MOISTURE RETENTION CHARACTERISTICS OF RED AND FOREST SOILS OF KERALA

BY

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THESIS

submitted in partial fulfilment of
the requirement for the degree

Master of Science in Agriculture

Faculty of Agriculture
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Department of Agronomy
COLLEGE OF HORTICULTURE
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DECLARATION

I hereby declare that this thesis entitled "Moisture retention characteristics of red and forest soils of Kerala" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

Vellanikkara,
25-2-1985.

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Dated: 25.2.85

CERTIFICATE

Certified that this thesis entitled "Moisture retention characteristics of red and forest soils of Kerala" is a record of research work done independently by Miss. Reena Mathew under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

R. Vikraman Nair,
Chairman,
Advisory Committee

CERTIFICATE

We, the undersigned, members of the Advisory Committee of Smt. Reena Mathew, a candidate for the degree of Master of Science in Agriculture with major in Agronomy, agree that the thesis entitled "Moisture retention characteristics of red and forest soils of Kerala" may be submitted by Smt. Reena Mathew in partial fulfilment of the requirement for the degree.

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F I G U R E S

INTRODUCTION

Storage of water in the root zone of field soil is of importance to both dry land and irrigated agriculture. It has been recognised since long that the total water content of a soil *per se* gives only inadequate information on the quantity of water available to plants as soils differ widely in the capacity to store water in the plant available form. Meaningful information on this can be had only when water content is related to soil moisture tension. Though plants have been found to differ again on the ability to extract stored water, relevant generalisations could be made on this. Much larger variations, however, occur in the ability of soils to retain water. The soil moisture content-tension relations usually represented through soil moisture characteristic curves give information on this aspect of water content in available form.

Much of the soil-to-soil difference in moisture content-tension relation is often accountable as due to differences in texture and organic matter content. The former affects through increased capillary porosity resulting from increasing fineness of texture and through larger surface area exposed by finer soil particles.

Introduction

The organic matter content affects through modified soil structure in addition to the above mechanisms.

Among the soil moisture constants, the two that are most important in deciding the plant available water content are the field capacity and wilting coefficient. Though there are criticisms on the validity and constancy of these, they are the only measures presently available to define available water with reasonable accuracy. As in the case of moisture contents at other moisture tension values, those at these moisture constants also show high degree of dependence on fineness of soil as defined by texture and organic matter content.

In as much as data on texture and organic matter content of soils are more easily gathered than those on field capacity and wilting coefficient, it may be worthwhile deriving the latter from information on texture and organic matter content. In the case of many soils of Kerala, data from such calculations are incomplete as there is often large preponderance of gravel which normally is not estimated as a textural component. Allowances for the extent of occurrence of gravel and moisture retention by this fraction are also to be made in such cases.

The present study was aimed at working out some of the above relationships in the red and forest soils of Kerala. A list of the main objectives of the study is given below. This forms a continuation of earlier studies on identical lines on the laterite and alluvial soils of the State.

i) To find out the moisture retention characteristics of red and forest soils of Kerala at varying levels of matric potential.

ii) To find out the correlation between moisture retention at different tensions, texture and organic carbon contents of soil.

iii) To work out suitable prediction models for arriving at moisture retention at 0.3 and 15 bars based on the knowledge of textural separates and organic carbon.

Review of Literature

REVIEW OF LITERATURE

Soil moisture retention and its different aspects had been the subject of many an investigation of the present century. Work done on the soil moisture retention and availability, and their relationship with texture and organic carbon content of the soil has been reviewed by Thulasidharan (1983) and Prameela (1983). So only a brief report of the studies which were not included by them are being presented in this section.

Concepts of soil moisture availability

A summary of the review by Thulasidharan (1983) and Prameela (1983) on this aspect is given below.

The available range of moisture was considered to be that held between field capacity and permanent wilting point. In the early days, it was thought that this whole range of soil moisture was equally available to plants. But later workers proved it not to be so. As such, the concept of readily available water had come up. Plants were found to vary in their optimum percentage of available water. Since these soil water contents based on soil wetness could not be applied universally, attempts were made to correlate the water status of plants with the energy status of soil water. Accordingly, potential values of

-1/10 or -1/3 bar were assigned to field capacity and -15 bar for permanent wilting point. There had been controversy among workers regarding these potential values also.

Recent developments in the last two decades have made clear that in a dynamic soil water system, such static concepts as soil water constants are physically meaningless. Furthermore, the amount and rate of water uptake by plants is not an exclusive function of the content or potential of soil water (Hillel, 1971). However they carry some ideas about the storage capacity of the soil and serve as the useful basis for scheduling irrigation in the absence of any other criterion.

Moisture retention in relation to texture

The relative proportion of different sized particles in the soil greatly influences its ability to retain moisture. The main conclusions of the reviews by Thulasidharan (1983) and Prameela (1983) are as follows:

i) Soil moisture content at all tensions showed strong relation with the fine fractions, silt and clay.

ii) The relation between available moisture content and content of clay had been variable, there being an increase in the content of available water with increasing clay content in some cases and a decrease in some others especially at higher clay contents.

iii) There had been a consistent positive correlation between the content of silt and available water content. The relation with sand was always negative.

iv) Predicting moisture retention at 0.3 bar and 15 bars and available water content using equations which incorporated textural separates and organic carbon had been successful.

Moisture retention and available water content were shown to be higher for soils with more of fine fraction (Packard, 1954; Croegaert et al., 1954). Gavande (1968) attributed the differences between latosols, andosols and alluvial soils of Costa Rica in respect to changes in soil water content with suction to the differential clay, silt, fine sand and organic matter contents.

The study on soil moisture retention and release characteristics conducted at Hyderabad revealed the volumetric water content at 0.3 and 15 bars to be substantially higher in a sandy clay loam soil than in a sandy loam soil (Anon., 1982). Experimental results of Jong et al. (1983) proved texture as the main soil property influencing the shape and position of the water retention curve. But this influence varied with the area in which the study was conducted because of the difference in clay mineralogy and organic matter content.

The positive influence of clay and the negative influence of sand on field capacity, permanent wilting percentage and available water content had been reported by many workers (Sommes, 1963; Jadhav, 1978; Talha et al., 1979; Ghazy et al., 1981). Contrary to this, Dias-Fierros and Guitear-Ojea (1968) obtained a negative correlation between available water and clay content. Gupta et al. (1983) also stated that clay alone did not produce any significant effect on water retention.

Moisture retention by black soils was found to surpass all other soil groups of South India because of its good structure and high content of 2:1 clay (Selvakumari et al., 1973). It was concluded that retentivity of moisture in the red soil was generally poor.

Fripiat (1950) showed the amount of extractable water to be higher in soils containing silt. Petersen et al. (1968) considered silt as the most important factor controlling field capacity and available moisture in the textural class, silt loam. A positive correlation was obtained between silt and water content. Moisture retention decreased as the coarse fragments increased in the different horizons. Diaz-Fierros and Guitian-Ojea (1968) reported that available water content was positively correlated with silt. The higher water holding capacity of the subsoil layers of red soil pedons of Madurai was explained on the basis of increased contents of clay and silt (Raguraj, 1981).

For the laterite soils of Kerala, Thulasidharan (1983) indicated an increasing influence of silt content in deciding the moisture retention by the 2 mm sieved fraction at increasing tensions. Clay content was shown to have a significant positive effect. But an inverse relation was shown with coarse fraction. A similar result was observed by Prameela (1983) for the alluvial soils of Kerala.

In light textured soils, the majority of soil water was released at 0.4 bar, whereas in heavy textured soils, only about 20 per cent of water was released at this tension. Moisture retention at 0.1 bar was found to be dependant on (silt + clay) percentage and exchangeable calcium percentage while at 15 bar, it depended only on (silt + clay) percentage. Slope of the log h (cm) - log curve was mainly governed by texture (El-Kommos, 1983).

Multiple linear regression procedures were employed by Jong and Leobel (1982) to relate particle size distribution and organic carbon to the gravimetric water content at 1/3 and 15 bar tensions. Williams *et al.* (1983) grouped soils having similar moisture retention characteristics and suggested that developing simple prediction models for these groups based on soil physical properties will be useful in many agricultural and hydrologic operations. Prameela (1983) developed prediction equations for the alluvial soils of Kerala incorporating organic carbon and texture to estimate the moisture retention at 0.3 and 15 bars and also the available moisture percentage. They were as follows:

a) Moisture percentage at 0.3 bar (y_1)

$$y_1 = 10.3387 + 0.3405\ x_1 + 0.3610\ x_2 + 0.0030\ x_3 - 0.1170\ x_4 + 0.0176\ x_5\ (R^2 = 0.87)$$

b) Moisture percentage at 15 bars (y_2)

$$y_2 = -14.110 + 0.4309\ x_1 + 0.4198\ x_2 + 0.1575\ x_3 + 0.1547\ x_4 - 1.6651\ x_5\ (R^2 = 0.91)$$

c) Percentage of available water (y_3)

$$y_3 = 24.7534 - 0.0936\ x_1 - 0.0618\ x_2 - 0.1576\ x_3 - 0.2748\ x_4 + 1.6790\ x_5\ (R^5 = 0.65)$$

where x_1 = clay per cent
x_2 = silt per cent
x_3 = fine sand per cent
x_4 = coarse sand per cent
x_5 = organic carbon per cent

The amount and availability of water contained in coarse fragments is often considered to be negligible but may have an impact on soils with high content of coarse fragments. That stones (>2 mm fraction) contribute to water available to plants had been proved by Coile (1953). He suggested that retention by stones varied according to the kind, size and content of the stones.

Haridasan (1978) could find that soil moisture characteristic curves obtained with the 2 mm sieved fraction greatly overestimated the moisture retention of laterite soils, in comparision with that of undisturbed samples. The high gravel content (28-58 per cent) of these soils was attributed to this. It was also found that in the red soils nearly free of gravel, the moisture retention curves obtained were similar in both sieved and undisturbed soils.

Hanson and Blevins (1979) separated the more than 2 mm fraction from the surface layers of Cutshine soil and Colyer soil into three size groups viz. 2-5, 5-20 and 20-55 mm. In the case of cutshin gravely loam, the available water capacity ranged from 3.6 per cent in the 20-35 mm size fraction to 5.6 per cent in the 2-5 mm size fraction. The shale fragments showed relatively higher retention to the tune of 6.2 - 12.9 per cent.

While studying the physical properties of three soils in Southern Nigeria, Mbagwu *et al.* (1983) made a correction in the total available water holding capacity of each sampling depth for their gravel contents which ranged from 21 to 58 per cent.

Thulasidharan (1983) estimated the moisture retention by gravel in the laterite soils of Kerala where a preponderance of gravel was seen. The moisture retention amounted to 8.7 per cent at 0.3 bar and 7.1 per cent at 15 bars. The available water in the gravel was found to be 1.6 per cent by weight which would come to a magnitude of 27 per cent of the available water retention of sieved portion. The following prediction equations were developed to find out the moisture retention at 0.3 bar and 15 bars utilising the data of organic carbon contents and particle size separates including gravel.

a) Moisture retention at 0.3 bar (y_1)

$$y_1 = -68.054 + 0.2558\,x_1 + 0.881\,x_2 + 1.27\,x_3 + 0.756\,x_4 + 0.752\,x_5 + 0.794\,x_6 \quad (R^2 = 0.49).$$

b) Moisture retention at 15 bars (y_2)

$$y_2 = 14.656 - 0.156\,x_1 + 0.0234\,x_2 + 0.3428\,x_3 - 0.173\,x_4 - 0.0489\,x_5 - 0.0503\,x_6 \quad (R^2 = 0.41).$$

where, x_1 - organic carbon per cent

x_2 - clay per cent

x_3 - silt per cent

x_4 - fine sand per cent

x_5 - coarse sand per cent

x_6 - gravel per cent

Moisture retention in relation to organic carbon content

The literature on the influence of organic carbon on soil moisture retention had been reviewed by Thulasidharan (1983). Prameela (1983) quoted some of the reports not included by him. Their conclusions were as follows:

i) Moisture retention and content of available water were positively correlated with the organic carbon content in most cases.

ii) There were reports of a lack of such relation presumably because the favourable effect of organic matter was masked by the dominant effect of the content of fine fractions.

