	13.1	10.3	181.4
	30-60	5.34	11.6	4.5	199.4
	60-90	4.92	10.6	1.8	226.2
	90-120	4.90	9.3	0.9	228.5
Rongara	0-30	4.82	13.0	3.1	112.0
	30-60	4.93	12.7	2.7	114.2
	60-90	4.77	6.6	1.6	121.0
	90-120	4.99	5.9	1.1	129.9
Byrnihat	0-30	4.83	12.9	12.8	120.9
	30-60	4.89	11.7	9.2	127.7
	60-90	4.91	10.5	7.6	141.1
	90-120	4.93	8.5	17.9	154.6
LSD (P= 0.05)		0.21	0.40	1.12	15.23

in the Mendipather profile followed by Brynihat profile (162.49 mm mm^{-1}). The profile from Chhebragre, showed mean available water content of 183.43 mm mm^{-1} while that of Rongara, Ganolgre, and Jengichekgre, were 148.98, 140.57 and 104.20 mm mm^{-1}, respectively.

The correlation study revealed that, the clay content was negatively correlated with moisture at -0.033 MPa (Table 5). The correlation coefficient was significant for Jengkichegre, Ganolgre, Chhebragre and Byrnihat profiles. While clay governed the moisture retention at -0.033 MPa in the soil profile from West Garo Hills (WGH), clay as well as sesquioxides together was found to influence moisture retention at this tension at Ribhoi Hills. For the profiles of West Garo Hills district (Chhebragre, Ganolgre and Jengichekgre) and South Garo

Table 3. **Mechanical composition of the soil**

Location	Depth (cm)	Bulk density (Mg m^{-3})	Particle density (Mg m^{-3})	Porosity (%)	Sand (%)	Silt (%)	Clay (%)	Textural class
Jengichekgre	0-30	1.32	2.47	46.55	41.5	21.5	37.0	cl*
	30-60	1.41	2.50	43.60	39.5	22.0	38.5	cl
	60-90	1.47	2.53	41.89	38.0	22.5	39.5	cl
	90-120	1.52	2.54	40.15	36.5	23.0	40.5	cl
Ganolgre	0-30	1.34	2.43	44.85	39.0	20.5	40.8	cl
	30-60	1.40	2.47	43.51	37.0	21.5	41.5	cl
	60-90	1.44	2.42	40.74	37.0	21.0	42.0	cl
	90-120	1.51	2.49	39.36	34.0	22.0	43.0	cl
Chhebragre	0-30	1.29	2.37	45.60	40.0	20.0	40.0	cl
	30-60	1.34	2.36	43.20	38.0	22.0	40.5	cl
	60-90	1.41	2.51	43.80	36.0	23.0	41.0	cl
	90-120	1.45	2.49	41.80	35.0	24.0	41.0	cl
Mendipathar	0-30	1.40	2.39	41.42	41.0	21.0	38.0	cl
	30-60	1.44	2.45	41.22	40.5	22.5	38.5	cl
	60-90	1.48	2.50	40.80	38.5	22.5	39.0	cl
	90-120	1.55	2.60	40.38	37.0	23.5	39.5	cl
Rongara	0-30	1.39	2.44	43.03	36.5	22.0	41.5	cl
	30-60	1.45	2.55	43.14	37.0	21.0	42.0	cl
	60-90	1.47	2.56	43.57	33.5	22.5	44.0	cl
	90-120	1.58	2.60	39.23	34.5	23.0	42.5	cl
Byrnihat	0-30	1.30	2.36	44.90	39.5	20.5	40.0	cl
	30-60	1.37	2.42	43.40	38.5	21.0	40.5	cl
	60-90	1.49	2.54	41.40	36.0	22.5	41.5	cl
	90-120	1.51	2.49	39.40	34.0	23.5	42.5	cl
LSD (P= 0.05)		0.06	0.07	1.23	1.86	1.23	1.30	

* cl- clay loam

Hills the moisture retention at -0.033 MPa was found to be influenced by organic carbon and silt respectively. The influence of organic carbon on moisture retention at -0.033 MPa was negatively correlated. Lack of influence of organic matter on moisture retention was reported by many workers (Bertramson and Rhodes, 1939; Rajgopal, 1967; Rid, 1968; Kuntze, 1968; Tulasidharan and Nair, 1984 and Krishnakumar *et al.*, 1990a). Bulk density is significantly correlated with moisture retention at -0.033 MPa except in the profile from the East (now North) Garo Hills.