Feustel and Byers as early as 1936 reported that addition of organic matter increases the water retention capacity of soils. The positive influence of organic carbon on available water content was found to be marked in coarse textured soils (Bouyoucos, 1939). On the other hand, Klute and Jacob (1949) observed no significant effect on the wilting point and moisture equivalent of a silt loam soil which had received 0-40 tonnes of horse or duck manure for 25 years. Jamison (1953) concluded that any increase in available water capacity of soil following the application of organic manures was so small even in sandy soils, as to be of no practical value.

According to Salter and Haworth (1961), the increased available water capacity was the result of a significant increase in field capacity as compared to the nonsignificant effect on permanent wilting point.

Rajagopal and Mariakulandai (1967) indicated that the added organic matter had no effect on the moisture holding capacity of South Indian soils upto a level of 10 tonnes of farm yard manure per acre. This was attributed to the predominant effect of clay in these soils.

Shetron (1974) reported the dominant influence or organic carbon and free iron contents on the water retention in the B horizon of some forested sandy soils. Soil water retention expressed as per cent by weight in a peat soil was reported to increase at each soil water suction with each increment of peat (Stevenson, 1974).

Bulk densities on the other hand decreased with the result that quantity of stored water on volumetric basis depended on the relative increases in per cent water by weight and decreases in bulk densities.

Ghatol and Malewar (1978) and Riley (1983) observed an increase in porosity and water holding capacity with increasing organic matter contents. Thulasidharan (1983) observed that in the laterite soils of Kerala, organic carbon was found to have no bearing on the moisture retention as indicated by its correlation being non-significant with moisture retention at all the tensions. Prameela (1983) also reported a lack of significant correlation of organic matter content for the alluvial soils of Kerala.

Jacobowits and Steenhuis (1984) found that when sewage sludge compost was added at rates of 0, 50, 200 and 500 tonnes per hectare to sandy loam and silt loam field plots, the volumetric water content increased in the sandy loam soil only.

<u>Soil moisture suction relationship</u>

Mathematical functional relationship between soil moisture contents and soil moisture tension had been reported. Ghosh (1976) established the soil-moisture characteristic of sandy soils as $\psi = \psi_e \left(\frac{\theta}{\theta_0}\right)^{-\beta}$, where

ψ_e was the air entry capillary suction in bars, β was an empirically determined constant, θ was the volume moisture content of soil and θ_o was the volume of θ in saturation. The value of β was estimated as $\beta = 26.5 \left(\frac{l_2}{l_1}\right)^{1.786}$ where l_1 and l_2 are the percentage of sand and silt in the soil.

Haridasan *et al.* (1979) described the moisture characteristic curves for two laterite soils and a red sandy loam soil of Kasaragod by a linear model of the type $\log h = a - b\ (\theta - \theta\ )$ where the constant 'a' reflected the adsorptive properties and 'b' the hydrophysical properties of the soils.

Bache *et al.* (1981) showed that water content was linearly related to log suction (suction in milli bars so that $\log \psi = p^F$) and water content on volumetric basis. The linear model was considered acceptable for sandy loams, loams, silt loams and clay loams but inappropriate for soils dominated in sand or clay, since the relationship was slightly curved.

Function relationship between soil water content and water suction were examined for various soils of Canadian prairies and Jong *et al.* (1983) showed that the best fit was obtained with a two straight line regression model of the form

$WC = a + b_1 (\log_s S-t)$ for $S \leq 10^t$ and

$WC = a + b_2 (\log_s S-t)$ for $10^t \leq S$ where

S = soil water suction in bars

t = 'breaking point' denoting the log of suction at which water becomes more difficult to remove from the soil when the suction is further increased.

a, b_1 and b_2 - regression coefficients

For the laterite soils of Kerala, Thulasidharan (1983) found that the exponential quadratic model was the most suitable prediction model for moisture characterisation. It was of the form $\log y = a-bx + cx^2$, where y was the soil moisture tension in bars, x the moisture percentage on weight basis and a and b are constants. Prameela (1983) showed that the Cobb Douglas function $\log y = a - \log bx$ as the best fit for moisture characterisation of the alluvial soils of Kerala.

Material and Methods

MATERIAL AND METHODS

The study was conducted at the College of Horticulture, Vellanikkara during the period from November 1983 to September 1984.

1. Soil

Red and forest soil groups were selected for the study. Soil samples were collected from three series each established by the soil survey unit of the Department of Agriculture. The three series of red soil, Beypore, Kunhimangalam and Cherniyoor, were located at Calicut, Cannanore and Trivandrum districts, respectively. Forest soils were collected from Sholayar, Periya and Sankiri series of Trichur, Wynad and Trivandrum districts. From each series, soil samples were collected from three profiles at different locations. Morphological descriptions of the typifying pedon of each series are given in Appendix-1.

2. Sampling procedure

For red soil, pits of 1.5 m were dug at three different locations from each series. Soil samples were collected by scraping the sides of the pit at five depths viz.0-30 cm, 30-60 cm, 60-90 cm, 90-120 cm and 120-150 cm. In the case of forest soil, it was not possible to take the samples from the five depths due to the limits of depth of the soil. The sampled depths varied for the profiles according to the depth possible. These samples were used for studying moisture retention and soil properties.

The samples for the determination of bulk density were collected using core samplers of 10 cm length and 4.4 cm diameter. The core samplers were hammered vertically down into the soil from the top of the pit after removing the top 10 cm soil layer of each depth.

The gravel percentage of each sample was determined separately from samples taken for bulk density determination after oven drying. The more than 2 mm fraction was washed, oven dried and weighed and expressed as the percentage of the total weight of soil.

3. Moisture retention measurements

The collected soil samples were air dried and passed through a 2 mm sieve. Moisture retention studies were made at pressures of 0.3, 1, 3, 5, 10 and 15 bars using the pressure plate apparatus (Richards, 1947). For this, the samples were saturated overnight in rubber rings and transferred to the pressure plate, also saturated overnight. The plates with the samples were then brought into equilibrium with the applied pressure for 24-48 hours. The moisture contents of the samples in equilibrium with the applied pressure were then determined by gravimetric method after drying in an electric oven at 105-110^{o}C. Moisture retention studies were replicated thrice for each sample.

Moisture retention by gravel was determined for forest soil samples only. The gravel content of red soil samples was too low to be considered. The washed and dried gravel was saturated overnight in water and then used for the determination of moisture retention at 0.3 and 15 bars. The overall mean retention by the gravel was then calculated. The moisture retention at 0.3 and 15 bars including gravel on volume basis was calculated by multiplying the weighted values on weight basis including gravel with the bulk density of each sample.

4. Determination of available water

Available water of the soil samples was determined by finding the moisture held between 0.3 bar and 15 bars pressures. The available water content of the sieved soils was determined on weight basis.

Moisture retention by the soil including gravel at 0.3 and 15 bars was separately calculated for each sample from the water retention by sieved soil, its proportion, the retention by gravel and its proportion. These retention values were then converted to volume basis by multiplying the water retention on weight basis with the bulk density of each sample. The available water content on volume basis was finally calculated as the difference in water content at 0.3 bar and 15 bars on volume basis.

5. Particle size distribution analysis

Mechanical composition of the 2 mm sieved soil fraction was found out by the International pipette method as proposed by Piper (1942). The particle size distribution including gravel was also found out by incorporating the weights of gravel and sieved soil of each sample.

6. Determination of organic carbon

Walkley and Black titration method (Jackson, 1958) was used to determine the organic carbon content of the 0.2 mm sieved soil.

7. Statistical analysis

Correlation studies were made between the moisture retention of the sieved soil at different tensions and organic carbon and textural components. Multiple regression analysis as suggested by Snedecor and Cochran (1967) was employed to arrive at suitable prediction equations relating moisture content at field capacity and wilting percentage with organic carbon and texture. In the case of forest soil, two sets of prediction equations were developed, one for moisture retention of sieved soil and another for moisture retention including gravel. Moisture retention characteristic curves were also arrived at for the red and forest soils using the mean retention values of the sieved soil, obtained from the entire samples.

Results

RESULTS

Red Soil

1. Moisture retention by the profiles

Data on the mean moisture retention of the 2 mm sieved soil on weight basis for the different series and their overall mean values are furnished in Table 1.

In general, as the tension increased from 0.3 to 15 bars, there was a decrease in the amount of moisture retained by the soil. But the rate of decrease was small at the highest tensions i.e. 10 and 15 bars. Among the three series, Cherniyoor series showed comparatively higher retention at all the tensions for the different layers.

The values for the moisture retention at field capacity ranged from 9.4 per cent to 11.7 per cent in the different series with a mean of 10.45 per cent. At permanent wilting point, the mean retention was 7.21 per cent, while the values ranged from 6.5 to 8.4 per cent. Similarly, the mean available water content amounted to 3.24 per cent, the range of values being from 2.93 to 3.46 per cent in the different series. The available water content remained nearly the same in all the profiles of the three series.

Table 1. Moisture retention by 2 mm sieved soil (Percentage by weight)
a) Beypore series

Depth cm	Soil moisture tension (bars)						Available water
	0.3	1.0	3.0	5.0	10.0	15.0	
0 - 30	8.59	6.93	6.05	5.65	5.46	5.09	3.50
30 - 60	8.84	7.73	6.88	6.50	6.59	6.10	2.74
60 - 90	9.69	8.47	7.84	7.39	7.21	7.06	2.63
90 - 120	10.08	8.65	7.85	7.60	7.37	7.22	2.86
120 - 150	10.03	8.36	7.64	7.25	7.26	7.09	2.94
Mean	9.45	8.03	7.25	6.88	6.78	6.51	2.93

b) Kunhimangalam series

Depth cm	Soil moisture tension (bars)						Available water
	0.3	1.0	3.0	5.0	10.0	15.0	
0 - 30	8.48	7.35	6.27	5.75	5.26	5.25	3.23
30 - 60	9.58	8.34	7.19	6.67	6.11	6.31	3.27
60 - 90	11.11	8.73	7.68	7.18	6.78	6.97	4.14
90 - 120	10.78	8.00	7.64	7.22	6.69	7.12	3.66
120 - 150	10.94	9.48	8.53	8.14	7.85	7.84	3.10
Mean	10.18	8.38	7.46	6.99	6.94	6.70	3.48

(Contd.)

Table 1 (Contd.)

c) Cherniyoor series

Depth cm	Soil moisture tension (bars)						Available water
	0.3	1.0	3.0	5.0	10.0	15.0	
0 - 30	9.72	8.12	7.34	6.83	6.39	6.41	3.31
30 - 60	12.46	11.02	10.00	9.40	8.92	8.76	3.70
60 - 90	13.01	13.36	10.16	10.09	9.59	9.40	3.61
90 - 120	11.37	9.65	9.05	8.85	8.53	8.46	2.91
120 - 150	12.13	10.77	9.64	9.57	9.16	9.06	3.07
Mean	11.74	10.18	9.24	8.95	8.52	8.42	3.32

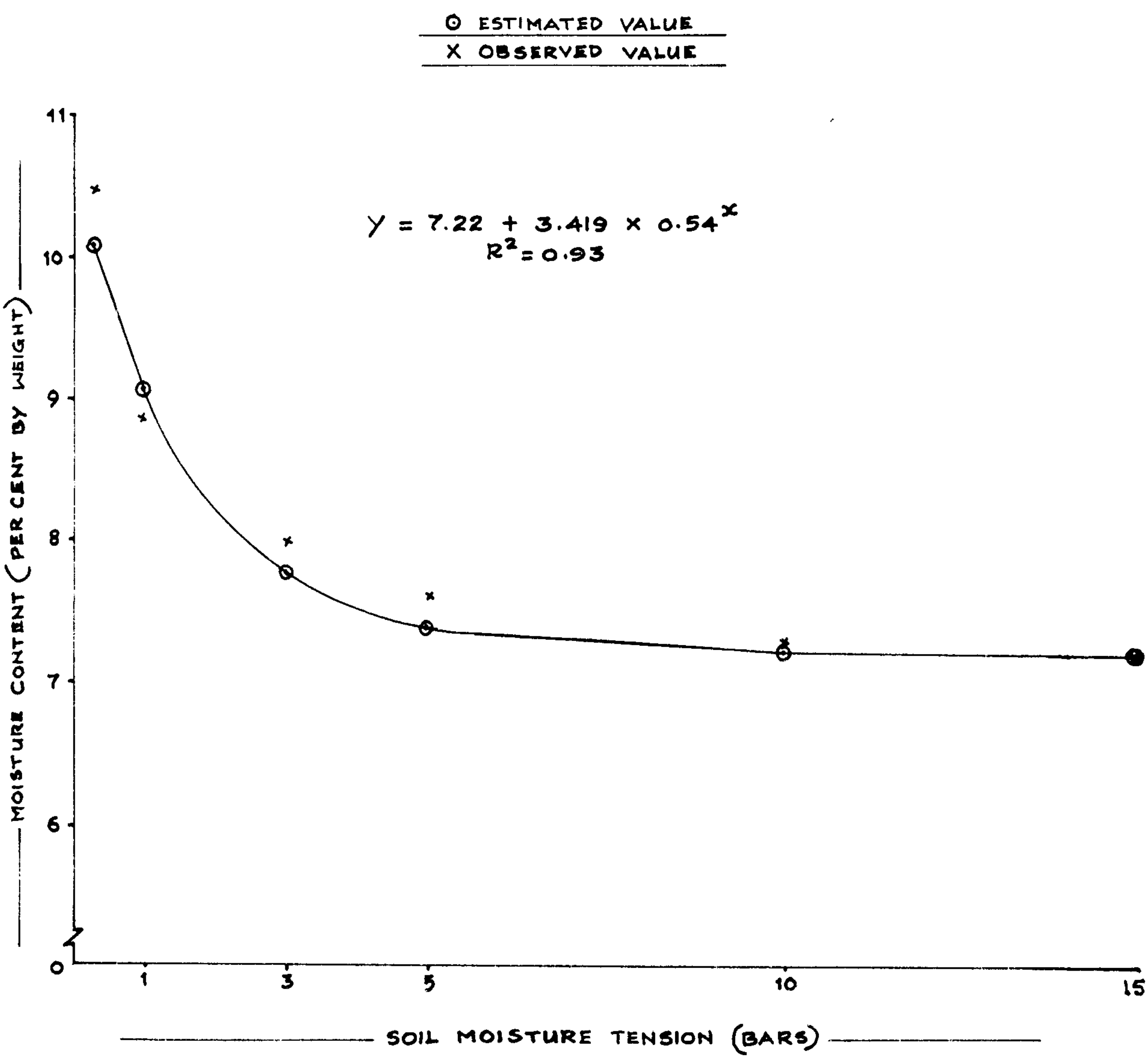
d) Overall mean retention at different tensions (percentage by weight)

Depth cm	Soil moisture tension (bars)						Available water
	0.3	1.0	3.0	5.0	10.0	15.0	
0 - 30	8.93	7.46	6.55	6.07	5.70	5.58	3.35
30 - 60	10.29	9.03	8.02	7.52	7.21	7.06	3.23
60 - 90	11.27	9.52	8.56	8.22	7.86	7.81	3.46
90 - 120	10.74	8.77	8.18	7.89	7.53	7.60	3.14
120 - 150	11.03	9.54	8.60	8.32	8.09	8.00	3.03
Mean	10.45	8.86	7.98	7.60	7.28	7.21	3.24

When the tension was increased from 0.3 to 1 bar, 49 per cent of the total available water was removed. The depletion was 27 per cent as the tension increased from 1 to 3 bars. The increase of tension from 3 to 5 bars and 5 bars to 10 bars resulted in the removal of 11.7 per cent and 9.8 per cent available water respectively. The moisture extraction was only 2.1 per cent when the applied pressure changed from 10 to 15 bars. Thus it was observed that most of the total available water was removed as the tension reached 3 bars (87.7 per cent). An attempt was made to arrive at a suitable prediction model for moisture characterisation and the best fit was obtained with the modified exponential curve $y = k + ab^x$ .... (Equation 1) where k is a constant called asymptote, a and b are constants, y is the soil moisture tension in bars and x is the corresponding soil moisture content on percentage weight basis.

Data on the overall mean retention for the layers indicated that the moisture retention was lowest in the topmost layer and highest in the last layer. An increasing trend with depth was observed for moisture retention, though it was not consistent. However, the available water content failed to show any such trend and the values were almost the same.

Fig-1. MOISTURE CHARACTERISTIC CURVE FOR THE 2 MM SIEVED FRACTION IN RED SOIL.



No marked variation was observed between the water holding capacities of the three different profiles of a series (Data not presented).

2. Soil properties

2.1. Texture of the 2 mm sieved portion

Table 2 presents the data on the mean textural composition of the different series.

The predominant textural class was sandy clay loam. Excepting Cherniyoor series, the other two series were found to belong to the above textural class. Among the two sand fractions, the content was higher for fine sand (0.02 - 0.2 mm). The mean values for the textural separates for the different series ranged from 20 to 29 per cent in the case of clay, 49 to 66 per cent for fine sand and 9.4 to 16.8 per cent for coarse sand. The overall mean values in these cases were 24.1, 58.5 and 13.4 per cent, respectively. The silt content remained almost the same in all the series with a mean value of 4 per cent.

It was observed that the clay content was minimum in the surface layer in all the series and the other layers showed similar values. On the contrary, the sand fraction was generally higher in the surface layers. The total fine fraction (clay + silt) indicated an increasing trend

Table 2. Textural composition of the soil (percentage)

a) Beypore series

Depth cm	Clay	Silt	Fine sand	Coarse sand	Textural class
0 - 30	14.66	6.32	68.21	10.81	Sandy loam
30 - 60	20.72	2.79	67.63	8.86	Sandy clay loam
60 - 90	21.79	2.94	65.27	10.00	Sandy clay loam
90 -120	[illegible]	3.22	64.92	8.91	Sandy clay loam
120 -150	20.18	6.27	64.82	8.73	Sandy clay loam
Mean	20.06	4.31	66.17	9.46	Sandy clay loam

b) Kunhimangalam series

Depth cm	Clay	Silt	Fine sand	Coarse sand	Textural class
0 - 30	18.81	3.41	62.72	15.06	Sandy loam
30 - 60	20.56	4.75	61.28	13.41	Sandy clay loam
60 - 90	22.86	3.75	60.64	12.75	Sandy clay loam
90 - 120	26.40	1.53	59.52	12.55	Sandy clay
120 - 150	24.38	4.24	57.38	14.00	Sandy clay loam
Mean	22.60	3.54	60.31	13.55	Sandy clay loam

(Contd.)

Table 2. (Contd.)
c) Cherniyoor series

Depth cm	Clay	Silt	Fine sand	Coarse sand	Textural class
0 - 30	22.50	4.72	53.79	18.99	Sandy clay loam
30 - 60	31.69	4.40	47.79	16.12	Sandy clay
60 - 90	30.26	4.06	47.95	17.78	Sandy clay
90 - 120	29.66	3.18	50.41	16.75	Sandy clay
120 - 150	33.83	3.89	45.74	16.54	Sandy clay
Mean	29.58	4.05	49.14	17.23	Sandy clay

d) Overall mean textural composition

Depth cm	Clay	Silt	Fine sand	Coarse sand	Textural class
0 - 30	18.66	4.82	61.57	14.95	Sandy loam
30 - 60	24.31	3.98	58.90	12.81	Sandy clay loam
60 - 90	24.96	3.58	57.95	12.51	Sandy clay loam
90 - 120	26.34	2.64	58.28	12.74	Sandy clay loam
120 - 150	26.13	4.80	55.98	13.09	Sandy clay loam
Mean	24.08	3.96	58.58	13.42	Sandy clay loam

with depth, as evidenced by the data on the overall mean textural composition and the textural composition of the different series. The above depth wise variation in contents of textural separates was, however, not consistent and erratic values were observed in several profiles.

Comparatively higher clay and coarse sand contents were noticed in the Cherniyoor series in all the five depths. The fine sand content was relatively low in this series. The variation among the different profiles in a series with respect to their particle size distribution was erratic and the overall range was from sandy loam, through sandy clay loam to sandy clay.

2.2. Organic carbon content

The organic carbon percentage of the three series was found to decrease consistently as the depth increased (Table 3). The topmost layer had a mean content of 0.38 per cent which dropped to almost half (0.2 per cent) in the lowermost layer. The values for these two layers ranged from 0.31 to 0.43 and 0.13 to 0.30 per cent, respectively in the different series. The overall mean organic carbon content was 0.26 per cent. Conspicuous variations were observed between profiles and even within a profile between the different layers.

Table 3. Organic carbon contents of the different series (percentage)

Depth cm	Beypore series	Kunhimangalam series	Cherniyoor series	Overall mean
0 - 30	0.38	0.32	0.43	0.38
30 - 60	0.26	0.23	0.39	0.29
60 - 90	0.23	0.15	0.32	0.23
90 - 120	0.19	0.11	0.25	0.18
120 - 150	0.17	0.13	0.30	0.20
Mean	0.25	0.19	0.34	0.26

Table 4. Bulk densities of the different series ($g\ cc^{-1}$)

Depth cm	Beypore series	Kunhimangalam series	Cherniyoor series	Overall mean
0 - 30	1.44	1.41	1.48	1.44
30 - 60	1.41	1.44	1.43	1.43
60 - 90	1.42	1.46	1.30	1.39
90 - 120	1.38	1.44	1.35	1.39
120 - 150	1.38	1.48	1.35	1.40
Mean	1.41	1.45	1.38	1.41

2.3. Bulk density

The bulk density values for the different series together with the overall mean for the entire samples are presented in Table 4.

The mean bulk density values ranged from 1.30 to 1.48 g cc^{-1} with an overall mean of 1.41 g cc^{-1}. Though variations were noted in different series, the bulk density values averaged over all the series showed a steady decrease with increasing depth, the averages for depths of 0-30 cm and 120-150 cm being 1.44 and 1.40 g cc^{-1}, respectively.

3. Moisture retention on volume basis

Moisture retention at 0.3 and 15 bars and available water on volume basis were determined by multiplying the corresponding retention values on weight basis with the bulk density of each. Data on these are presented in Table 5.