The moisture retention at -1.5 MPa showed that, there was a significant negative correlation (Table 5) between clay, organic carbon, silt and moisture content in the profiles from West Gharo Hills district *viz.*, Jengichekgre, Ganolgre and Chhibragre and

Table 4. **Soil moisture retention characteristics**

Location	Depth (cm)	Moisture percentage		Available water content (mm mm^{-1})	AWSC (mm m^{-1})
		-0.033 MPa	-1.5MPa		
Jengichekgre	0-30	26.30	18.63	101.24	1.01
	30-60	26.65	19.58	99.69	0.99
	60-90	29.67	23.39	92.32	0.92
	90-120	33.41	25.28	123.58	1.24
Mean	29.01	21.72	104.20	1.04	
Ganolgre	0-30	28.15	19.71	113.09	1.13
	30-60	29.85	20.01	137.76	1.38
	60-90	32.92	22.04	156.67	1.57
	90-120	34.24	23.99	154.77	1.55
Mean	31.29	21.44	140.57	1.41	
Chhebragre	0-30	30.01	17.97	155.32	1.55
	30-60	31.77	18.92	172.19	1.72
	60-90	33.35	19.36	197.26	1.97
	90-120	34.56	20.15	208.94	2.09
Mean	32.42	19.10	183.43	1.83	
Mendipathar	0-30	36.08	23.92	170.24	1.70
	30-60	39.03	25.07	201.02	2.01
	60-90	39.70	25.29	213.27	2.13
	90-120	35.67	23.70	185.54	1.86
Mean	37.62	24.49	192.52	1.93	
Rongara	0-30	21.05	12.93	112.87	1.13
	30-60	22.96	13.04	143.84	1.44
	60-90	23.01	11.21	173.46	1.73
	90-120	26.23	15.74	165.74	1.66
Mean	23.31	13.23	148.98	1.49	
Byrnihat	0-30	27.23	19.41	101.66	1.02
	30-60	32.46	23.05	128.92	1.29
	60-90	39.84	25.10	219.78	2.20
	90-120	40.01	26.79	199.62	2.00
Mean	34.88	23.58	162.49	1.62	
LSD (P= 0.05)		0.77	1.11	1.81	0.02

the profile from Byrnihat of Ribhoi Hills. Franzmier *et al*. (1960) suggested that, clay is either not well dispersed or some water is hold by gels that have high colloidal particles. The results obtained in the present study revealed that silt along with clay played an active role in the moisture retention at wilting point, suggesting that,

Table 5. **Simple correlation of moisture retention with some soil properties**

Soil properties	Location	Moisture percentage at -0.033 MPa	Moisture percentage at -1.5 MPa
Clay	Jengichekgre	-0.88 **	-0.93 **
	Ganolgre	-0.80 **	-0.52 *
	Chhebragre	-0.62 **	-0.51 *
	Mendipathar	0.04	-0.13
	Rongara	-0.15	-0.23
	Byrnihat	-0.79 **	-0.89 **
Bulk Density	Jengichekgre	0.83 **	0.90 **
	Ganolgre	0.90 **	0.68 **
	Chhebragre	0.94 **	0.91 **
	Mendipathar	-0.12	-0.20
	Rongara	0.83 **	0.65 **
	Byrnihat	0.95 **	0.77 **
Organic carbon	Jengichekgre	-0.91 **	-0.93 **
	Ganolgre	-0.96 **	-0.89 **
	Chhebragre	-0.94 **	-0.90 **
	Mendipathar	0.02	0.08
	Rongara	-0.72 **	-0.22
	Byrnihat	-0.88 **	-0.89 **
Silt+ Clay	Jengichekgre	-0.82 **	-0.90 **
	Ganolgre	-0.64 **	-0.43 *
	Chhebragre	-0.78 **	-0.71 **
	Mendipathar	0.14	0.20
	Rongara	-0.26	-0.02
	Byrnihat	-0.91 **	-0.91 **

* Significant at 5 per cent level
** Significant at 1 per cent level

silt in the sub tropical soils might also be colloidally active. Except for the profile from North Garo Hills (Mendipather) a positive correlation (Table 5) was obtained between bulk density and moisture retention at -0.1.5 MPa.