The different series showed relatively similar values of available volumetric water content with the mean value of 4.6 per cent. The field capacity and permanent wilting percentage were 14.7 and 10.1 per cent, respectively. The range of values was from 13.3 per cent to 16.2 per cent in the case of field capacity and 9.2 to 11.6 per cent for

Table 5. Moisture retention on volume basis for different series (percentage by volume) at 0.3 and 15 bars.

a) Beypore series

Depth cm	0.3	15	Available water
0 - 30	12.38	7.34	5.04
30 - 60	12.48	8.61	3.87
60 - 90	13.75	10.02	3.73
90 - 120	13.92	9.97	3.95
120 - 150	13.83	9.78	4.05
Mean	13.27	9.14	4.13

b) Kunhimangalam series

Depth cm	0.3	15	Available water
0 - 30	11.96	7.41	4.55
30 - 60	13.79	9.08	4.71
60 - 90	16.23	10.19	6.04
90 - 120	15.54	10.27	5.27
120 - 150	16.19	11.60	4.59
Mean	14.74	9.71	5.03

c) Cherniyoor series

Depth cm	0.3	15	Available water
0 - 30	14.35	9.47	4.88
30 - 60	17.79	12.50	5.29
60 - 90	16.87	12.19	4.68
90 - 120	15.33	11.41	3.92
120 - 150	16.39	12.24	4.15
Mean	16.15	11.56	4.59

d) Overall mean retention on volume basis

Depth cm	0.3	15	Available water
0 - 30	12.90	8.07	4.83
30 - 60	14.69	10.06	4.63
60 - 90	15.62	10.80	4.82
90 - 120	14.93	10.55	4.38
120 - 150	15.47	11.21	4.26
Mean	14.72	10.14	4.58

permanent wilting point. No consistent trend was observed with depth in any of the series.

4. Correlation studies

Correlation coefficients were worked out for moisture retention at the six tensions with organic carbon content and texture. They are furnished in Table 6.

The clay content showed a highly significant positive correlation with water content at all the tensions. With silt, a positive relation was obtained at all excepting 5 and 15 bars. A significant negative relation was obtained with fine sand but the negative relation with course sand was not significant. A lack of significant correlation with organic carbon content was observed. Available water followed a trend similar to the moisture percentage at 15 bars with clay giving significant positive relation and fine sand showing significant negative correlation.

Intercorrelations of field capacity, permanent wilting point and available water with organic carbon and textural separates indicated that the clay fraction was positively correlated with all the three parameters. Silt content had significant influence on field capacity

Table 6. Correlation coefficients of moisture percentages at different tensions and available water content of 2 mm sized soil with textural separates and organic carbon.

Soil moisture tension (bars)	Clay	Silt	Fine sand	Coarse sand	Organic carbon
0.3	0.8599**	0.3252*	-0.7332**	-0.0352	0.1839
1.0	0.[illegible]27**	0.3720*	-0.7540**	-0.0013	0.2492
3.0	0.8917**	0.3064*	-0.7732**	-0.0025	0.1804
5.0	0.8914**	0.2878	-0.7736**	-0.0066	0.1863
10.0	0.8836**	0.2959*	-0.7286**	-0.0610	0.1134
15.0	0.9023**	0.2807	-0.7499**	-0.0431	0.1124
Available water	0.3609*	0.2748	-0.3518*	-0.0016	0.2674

* Significant at 5 per cent level

** Significant at 1 per cent level

only. Fine sand was significantly and negatively correlated with all the variables studied except silt. Both field capacity and permanent wilting point influenced the percentage of available water but field capacity had the greater effect than the other. The organic carbon content had a significant positive relation with content of coarse sand while with fine sand, a significant but inverse relation was noticed (Table 7).

Prediction equations were developed to estimate the moisture retention at 0.3 and 15 bars from a knowledge of the contents of organic carbon and various size fractions. These equations are presented below. The analyses of variance are given in Appendices 2 and 3.

a) Moisture percentage at 0.3 bar (y_1)

$$y_1 = 1.9228 + 0.2920\ x_1 + 0.3171\ x_2 + 0.0020\ x_3 - 0.0186\ x_4 + 1.3930\ x_5\ (R^2 = 0.87).$$

b) Moisture percentage at 15 bars (y_2)

$$y_2 = 19.8026 + 0.0552\ x_1 + 0.0352\ x_2 - 0.1938\ x_3 - 0.2064\ x_4 + 0.1635\ x_5\ (R^2 = 0.90)$$

where

x_1 = clay per cent

x_2 = silt per cent

x_3 = fine sand per cent

x_4 = coarse sand per cent

x_5 = organic carbon per cent

Table 7. Matrix of intercorrelations of moisture contents at 0.3 and 15 bars and available water with textural separates and organic carbon.

	Moisture per cent at 0.3 bar	Moisture per cent at 15 bars	Available water	Clay	Silt	Fine sand	Coarse sand	Organic carbon
Moisture per cent at 0.3 bar	1.0000	0.9467**	0.6499**	0.8599**	0.3252*	-0.7332**	-0.0352	0.1839
Moisture per cent at 15 bars		1.0000	0.3802**	0.9023**	0.2807	-0.7498	-0.0431	0.1124
Available water			1.0000	0.3610*	0.2748	-0.3518*	-0.0018	0.2674
Clay				1.0000	-0.0114	-0.7817**	0.0153	0.0793
Silt					1.0000	-0.1948	-0.1064	0.1255
Fine sand						1.0000	-0.5758**	-0.3021*
Coarse sand							1.0000	0.3455*
Organic carbon								1.0000

* Significant at 5 per cent level

** Significant at 1 per cent level

Attempts made to work out a prediction model for available water content yielded an equation with low predictability ($R^2 = 0.25$) and hence is not presented here.

FOREST SOIL

1. Moisture retention by the profiles

1.1. Moisture retention by 2 mm sieved fraction

Data on the moisture retention at different tensions for the different series and their overall mean are given in Table 8.

As expected, increase in the applied pressures from 0.3 to 15 bars resulted in the decrease in retained moisture content. The retention was almost the same at the higher tensions, 10 and 15 bars. The different layers exhibited varying extraction rates at different tensions.

The moisture retention values showed considerable variation among the different profiles and at all the tensions studied, Sholayar series contained the lowest amount of moisture. The field capacity values ranged from 20 to 26.4 per cent, with the mean value of 24.8 per cent. Similarly, the values for permanent wilting point varied from 14 to 19 per cent, while the mean was 18.1 per cent.

Table 8. Moisture retention by 2 mm sieved soil (percentage by weight)

a) Sholayar series

Depth cm	Soil moisture tension (bars)						Available water
	0.3	1.0	3.0	5.0	10.0	15.0	
0 - 30	20.77	17.36	15.01	15.43	15.14	15.17	5.60
30 - 60	19.29	15.89	14.27	14.01	13.51	13.26	6.03
Mean	20.03	16.63	14.64	14.72	14.33	14.22	5.81

b) Periya series

Depth cm	Soil moisture tension (bars)						Available water
	0.3	1.0	3.0	5.0	10.0	15.0	
0 - 30	28.75	25.35	22.71	21.83	21.53	21.54	7.21
30 - 60	26.44	23.42	21.11	21.00	19.77	19.76	6.68
60 - 90	25.18	20.94	18.83	18.95	18.69	18.46	6.72
90 - 120	25.56	22.43	20.64	19.44	19.50	19.09	6.47
Mean	26.48	23.03	20.82	20.31	19.87	19.71	6.77

(Contd.)

Table 8 (Contd.)

c) Samkiri series

Depth cm	Soil moisture tension in bars						Available water
	0.3	1.0	3.0	5.0	10.0	15.0	
0 - 30	24.03	20.51	18.65	17.26	17.31	17.18	6.85
30 - 60	25.52	22.01	20.06	19.46	18.41	18.80	6.72
60 - 90	25.91	21.49	19.93	18.89	18.43	18.07	7.84
Mean	25.15	21.34	19.55	18.54	18.05	18.02	7.13

d) Overall mean moisture retention by the 2 mm sieved fractions at different tensions (percentage by weight)

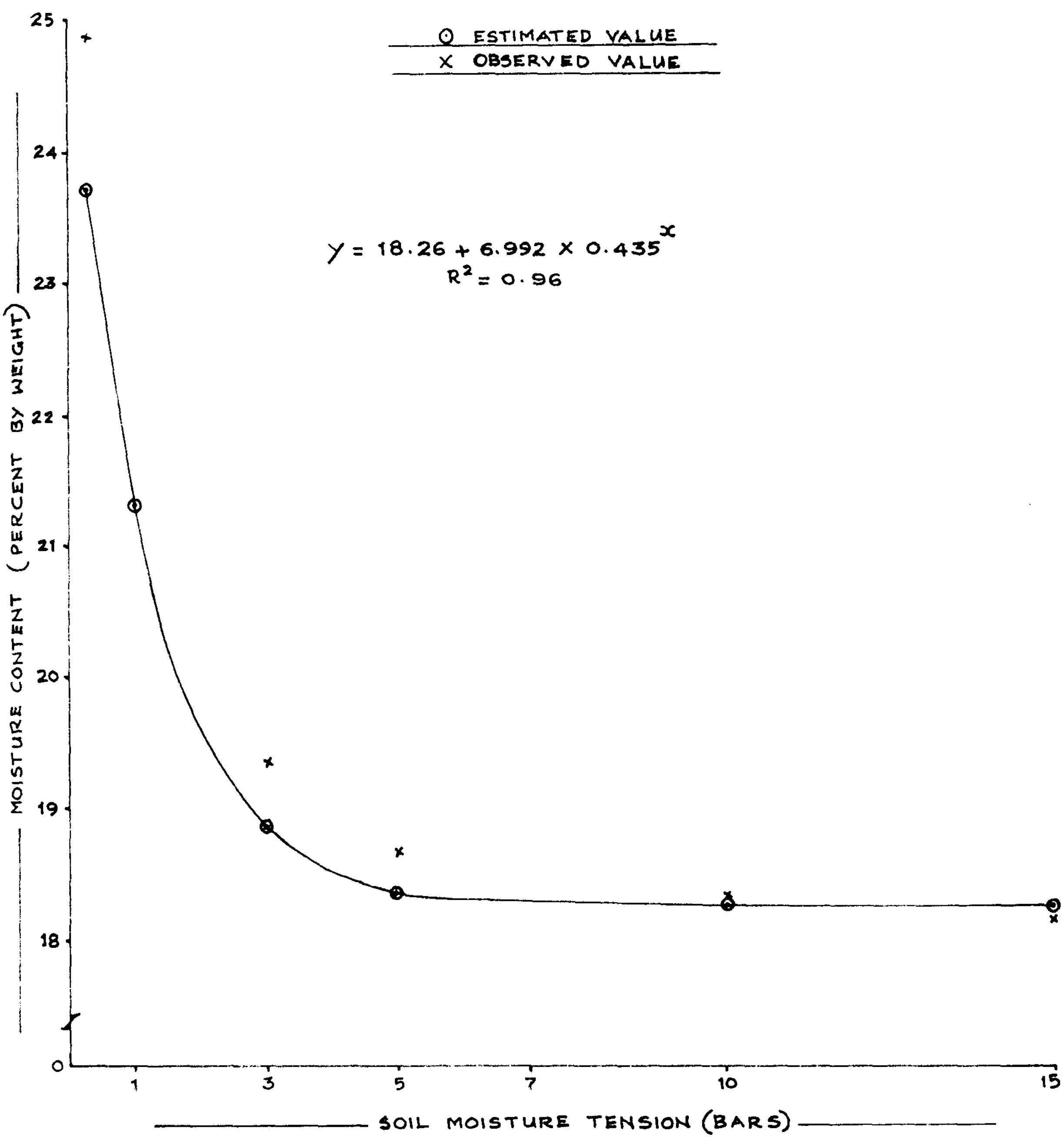
Depth cm	Soil moisture tension in bars						Available water
	0.3	1.0	3.0	5.0	10.0	15.0	
0 - 30	24.52	21.07	18.79	18.17	17.99	17.96	6.56
30 - 60	23.75	20.44	18.48	18.16	17.23	17.27	6.48
60 - 90	25.55	21.22	19.45	18.92	18.56	18.26	7.29
90 - 120	25.56	22.43	20.64	19.44	19.50	19.09	6.47
Mean	24.85	21.29	19.34	18.67	18.32	18.15	6.70

However, almost similar available water contents, close to the mean value of 6.7 per cent were shown by the different series.

As the tension increased from 0.3 to 1 bar, about 53 per cent of available water was released. A change in pressure from 1 to 3 bars removed 29 per cent of water and the extraction was 10 per cent when the applied pressure was raised from 3 to 5 bars. The proportion of available water depleted was as low as 5.2 per cent when the tension increased from 5 to 10 bars and 2.5 per cent as it reached 15 bars. Thus it was evident that the greater part of the total available water was removed when the tension was raised to 3 bars from field capacity. Of the various prediction models tested to define moisture characterisation, modified exponential curve described by the equation (1) was found to be the best fitting.

The overall mean values indicated an inconsistent increasing trend in moisture retention with depth. However, with Sholayar and Periya series, the reverse was found to be true. It is to be noted that the soil depths varied in the different profiles being upto 60 cm only in Sholayar series, 90-120 cm in the Periya series and 60 to 90 cm in Sankiri series. The overall mean values thus are from

Fig-2. MOISTURE CHARACTERISTIC CURVE FOR THE 2MM SIEVED FRACTION IN FOREST SOIL.



profiles upto 60 cm, 120 cm and 90 cm respectively. In none of the profiles, the soil was deeper than 120 cm.

1.2. Moisture retention by gravel

Results of the studies on moisture retention by gravel showed that it was substantially less than that of 2 mm sieved soil. Moisture retention by gravel was determined for 0.3 and 15 bars only (Table 9).

There was considerable variation among the different series in the values of mean retention by gravel, Periya series showing comparatively higher values. The overall mean retention at 0.3 and 15 bars were worked out to be 10.80 and 9.46 per cent, respectively.

Contrary to the expected pattern, some of the samples recorded higher moisture contents at permanent wilting point than field capacity, resulting in negative values for available water content. This feature was mainly shown by the samples of the 0-30 cm layer. The overall mean available water calculated from the entire samples was 1.34 per cent

2. Soil properties

2.1. Texture of the 2 mm sieved portion

The mechanical composition of the different profiles, averaged for the three profiles of a series

Table 9. Moisture retention by gravel (percentage by weight)

a) Sholayar series

Depth cm	0.3 bar	15.0 bars	Available water
0 - 30	8.02	8.85	-0.83
30 - 60	8.72	8.83	-0.11
Mean	8.37	8.84	-0.47

b) Periya series

Depth cm	0.3 bar	15.0 bars	Available water
0 - 30	11.03	11.22	-0.19
30 - 60	11.66	9.99	1.67
60 - 90	12.47	9.90	2.57
90 - 120	12.80	10.76	2.04
Mean	11.99	10.47	1.52

c) Sankiri series

Depth cm	0.3 bar	15.0 bars	Available water
0 - 30	8.38	8.26	0.12
30 - 60	9.64	8.56	1.08
60 - 90	10.03	7.08	2.95
Mean	9.35	7.97	1.38

d) Overall mean retention by gravel

Depth cm	0.3 bar	15.0 bars	Available water
0 - 30	9.14	9.44	-0.30
30 - 60	10.00	9.13	0.87
60 - 90	11.25	8.49	2.76
90 - 120	12.80	10.76	2.04
Mean	10.80	9.46	1.34

and their overall mean values are furnished in Table 10.

The main textural class of the soil was found to be clay. The mean clay content was as high as 44 per cent which closely agreed with that of Periya and Sankiri series. Compared to this, Sholayar series contained lesser amount of clay, but more of fine sand. In all the series, clay content indicated an increasing trend with depth while the sand fraction decreased. The clay and fine sand together constituted about 70 per cent of the total size fractions.

2.2. Particle size distribution including gravel

The particle size distribution including gravel was found out by incorporating the weights of gravel and sieved soil of each sample. These data are presented in Table 11.

The content of gravel averaged over the entire samples amounted to 29.88 per cent and the mean values for the different series were in the range from 26.79 to 28.54. But the gravel contents in general showed an increase with depth. Values as low as 5.5 per cent in the surface layer (Sholayar series) to as high as 51 per cent in the fourth layer (Periya series) were observed (Data not presented).

Table 10. Textural composition of 2 mm sieved soil (percentage)
a) Sholayar series

Depth cm	Clay	Silt	Fine sand	Coarse sand	Textural class
0 - 30	34.80	11.63	35.05	18.52	Sandy clay loam
30 - 60	36.60	13.27	35.08	15.05	Sandy clay
Mean	35.70	12.45	35.06	16.79	Sandy clay

b) Periyar series

Depth cm	Clay	Silt	Fine sand	Coarse sand	Textural class
0 - 30	35.86	23.63	26.73	13.78	Clay loam
30 - 60	41.88	22.33	25.40	10.39	Clay
60 - 90	44.90	14.54	26.52	14.04	Clay
90 - 120	50.34	17.16	22.73	9.77	Clay
Mean	43.24	19.42	25.35	11.99	Clay

(Contd.)

Table 10 (Contd.)

c) Sankiri series

Depth cm	Clay	Silt	Fine sand	Coarse sand	Textural class
0 - 30	36.83	11.81	30.63	20.73	Sandy clay
30 - 60	49.94	9.94	21.08	21.44	Clay
60 - 90	50.77	3.56	21.98	23.69	Sandy clay
Mean	45.05	8.44	24.56	21.95	Sandy clay

d) Overall mean textural composition

Depth cm	Clay	Silt	Fine sand	Coarse sand	Textural class
0 - 30	35.83	15.69	30.80	17.68	Sandy clay
30 - 60	42.00	15.18	27.19	15.63	Clay
60 - 90	47.84	9.05	24.25	18.86	Clay
90 - 120	50.34	17.16	22.73	9.77	Clay
Mean	44.00	14.27	26.24	15.49	Clay

Table 11. Particle size distribution including gravel (percentage)

a) Sholayar series

Depth cm	Clay	Silt	Fine sand	Coarse sand	Gravel
0 - 30	29.98	10.23	30.09	16.06	13.64
30 - 60	22.71	7.88	20.73	8.74	39.94
Mean	26.35	9.06	25.40	12.40	26.79

b) Periya series

Depth cm	Clay	Silt	Fine sand	Coarse sand	Gravel
0 - 30	27.89	18.65	21.63	10.53	21.30
30 - 60	31.08	15.54	18.34	7.74	27.30
60 - 90	31.49	10.38	19.35	10.18	28.60
90 - 120	31.72	10.77	14.73	5.83	36.95
Mean	30.54	13.84	18.51	8.57	28.54

Table 11 (Contd.)

c) Sankiri series

Depth cm	Clay	Silt	Fine sand	Coarse sand	Gravel
0 - 30	29.87	9.12	25.60	16.94	18.47
30 - 60	38.23	8.22	17.12	17.60	18.83
60 - 90	28.62	2.01	12.43	13.39	43.55
Mean	32.24	6.45	18.38	15.98	26.95

d) Overall mean particle size distribution including gravel

Depth cm	Clay	Silt	Fine sand	Coarse sand	Gravel
0 - 30	29.25	12.67	25.77	14.51	17.80
30 - 60	30.67	10.55	18.73	11.36	28.69
60 - 90	30.06	6.20	15.89	11.77	36.08
90 - 120	31.72	10.77	14.73	5.83	36.95
Mean	30.42	10.05	18.78	10.87	29.88

A comparison of the individual profiles indicated that conspicuous variation existed between the profiles within a series and also between the profiles from different series for the different layers with respect to percentages of size separates.

2.3. Organic carbon content

Data on the mean organic carbon contents of the different series and the overall mean values for the four layers are presented in Table 12.

The relation between organic carbon content and depth of the soil layers was inverse. The surface layers showed as high values as 2.72 per cent which decreased by more than half in the second layer. The content in the third layer was only about one-fourth of that of the top layer. The overall mean organic carbon content was estimated to be 1.35 per cent which differed considerably only in the Sholayar series. But this variation should be treated as incidental since the number of samples was less for this series.

Surface layers of the different profiles showed more or less similar organic carbon contents but there was greater variation for the other layers.

Table 12. Organic carbon contents of the different series (Percentage)

Depth cm	Sholayar series	Periya series	Sankiri series	Overall mean
0 - 30	2.41	3.02	2.74	2.72
30 - 60	1.22	1.27	1.09	1.19
60 - 90	-	0.79	0.47	0.63
90 - 120	-	0.84	-	0.84
Mean	1.82	1.48	1.43	1.35

Table 13. Bulk densities of the different series (g cc^{-1})

Depth cm	Sholayar series	Periya series	Sankiri series	Overall mean
0 - 30	1.26	1.14	1.25	1.22
30 - 60	1.24	1.20	1.39	1.28
60 - 90	-	1.24	1.53	1.39
90 - 120	-	1.33	-	1.33
Mean	1.25	1.23	1.39	1.31

2.4. Bulk density

From Table 13, it could be observed that the bulk density showed an increasing trend with depth. The bulk density was relatively low in the Periya series where the organic carbon content was higher. The overall mean was worked out to be 1.31 g cc^{-1}.

3. Moisture retention including gravel

3.1. Moisture retention and available water including gravel on weight basis

The moisture retention by gravel at 0.3 bar and 15 bars was separately found out for each sample. These values were then incorporated into the retention by the 2 mm sieved soil to estimate the retention including gravel at 0.3 and 15 bars. The available water was then calculated and these values are presented in Table 14.

Both at 0.3 bar and 15 bars, the moisture retention by the profiles showed a decreasing trend with depth, but it was not consistent. However, the overall mean values failed to show this trend due to the variation in the number of samples constituting the mean. As in the case of 2 mm sieved fraction, Sholayar series deviated from the mean values. The mean moisture retention calculated from the entire samples was 20.7 per cent at field capacity and 15.6 per cent at permanent wilting point.

Table 14. Moisture retention including gravel on weight basis for different series (percentage by weight) at 0.3 and 15 bars.

a) Sholayar series

Depth cm	0.3 bar	15 bars	Available water
0 - 30	19.02	14.27	4.75
30 - 60	15.21	11.68	3.53
Mean	17.12	12.98	4.14

b) Periya series

Depth cm	0.3 bar	15 bars	Available water
0 - 30	24.95	19.15	5.80
30 - 60	22.27	17.03	5.24
60 - 90	21.52	16.01	5.51
90 - 120	21.00	16.23	4.77
Mean	22.44	17.11	5.33

c) Sankiri series

Depth cm	0.3 bar	15 bars	Available water
0 - 30	20.98	15.46	5.52
30 - 60	22.47	16.78	5.69
60 - 90	18.98	13.28	5.70
Mean	20.81	15.17	5.64

d) Overall mean

Depth cm	0.3 bar	15 bars	Available water
0 - 30	21.65	16.29	5.36
30 - 60	19.98	15.16	4.82
60 - 90	20.25	14.65	5.60
90 -120	21.00	16.23	4.77
Mean	20.72	15.58	5.14

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The available water content also followed the same pattern as that of retention at 0.3 bar and 15 bars. Wide variation between the mean values for different series was absent and they closely approximated the overall mean value of 5.14 per cent.

3.2. Moisture retention and available water including gravel on volume basis

Data on the moisture retention and available water were obtained for each sample by multiplying the corresponding values on weight basis including retention by gravel by their respective bulk densities. The mean values for the different layers in each series and the overall mean retention values were then worked out (Table 15).