The quantity of moisture retained in different profiles showed that, on an average

Table 6. **Percentage of moisture desorbed at different tensions**

Location	Moisture retention (%)			
	Profile Mean		Surface soil	
	-0.033 MPa	-1.5 MPa	-0.033 MPa	-1.5 MPa
Jengichekgre	29.01	21.92	26.30	18.63
Ganolgre	31.29	21.44	28.15	19.71
Chhebragre	32.42	19.10	30.01	17.97
Mendipathar	37.62	24.49	36.08	23.92
Rongara	23.31	13.23	21.05	12.93
Byrnihat	34.88	23.58	27.23	19.41
Mean	31.4	20.6	28.2	18.8

31.4 per cent of available moisture was retained at -0.033 MPa and about 20.6 per cent at -1.5 MPa tension (Table 6). This range of tension was significant from the water availability point of view, in crops like *Hevea* grown under rainfed condition because during January to March, the soil moisture tension generally reduced to around -0.2 to -0.4 MPa with the lowest occurrence during March (Krishnakumar, 1989; Krishnakumar *et al*., 1990a).

It is reported that, in rubber, it is the nature of moisture retention and the desorption characteristics of the profile which would largely govern the productive potential of the soil by regulating the available water to the plants (Krishnakumar *et al*., 1990b). The sub surface layer, rich in clay content would help in replenishment of the moisture in the surface layer as the latter would become depleted during the dry months. Since the moisture in these soils was found getting rarely depleted beyond -0.4 MPa tension even during the stressful dry months, a small amount of water received either as rain or as irrigation during this period, would readily restore the capillary potential and render the already stored water available (Krishnakumar, 1989).

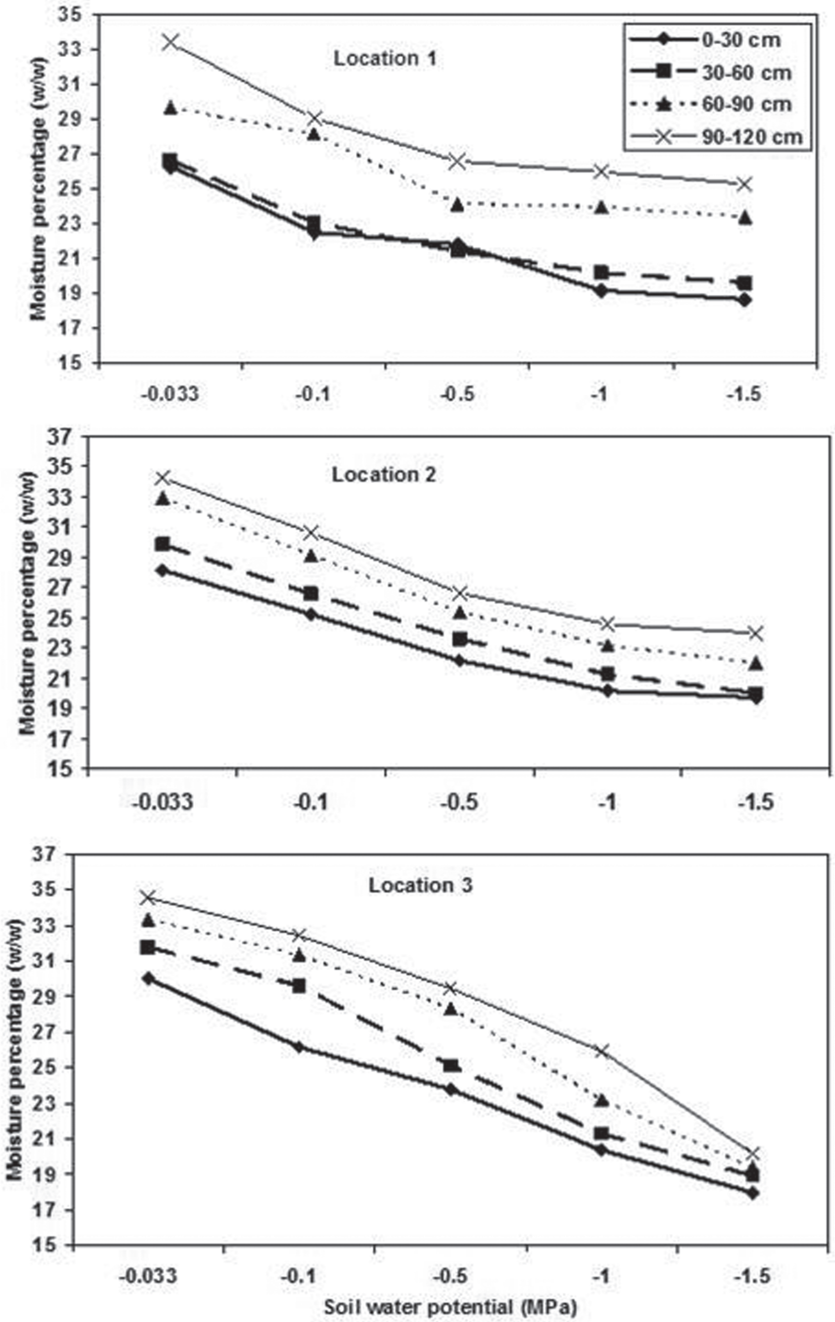

Fig. 1. Soil moisture retention curve for Jengichekgre (1), Ganolgre (2) and Chhebragre (3) locations