The mean values of field capacity for the three series ranged from 21.41 to 28.83 per cent while in the case of permanent wilting point, the range was from 16.23 to 20.99 per cent. The overall mean value in each case was 26.90 and 20.20 per cent, respectively. The mean available water content estimated as 6.70 per cent ranged from 5.20 to 7.80 per cent. More or less similar values were shown by the different layers except in the Sholayar series where the retention was low. The available water contents also were found to be higher in the layers having higher retention.

Table 15. Moisture retention including gravel on volume basis (percentage by volume) for different series at 0.3 and 15 bars.

a) Sholayar series

Depth cm	0.3 bar	15 bars	Available water
0 - 30	23.96	17.98	5.98
30 - 60	18.86	14.48	4.38
Mean	21.41	16.23	5.18

b) Periya series

Depth cm	0.3 bar	15 bars	Available water
0 - 30	26.44	21.83	6.61
30 - 60	26.72	20.44	6.28
60 - 90	26.68	19.85	6.83
90 - 120	27.93	21.59	6.34
Mean	27.44	20.93	6.52

c) Sankiri series

Depth cm	0.3 bar	15 bars	Available water
0 - 30	26.23	19.33	6.90
30 - 60	31.23	23.32	7.91
60 - 90	29.04	20.32	8.72
Mean	28.83	20.99	7.84

d) Overall mean

Depth cm	0.3 bar	15 bars	Available water
0 - 30	26.21	19.71	6.50
30 - 60	25.60	19.41	6.19
60 - 90	27.86	20.09	7.77
90 - 120	27.93	21.59	6.34
Mean	26.90	20.20	6.70

4. Correlation studies

4.1. Relation of water content of sieved soil on weight basis with organic carbon and texture

Correlation coefficients for the moisture percentages at different tensions with soil properties were worked out and these are presented in Table 16.

Clay content was found to be positively related to the moisture percentages at all the tensions. Highly significant correlation coefficients were obtained especially at the higher tensions. The relation with silt fraction was significant and positive. Fine sand showed high negative correlation but the negative effect shown by coarse sand was not significant. Organic carbon content failed to have any effect on moisture content at any of the six tensions studied.

Prediction models were developed to predict the moisture percentages at 0.3 and 15 bars and also the available water content with organic carbon and texture. Since the predictability of the equation for available water content was less than 50 per cent ($R^2 = 0.32$) only the equations for moisture contents at 0.3 bar and 15 bars are presented here.

a) Moisture percentage at 0.3 bar (y_1)

$$y_1 = 1154.219 - 11.1944\,x_1 - 11.1326\,x_2 - 11.6046\,x_3 - 11.3099\,x_4 + 1.3482\,x_5 \quad (R^2 = 0.85)$$

Table 16. Correlation coefficients of moisture percentages at different tensions and available water content of 2 mm sieved soil with textural separates and organic carbon.

Tension in bars	Clay	Silt	Fine sand	Coarse sand	Organic carbon
0.3	0.4547*	0.4255*	-0.8063**	-0.1153	0.1849
1	0.4755*	0.4563*	-0.8099**	-0.1805	0.2054
3	0.5375**	0.4028*	-0.8384**	-0.1718	0.1587
5	0.5543**	0.4161*	-0.8365**	-0.2171	0.1251
10	0.5190**	0.4229*	-0.8330**	-0.1752	0.1830
15	0.5120**	0.4215*	-0.8205**	-0.1798	0.2063
Available water	0.0058	0.2393	-0.3122	-0.1277	-0.0430

* Significant at 5 per cent level

** Significant at 1 per cent level

b) Moisture percentage at 15 bars (y_2)

$$y_2 = 586.984 - 5.5771\ x_1 - 5.5717\ x_2 - 5.9661\ x_3 - 5.7616\ x_4 + 1.4507\ x_5 \quad (R^2 = 0.91)$$

where

x_1 = clay per cent

x_2 = silt per cent

x_3 = fine sand per cent

x_4 = coarse sand per cent

x_5 = organic carbon per cent

The analyses of variance are given in Appendices 4 and 5.

4.2. Relation of water content on weight basis including gravel with organic carbon, sieved fractions and gravel.

Intercorrelations among textural separates including gravel, organic carbon and moisture retention at 0.3 and 15 bars and available water were worked out and are presented in Table 17. Both at 0.3 and 15 bars, moisture content was positively and significantly correlated with clay and silt. The gravel content indicated a significant negative correlation only at 0.3 bar. The negative influence of fine sand on moisture content at both tensions was not significant. Organic carbon also did not show significant influence on moisture retention.

Table 17. Matrix of intercorrelations of moisture content at 0.3 bar and 15 bars and available water with organic carbon and textural separates including gravel.

	Moisture per cent at 0.3 bar	Moisture per cent at 15 bars	Available water	Clay	Silt	Fine sand	Coarse sand	Gravel	Organic carbon
Moisture per cent at 0.3 bar	1.0000	0.9528**	0.6972**	0.5782**	0.5785**	-0.2151	0.1631	-0.4452*	0.3091
Moisture per cent at 15 bars		1.0000	0.4590*	0.5494**	0.5799**	-0.3504	0.1765	-0.3029	0.3506
Available water			1.0000	0.4470*	0.3339	0.1279	0.3857	-0.5850**	0.0398
Clay				1.0000	-0.0166	-0.0674	0.2803	-0.5663**	-0.1594
Silt					1.0000	0.1619	-0.2198	-0.3712	0.4430*
Fine sand						1.0000	0.2382	-0.6716	0.3166
Coarse sand							1.0000	-0.5534**	0.2514
Gravel								1.0000	-0.3490
Organic carbon									1.0000

Only clay and gravel contents were found to have any significant effect on available water. While the available water content was closely dependent on moisture content at 0.3 bar, the correlation coefficient obtained with moisture contents at 15 bars was significant only at five per cent level.

All the variables studied were found to be negatively influenced by gravel content.

Suitable regression equations with high predictability were arrived at for predicting moisture percentages at 0.3 bar and 15 bars using textural separates including gravel and organic carbon content. However, the predictability of the equation for available water content was low. The equations are presented below. The analyses of variance are given in Appendices 6 and 7.

a) Moisture percentage at 0.3 bar (y_1)

$$y_1 = -10.7186 + 0.4584\, x_1 + 0.5927\, x_2 + 0.0394\, x_3 + 0.3251\, x_4 + 0.2031\, x_5 + 0.7594\, x_6 \quad (R^2 = 0.84).$$

b) Moisture percentage at 15 bars (y_2)

$$y_2 = -27.780 + 0.5820\, x_1 + 0.6201\, x_2 + 0.1789\, x_3 + 0.3483\, x_4 + 0.3563\, x_5 + 1.1699\, x_6 \quad (R^2 = 0.93)$$

where

x_1 = silt per cent

x_2 = clay per cent

x_3 = fine sand per cent

x_4 = coarse sand per cent

x_5 = gravel content

x_6 = organic carbon content

Discussion

DISCUSSION

RED SOIL

Data on mechanical analysis revealed that the red soil was moderately fine textured, coming under the textural class, sandy clay loam. The different series showed uniform textural composition with the average contents of clay and sand being 24 per cent and 70 per cent, respectively. Only Cherniyoor series showed a slight deviation, where the texture was observed to be sandy clay with a mean clay content of 30 per cent. The content of silt was low in all the series. There was an increasing trend for the total fine fraction with depth, though it was not consistent.

The organic carbon content in general was low, to the tune of 0.26 per cent and values ranging from 0.19 to 0.34 per cent were observed for the different series. The organic carbon contents were found to decrease with increasing depth.

As could be expected from the more or less uniform texture, the variation in moisture retention was small between the different series. At all the six tensions studied, the retention was relatively low except in the Cherniyoor series where the values were comparatively higher.

It is to be noted that the clay content of this series was also generally higher. The low retention of red soil can be attributed to the relatively large proportion of sand (67-75 per cent). In such a soil group, the proportion of pores effectively retaining water between field capacity and permanent wilting point should be expected to be low. In addition to the content of fine fractions, the nature of the clay mineral also influences the moisture retention capacity. It has been reported that the predominant clay mineral in red soil is kaolinite though illite and montmorillonite also occur to some extent (Ali *et al.*, 1966; Biswas and Ali, 1967, Rajan and Rao, 1978). Among the groups of clay minerals, kaolinite has got the minimum ability to retain moisture.

The field capacity values ranged from 9.45 per cent to 11.74 per cent, with a mean value of 10.45 per cent. The range for permanent wilting point was from 6.5 to 8.42 per cent and the mean value was 7.21 per cent. The resultant mean available water content works out to 3.24 per cent (the difference between field capacity and permanent wilting percentage). The retention values obtained in the present study nearly tally with the figures reported for red soils of Kasaragod (Haridasan, 1978). The field capacity, wilting coefficient and available water content reported for these Kasaragod red soils are 9.1, 4.5 and 4.6 per cent, respectively, for the surface layer.

A comparison between the five layers revealed that moisture retention was lowest in the top 0-30 cm layer. The downward increase in moisture retention values is in agreement with the increase of finer fractions along the profiles.

An idea about the extraction pattern of available water at different tensions can be had from the graph representing the soil moisture-tension relationship (Fig.1). About 50 per cent of available water was depleted when the tension reached 1 bar, and the curve runs more or less parallel to the tension axis after 5 bars. This means that no pores are available of a size that can drain over the tension range concerned. It was inferred from the curve that for crops having the optimum permissible limit of depletion as 50 per cent, irrigation should be given as the tension reaches 1 bar.

The moisture percentages both at field capacity and permanent wilting point showed high positive correlation with clay (correlation values 0.85 and 0.90, respectively). The influence of clay on moisture retention at higher suctions is well substantiated by these correlation values. But the silt content showed significant positive influence only on moisture retention at 0.3 bars. Even in this case, the correlation coefficient values were low and significant only at 5 per cent level. Being a fine fraction, consistent, significant positive relation between moisture retention and silt content is to be normally expected. The reason for lack of it in this study is attributable to the very low content of this textural separate in the red soil. The overall mean silt percentage was only 3.96 as against the clay content of 24.08 per cent. Of the two sand fractions, highly significant negative relation was obtained with fine sand probably due to its higher amount as compared to coarse sand.

The available water content showed significant positive correlation with the content of clay fraction and negative relation with fine sand content. This expected relation is attributable to the influence of clay in increasing capillary porosity and that of sand in decreasing it. It is frequently reported that the textural fraction having highest degree of association with available water content is the silt (Abrol et al., 1968; Petersen et al., 1968). The extremely low silt percentage of red soil noted in the study will justify the lack of satistically significant correlation between available water content and percentage contents of silt.

The positive correlation obtained with organic carbon was not significant even at the five per cent level. Since organic colloidal fraction has got an important role in deciding moisture retention, a significant correlation was expected. The very low organic carbon content and the over riding influence of clay could be the possible explanations for this. Such results were noted and similar conclusions drawn by Thulasidharan (1983) and Prameela (1983) for the laterite and alluvial soils of Kerala, respectively. It is also to be noted that one of the major influences of organic carbon on water retention is through the improvement on structure (Jamison, 1956). Such an effect of organic matter, even if significant in this soil, cannot be apparent from the results of the study as it was done with disturbed soil whose structure was damaged in sample preparation for estimation. It is only through enhanced retention of adsorbed water that organic matter would have influenced the values of moisture retention and available water content and as the results show, the existing organic matter levels could not have significant impact through the content of adsorbed water.

Multiple regression analysis suggested that suitable equations could be used to predict the moisture retention at 0.3 bar and 15 bars on the basis of the contents of textural separates and organic carbon.

The multiple correlation coefficient values of 0.87 and 0.90 indicated high predictability which in turn shows that the differences in the quality of soil organic matter and fine fractions in the red soil are not substantial. The equations are as follows:

a) Moisture percentage at 0.3 bar (y_1)

$$y_1 = 1.9228 + 0.2920\ x_1 + 0.3171\ x_2 + 0.0020\ x_3 - 0.0186\ x_4 + 1.3930\ x_5 \quad (R^2 = 0.87)$$

b) Moisture percentage at 15 bars (y_2)

$$y_2 = 19.8026 + 0.05522\ x_1 + 0.0352\ x_2 - 0.1938\ x_3 - 0.2064\ x_4 + 0.1635\ x_5 \quad (R^2 = 0.90)$$

where

x_1 = clay per cent

x_2 = silt per cent

x_3 = fine sand per cent

x_4 = coarse sand per cent

x_5 = organic carbon per cent

Contrary to this, the prediction equation for available water content lacked the required high predictability. It is concluded that calculation of available water from the estimated values of these two soil moisture constants would be more reliable.

The values of field capacity, permanent wilting point and available water content on weight basis for the different series were converted to volume basis by multiplying with the respective bulk density values and these are presented in Table 5. As the data show, there were some variations in the values of field capacity (13.3 to 16.2 per cent) and wilting coefficient (9.1 to 11.6 per cent) on volume basis between samples. However, the range in available water contents was smaller being in the range from 4.1 to 5.0 only. The overall mean available water content worked out to be 4.58 per cent. In as much as there is no considerable variation between samples on the volumetric available water content, it may be reasonable to rely on the overall mean value of 4.58 per cent as a representative of red soils of Kerala. However, in cases where significant deviations in texture and organic matter content are expected, it may be worthwhile calculating the field capacity and wilting coefficient values using the prediction equations and thus arriving at the available water content. The indirect indications that the quality of fine fractions and organic matter does not appear to have a role in moisture retention will justify such reliance on percentage contents of textural separates and organic matter for calculating the soil moisture constants, field capacity and wilting coefficient.

It is to be noted that based on the earlier studies, Thulasidharan (1983) had suggested that the mean moisture retention values would be more valuable in the laterite soils than depending on prediction equations. For the alluvial soils of highly variable textural composition, Prameela (1983) had indicated higher dependability of values calculated from the prediction equation.

FOREST SOIL

The soil series selected for the study were located in Trivandrum, Trichur and Wynad districts. Soil samples were to be collected from five depths upto 150 cm but owing to the locationwise variation in the depth of the soil, the number of layers sampled differed among the three series. Hence the overall mean values of the soil properties may not represent the actual values, especially for the deeper layers.

The amount of moisture retained by the 2 mm sieved soil decreased as the tension increased from 0.3 bar to 15 bars but the values were similar at higher tensions. The moisture retention at low tensions is recognised to be a function of the pore geometry of the soil whereas at higher tensions, the dependance would be on the external surface area of the clay (Biswas and Ali, 1967). Once the pores retaining water are emptied out, what remains is the moisture adsorbed on the clay surfaces.

The forest soil was found to be clayey in texture with the clay content ranging from 35.7 to 45 per cent (Table 10). The lowest value was observed in the Sholayar series where the sand fraction was higher. Accordingly, the moisture retention values for this series tended to be lower than the others. The overall mean retention at 0.3 bar observed in the present study was 24.85 per cent and the values ranged from 20 to 25 per cent for the different series. The wilting coefficient values ranged from 14 to 19 per cent, the mean being 18 per cent. A comparison with standard values reported for the moisture retention of similar textural class (Israelsen and Hansen, 1962) would indicate that the field capacity values are too low, the reported range of standard values being 31 to 39 per cent with a mean of 35 per cent. The comparable standard values for wilting coefficient are 15, 19 and 17 per cent, respectively. One of the major factors affecting soil water retention especially at lower moisture tensions is the arrangement of particles. The fact that preparation of soil samples for determination of moisture retention using pressure plate apparatus results in total destruction of structure may partly explain the low retention values noted in this study. Another factor that decides moisture retention by a soil is its relative change usually measured as cation exchange capacity. The cation exchange capacity of forest soils is known to be relatively low as the predominant clay mineral is kaolinite (Thomas, 1967; Venugopal, 1969). This factor of charge of soil particles is reported to decide mainly its content of adsorbed water (Hillel, 1971). In as much as adsorbed water is a more important component of retained water at higher tensions say, around wilting coefficient rather than at field capacity, the involvement of charge of soil particles as a factor responsible for the low moisture retention appears to be small. It may be recalled that it is in field capacity that larger deviations in moisture retention from standard values are noted.

The fine fractions, clay and silt, showed significant positive influence on moisture retention at all the six tensions studied (Table 16). Similar values of correlation coefficients were obtained with silt but the effect of clay was more pronounced at higher tensions. The correlation with fine sand was, as expected, negative and significant. The depthwise increase in clay content did not bring in the expected increase in moisture retention. This could be regarded as due to the positive influence being masked by the greater negative effect of fine sand, the contents of which did not show a declining trend with depth.

The gradual moisture extraction pattern with increasing tensions featured by fine textured soils was lacking for forest soil. More than 50 per cent of the available water was removed as the tension reached one bar. The soil moisture characteristic curve showed a levelling off at 3 bars (Fig.2). It has been reported by Uehara and Gillman (1981) that many highly weathered clayey soils of the tropics have moisture release curves similar to sandy soils and most of the plant available water is removed by the time tension reaches 1 bar. The more or less same values of moisture retention at higher tensions and the increasing influence of clay on moisture percentages at increasing tensions as compared to that at lower tensions indicate the tendency of clay to retain water in an unavailable form.

Multiple regression equations to predict the moisture contents at 0.3 and 15 bars from the contents of organic carbon and textural separates of the 2 mm sieved soil are as follows:

a) Moisture percentage at 0.3 bar (y_1)

$$y_1 = 1154.219 - 11.1944\, x_1 - 11.1326\, x_2 - 11.6046\, x_3 - 11.3099\, x_4 + 1.3482\, x_5 \quad (R^2 = 0.85)$$

b) Moisture percentage at 15 bars (y_2)

$$y_2 = 586.984 - 5.5771\,x_1 - 5.5717\,x_2 - 5.9661\,x_3 - 5.7616\,x_4 + 1.4507\,x_5 \quad (R^2 = 0.91)$$

where,

x_1 = clay per cent

x_2 = silt per cent

x_3 = fine sand per cent

x_4 = coarse sand per cent

x_5 = organic carbon per cent

The coefficients of determination were high, indicating that these equations are reliable for the estimation of the two soil moisture constants.

The organic carbon contents of the soil series ranged from 1.43 to 1.82 per cent, with a mean value of 1.35. The surface layers showed values higher than this. Even then, the correlation coefficients worked out between moisture retention and organic carbon content were not statistically significant at any of the tensions. The lack of significance indicates that the influence exerted by organic carbon was being dominated by the overriding effects of clay and silt. Rajagopal (1967) working on Tamil Nadu soils observed that organic carbon content had no bearing on the soil moisture constants and moisture characters due to the predominant effect of clay on soil moisture retention. Similar results were obtained by Thulasidharan (1983) and Prameela (1983) in the case of laterite and alluvial soils of Kerala.

It was mentioned earlier that sampling could not be made beyond a particular depth in each series, as the layers became hard after. Thomas (1967) while working on the forest soils of Kerala observed laterite in the lower horizon of some of the profiles. In some other profiles, the subsoil was extremely hard due to the compaction caused by quartz grain and clay. The proportion of gravel observed was very high (20.3 to 45.0 per cent). Venugopal (1969) also reported that the deeper horizons of forest soils tend to be lateritic. The gravel contents of the different profiles in the present study ranged from 5.5 per cent to 51 per cent. Considering the abundance of gravel in many of the samples, study on moisture retention by gravel was also attempted. Moisture retentions at 0.3 and 15 bars were found out for the gravel fractions from the entire samples irrespective of the proportion of gravel in order to have a uniform treatment to all samples. The mean moisture retentions at 0.3 and 15 bars were 10.8 and 9.46 per cent, respectively. Thulasidharan (1983) reported similar values of moisture retention for the gravel contents of laterite soils of Kerala. He attributed this high retention values to the fact that laterite gravels are secondary formations and have pore spaces in them.

In Periya and Sankiri series, while the retention of gravel at 0.3 bar increased with depth, that at 15 bars decreased. This resulted in an increasing trend for the available water content with depth. The mean available water content of gravel was estimated to be 1.34 per cent. But some of the surface samples showed higher retention at 15 bars than at 0.3 bar, giving a negative value for available water. However, this should be treated as incidental because the surface samples which had been hardened by exposure have got practically little pore space to hold water in an available form. Compared to this, the more than 2 mm fraction in the deeper layers is constituted by the partially weathered soft parent materials.

Assuming that the soil in each layer in its natural condition is intermixed with gravel, the moisture retention including gravel at 0.3 and 15 bars was calculated for each sample. This was done using the values of retention by 2 mm sieved soil, its proportion, retention by gravel and its proportion. The textural composition of the 2 mm sieved soil was also recalculated in order to incorporate the gravel content also on a proportionate basis. The moisture retention values were evidently less than that of 2 mm sieved soil but the decrease in moisture retention at the two tensions was not uniform, there being a greater decrease at 0.3 bar. This is further substantiated by the correlation coefficient values which indicated the negative influence of gravel being nonsignificant on moisture retention at 15 bars. The available water content, which showed a greater dependance on moisture retention at 0.3 bar, also decreased accordingly. The overall mean available water content of the 2 mm sieved soil was decreased by 24 per cent, from 6.7 to 5.4 per cent, while the proportion of gravel was 28 per cent. This means that gravel causes a less than proportionate reduction in the moisture retention capacity.

Prediction equations were arrived at to estimate the moisture percentages at 0.3 and 15 bars and the available water content based on the contents of organic carbon and textural separates including gravel. As indicated by the close correlation of moisture retention to these variables, the predictability values were high for the equations for field capacity and permanent wilting percentage. The equations are presented below.

a) Moisture percentage at 0.3 bar (y_1)

$$y_1 = -10.7186 + 0.4584\, x_1 + 0.5927\, x_2 + 0.0394\, x_3 + 0.3251\, x_4 + 0.2031\, x_5 + 0.7594\, x_6$$

$(R^2 = 0.84)$

b) Moisture percentage at 15 bars (y_2)

$$y_2 = -27.780 + 0.5820\, x_1 + 0.6201\, x_2 + 0.1789\, x_3 + 0.3483\, x_4 + 0.3563\, x_5 + 1.1699\, x_6$$

$(R^2 = 0.93)$

where

x_1 = clay per cent

x_2 = silt per cent

x_3 = fine sand per cent

x_4 = coarse sand per cent

x_5 = gravel per cent

x_6 = organic carbon per cent

The overall mean retention values on volume basis presented in Table 15 (d) are not to be much relied upon as the average for all the forest soils of Kerala on both the mean moisture retention and bulk density values showed fluctuations in the different locations. So for arriving at the required soil moisture constants of a particular location, separate estimation of gravel per cent, contents of organic carbon and textural separates are to be made and moisture retention worked out using the prediction equations. Then the available water content can be calculated from these estimated values and converted to volume basis by multiplying with the bulk density.

Summary

SUMMARY

A laboratory study was conducted at the College of Horticulture, Vellanikkara, during the period from November 1983 to September 1984, to investigate the moisture retention characteristics of red and forest soils of Kerala. Soil samples were collected from three series each, representing Cannanore, Calicut and Trivandrum districts in the case of red soil and Wynad, Trichur and Trivandrum districts in the case of forest soil. Moisture retention of the 2 mm sieved soil was studied at six applied pressures, viz. 0.3, 1, 3, 5, 10 and 15 bars. Correlation coefficients were worked out between moisture retention and contents of textural separates and organic carbon and suitable prediction equations developed using multiple regression analysis. In the case of forest soil, where a preponderance of gravel was observed, moisture retention by gravel was also estimated at 0.3 and 15 bars and these values were incorporated into moisture retention by the 2 mm sieved soil to get the retention of the total soil including gravel.