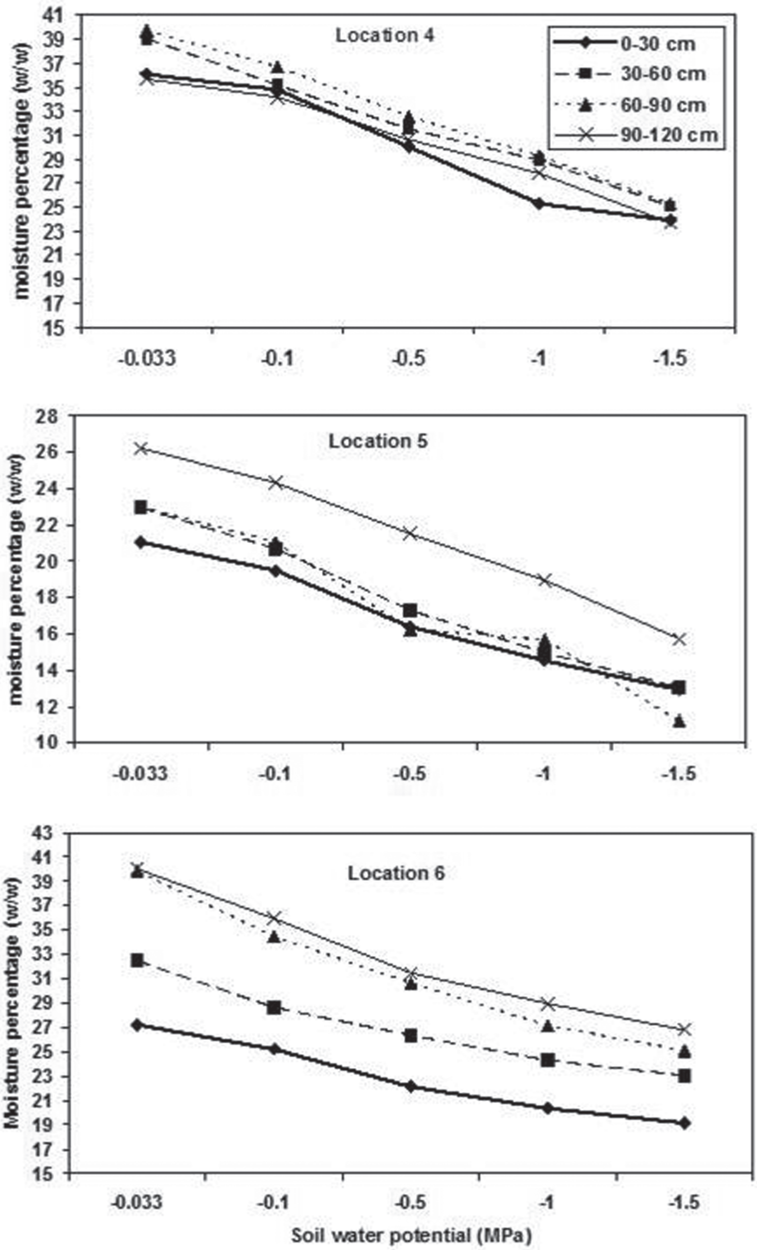

Fig. 2. Soil moisture retention curve for Mendipathar (4), Rongara (5) and Byrnihat (6) locations

This humid tropical soil containing predominantly large proportion of iron oxide-kaolin aggregates tend to hold a higher amount of moisture at lower tension between the inter- and intra-aggregates, but it behaves as clay at higher tension where moisture in the intra-aggregates held with tenacity, results in a narrower available water capacity (Franzmier *et al*., 1960). The available water capacity *per se* may not be therefore, used as a lone index of moisture availability in these soils (Krishnakumar *et al*., 1990a).

CONCLUSION

The present study, revealed that, the moisture retentive capacity of the soils had been found to vary in the different locations of rubber growing areas in Meghalaya. The moisture retention at -0.033 MPa in the surface layer ranged from 21.05 per cent in the profile from Rongara (South Garo Hills) to 36.08 per cent in the profile from Mendipathar (North Garo Hill) of Meghalaya. However, the AWSC did not show any variation as a result of the concomitant increase in the moisture retained at -1.5 MPa. The study revealed that about 31.4 per cent of the available moisture is desorbed at -0.033 MPa and about 20.6 per cent at -1.5 MPa indicating that this tension range could be of relevance to the water availability to crops like rubber grown under rainfed conditions.

ACKNOWLEDGEMENT

Authors are grateful to Dr. N. M. Mathew, Former Director of Research, RRII, Kottayam for providing facilities and inspiration to carry out this study and to Dr. D. Chaudhuri, Former Project Coordinator, North Eastern Research Complex, Regional Research Station, Guwahati for the administrative support.

REFERENCES

Baruah, T.C. and Barthakur, H.P. (1997). *A Text Book of Soil Analysis*. Vikash Publishers, New Delhi, 334 p.

Betramson, B.R. and Rhodes, H.O. (1939). The effect of cropping and manure application on some physical properties of a heavy soil of eastern Nebraska. *Proceedings of Soil Science Society of America*, **3:** 32-41.

Bhattacharya, T. Sehgal, J. and Sarkar, D. (1996). Soils of Tripura: Their kinds, distribution and suitability for major field crops and rubber, detailed bulletin and data base for optimizing land use. *NBSS Publication 65, Soils of India Series 6,* National Bureau of Soil Survey and Land Use Planning, Nagpur, 149 p.

Bray, R.H. and Kurtz, L.T. (1945). Determination of total organic and available forms of phosphorus in soils. *Soil Science*, **59**: 39-45.

Franzmeir, D.P., Whiteside, E.P. and Reickson, A.E. (1960). Relationship of textures classes of the earth to readily available water. *International Congress Soil Science Transaction, 7th, Madison, Wisconsin, USA*, **I**: 345-460.

Gupta, R.D., Sharma, P.D., Acharya, C.L. and Tripathi, E.R. (1983). Water retention characteristics of some soil profiles of North West India in relation to soil properties under different bio and chemical sequences. *Journal of Indian Society of Soil Science*, **31**: 458-463.

Hillel, D. (1971). *Soil and Water: Physical Properties and Processes,* Academic press, NewYork.

Jackson. M.L. (1973). *Soil Chemical Analysis.* Prentice Hall of India Pvt. Ltd. New Delhi, p- 485.

Krishnakumar, A.K. (1989). Soils under *Hevea* in India: A physical, chemical and mineralogical study with a reference to soil moisture cation influences on yield of *Hevea brasiliensis. Ph.D. Thesis,* India Institute of Technology, Kharagpur.

Krishnakumar, A.K., Datta, B. and Potty, S.N. (1990 a). Moisture retention characteristics of soils under *Hevea* in India. *Indian Journal of Natural Rubber Research*, **3** (1): 9-21.

Krishnakumar, A.K., Eappen, T., Rao, N., Potty, S.N. and Sethuraj, M.R. (1990b). Ecological impact of rubber *(Hevea brasiliensis*) plantation in N.E. India. 1. Influence of soil physical properties with special reference to soil moisture retention. *Indian Journal of Natural Rubber Research*, **3**(1**):** 53-63.

Kurtze, H. (1968). Influence of organic matter on water regime characteristics of Tennesse soils. *Tennesse Agricultural Experiment Station Bulletin*, **367**: 46-47.

Morgan, M.F. (1941). Chemical diagnosis by the universal soil testing system. *Bulletin of Connecticut Agricultural Experiment Statio*n, 45 p.

Piper, C. S. (1966). *Soil and Plant Analysis*. Hans Publishing House, Bombay, 368 p.

Rajgopal, A. (1967). The relationship of soil water with soil moisture constants. *Madras Agricultural Journal,* **54** (9): 470-475.

Rid, H. (1968). The movement of water in sandy soils after ploughing at a depth of 50 cm. Dubl. International Associations, Science, Hydrology, *UNESCO Symposium*, Waginegen, **83**: 401-406.

Rubber Board. (2014). *Rubber and its Cultivation*. p. 150.

Soong, N. K. and Lau, C. H. (1977). Physical and chemical properties of soils. In**:** *Soils under Hevea in Peninsular Malaysia and their management.* (Eds. E. Pushparajah and L. L. Amin). Rubber Research Institute of Malaysia, Kaula Lumpur, pp. 25-26.

Thulasidharan, C. K. and Nair, V. R. (1984). Moisture retention characteristics of leterite soils of Kerala. *Agricultural Research Journal of Kerala*, **22**(1): 11-16.