The results obtained in the study are summarised below separately for each soil.

1. Red soil

i) The moisture retained by the soil decreased as the tension increased from 0.3 to 15 bars. About 50 per cent of the available water was removed when the tension reached 1 bar. The values for field capacity ranged from 9.4 to 11.7 per cent for the different series with a mean of 10.45 per cent. Similarly, the wilting coefficient values ranged from 6.5 to 8.4 per cent and the mean was 7.21 per cent. It was observed that the differences in the moisture retention capacities of the three series were not substantial.

ii) The predominant textural class was sandy clay loam except in the Cherniyoor series. The mean values for the different textural separates were 24.1, 4.0, 58.5 and 13.4 per cent for clay, silt, fine sand and coarse sand, respectively.

iii) The organic carbon content was in general low, the overall mean content being 0.26 per cent. A consistent decreasing trend with depth was observed in all the series.

iv) Moisture retention values estimated on weight basis at 0.3 and 15 bars were converted to volume basis by multiplying with the respective bulk densities. The overall mean available water of 4.6 per cent on volume basis was found to represent all the series, though variations were seen in field capacity and wilting coefficient values.

v) Correlation coefficients worked out between clay content and moisture retention at the six tensions were positive and significant. The silt content showed significant positive influence at all tensions except 5 and 15 bars. Of the two sand fractions, significant negative correlation was obtained with fine sand only.

vi) The lack of a significant correlation between organic carbon percentage and moisture retention was attributed to its low content and its influence being dominated by clay.

vii) Prediction equations with high predictability were developed to estimate the moisture retention at 0.3 and 15 bars from a knowledge of the contents of textural separates and organic carbon.

2. <u>Forest soil</u>

i) Study on the moisture retention characteristic revealed that 53 per cent of the available water was removed as the tension increased from 0.3 to 1 bar. When the tension reached 3 bars, more than 80 per cent of water was depleted. The field capacity and permanent wilting percentage of the 2 mm sieved soil showed considerable variation between the series, the mean values being 24.8 and 18.1 per cent, respectively.

ii) The overall mean clay content of the soil was 44 per cent, and the soil was considered clayey in texture. The contents of textural separates varied widely among the three series.

iii) The fine fractions, clay and silt, showed significant positive correlation with moisture retention at all the tensions. An increasing influence of clay at increasing tensions was observed. The relation with sand fraction was, as expected, negative.

iv) The organic carbon content, with an overall mean value of 1.35 per cent, was not found important in deciding moisture retention as indicated by the correlation being nonsignificant. The surface samples showed values ranging from 2.41 to 3.02 per cent.

v) Prediction equations were developed to predict the moisture retention at 0.3 and 15 bars of the 2 mm sieved soil based on the contents of textural constituents and organic carbon.

vi) The content of gravel averaged over the entire samples amounted to 29.88 per cent. The mean retention by gravel was found to be 10.8 and 9.46 per cent at 0.3 and 15 bars, respectively. The available water content amounted to 1.34 per cent which would come to a magnitude of 20 per cent of the available water in the sieved portion.

vii) The mean moisture retention of the samples including gravel on weight basis was 20.7 per cent at 0.3 bar and 15.6 per cent at 15 bars. On volume basis, the moisture content at field capacity was 26.90 per cent while that at permanent wilting point was 20.2 per cent. The available water content ranged from 5.2 to 7.8 per cent.

viii) Moisture retention including gravel on weight basis at 0.3 and 15 bars and the available water were positively and significantly correlated with clay and silt. The gravel content showed negative correlation with moisture retention which was significant only in the case of retention at 0.3 bar.

ix) Prediction equations worked out to estimate moisture retention at 0.3 and 15 bars including the retention by gravel showed high values of coefficients of determination. These prediction models were based on the contents of gravel, organic carbon and textural components.

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* Original not seen

Appendices

Appendix-1. Morphological descriptions of typifying pedon of each series.

a) Beypore series

Horizon	Depth (cm)	Description
Ap	0-36	Red (2.5 YR 3/4) sandy loam, dark reddish brown (2.5 YR 4/4) when dry; structureless, single grain; loose, nonsticky and nonplastic; few quartz gravels present; abundant fibrous roots; very rapid permeability; clear smooth boundary.
B_{21}	36-66	Dark red (2.5 YR 3/6) sandy loam; structureless single grain; loose, nonsticky and nonplastic; few quartz gravels present; plentiful roots; rapid permeability; gradual wavy boundary.
B_{22}	66-102	Red (2.5 YR 4/6) sandy loam, structureless massive loose, nonsticky and nonplastic; few quartz gravels present; plentiful roots; rapid permeability; diffuse boundary.
B_{23}	102-140+	Red (2.5 YR 4/6) loam; weak fine granular structure, friable, slightly sticky and non plastic; few roots, moderately rapid permeability.

Source: Office of the Assistant Director (Soil Survey), Calicut.

b) Kunhimangalam series

Horizon	Depth (cm)	Description
A_p	0-21	Yellowish red (5 YR 5/8) loamy sand, weak medium granular to sub angular blocky structure; loose, nonsticky and nonplastic; many fine roots; clear smooth boundary; moderate permeability.
A_3	21-67	Yellowish red (5 YR 5/8) sandy clay loam, yellowish red (5 YR 4/6) moist; moderate, medium, subangular blocky structure; slightly hard, friable, slightly sticky and slightly plastic; many fine roots; gradual smooth boundary; moderate permeability.
B_1	67-115	Yellowish red (5 YR 5/6) sandy clay, red (2.5 YR 4/6) moist; moderate, medium, subangular blocky structure; slightly hard, friable, slightly sticky and slightly plastic; few coarse roots; gradual smooth boundary; moderate permeability.
B_2	115-141+	Dark red (2.5 YR 3/6) sandy clay loam, moderate, medium, subangular blocky structure; friable, slightly sticky and slightly plastic; few coarse roots; moderately slow permeability.

Source: Office of the Assistant Director (Soil Survey), Cannanore.

c) Cherniyoor series

Horizon	Depth (cm)	Descriptions
Ap	0-16	Yellowish red (5 YR 4/6) sandy clay loam, dark red (2.5 YR 3/6) moist; weak, medium, subangular blocky structure; firm, slightly sticky and slightly plastic; plentiful fine to medium roots; clear smooth boundary; moderately rapid permeability.
B_{21}	16-37	Red (2.5 YR 4/6) sandy clay loam; moderate, coarse, sub angular blocky structure; firm, slightly sticky and slightly plastic; many medium to coarse roots; gradual smooth boundary; moderately rapid permeability.
B_{22}	37-65	Dark red (2.5 YR 3/6) sandy clay; moderate, coarse, subangular blocky structure; firm, slightly sticky and slightly plastic; many fine to medium roots; gradual smooth boundary; moderate permeability.
B_3	65-151+	Red (2.5 YR 4/8) sandy clay; moderate, coarse, subangular blocky structure; friable, slightly sticky and slightly plastic; few fine to coarse roots; moderate permeability.

Source: Office of the Assistant Director (Soil Survey), Trivandrum.

d) Sholayar series

Horizon	Depth (cm)	Description
Ap	0-13	Dark brown (7.5 YR 4/4) sandy loam; medium, moderate crumb structure; friable, slightly sticky and slightly plastic; plentiful fine and few coarse roots; rapid permeability; clear smooth boundary.
A_3	13-27	Dark brown (7.5 YR 4/4) sandy loam; medium, moderate sub-angular blocky structure; friable, sticky and plastic; few gravels, medium roots few; moderate permeability; clear wavy boundary.

Source: Office of the Asst. Director (Soil Survey), Trichur.

e) Periya series

Horizon	Depth (cm)	Description
O_1	0-2	Partly decayed leaves and litter.
A_2	2-6	Dark brown (7.5 YR 3/2) clay loam; crumb; friable, slightly sticky and slightly plastic; fine roots plenty, few gneissic gravels; clear smooth boundary, rapid permeability.
B_1	6-21	Dark reddish brown (5 YR 3/4) clay loam; medium, weak subangular blocky; friable, sticky and slightly plastic; fine roots plenty, gravel 21%, clear wavy boundary, moderate permeability.
B_2	21-42	Yellowish red (5 YR 4/6) clay; weak, medium subangular blocky; friable sticky and plastic, fine to medium roots plenty, gravel 27%, clear wavy boundary, moderately slow permeability.
B_3	42-90	Yellowish red (5 YR 4/6) clay; weak medium, subangular blocky; friable, sticky and plastic, few medium to fine roots, moderately slow permeability.

Source: Office of the Asst. Director (Soil Survey), Calicut.

f) Sankiri series

Horizon	Depth (cm)	Descriptions
A_1	0-11	Very dark brown (10 YR 2/2) sandy clay; medium, weak, crumb; friable, wet, slightly sticky and nonplastic; abundant fine roots; clear smooth boundary; moderately rapid permeability.
A_2	11-23	Dark brown (7.5 YR 3/2) sandy clay; medium, moderate sub angular blocky, friable, slightly sticky and nonplastic, few fine roots, few gravels, clear wavy boundary, moderately rapid permeability.
B_1	23-35	Dark brown (7.5 YR 4/4) clay, medium moderate subangular blocky, friable sticky and plastic, fine to medium roots few. Gradual wavy boundary, moderate permeability.
B_2	35-55	Reddish brown (5 YR 4/4) clay; medium, moderate subangular blocky, friable sticky and plastic; few medium to coarse roots; moderately slow permeability, gradual wavy boundary.
B_3	55-85	Yellowish red (5 YR 5/8) gravely clay, medium moderate, subangular blocky, friable sticky and plastic, few fine roots, gneissic gravel (43%), moderately slow permeability.

Source: Office of the Asst. Director (Soil Survey), Trivandrum.

Appendix 2. Analysis of variance for the multiple regression equation of moisture content at 0.3 bar, particle size distribution and organic carbon content.

Source	Sum of squares	df	Mean squares	F
Total	129.05	44		
Regression	112.53	5	22.51	53.59**
Deviation from regression	16.52	39	0.42	

** Signifiśant at 1 per cent level

Appendix 3. Analysis of variance for the multiple regression equation of moisture content at 15 bars, particle size distribution and organic carbon content.

Source	Sum of squares	df	Mean squares	F
Total	154.27	44		
Regression	138.84	5	27.77	69.43**
Deviation from regression	15.43	39	0.40	

** Significant at 1 per cent level

Appendix 4. Analysis of variance for the multiple regression equation of moisture content of the 2 mm sieved soil at 0.3 bar, particle size distribution and organic carbon content.

Source	Sum of squares	df	Mean squares	F
Total	366.28	24		
Regression	310.61	5	62.12	21.20**
Deviation from regression	55.67	19	2.93	

** Significant at 1 per cent level

Appendix 5. Analysis of variance for the multiple regression equation of moisture content of the 2 mm sieved soil at 15 bars, particle size distribution and organic carbon.

Source	Sum of squares	df	Mean squares	F
Total	288.72	24		
Regression	262.16	5	52.43	37.45**
Deviation from regression	26.56	19	1.40	

** Significant at 1 per cent level

Appendix 6. Analysis of variance for the multiple regression equation of moisture content at 0.3 bar including the retention by gravel, particle size distribution including gravel and organic carbon content.

Source	Sum of squares	df	Mean squares	F
Total	302.06	24		
Regression	252.82	6	42.14	15.38**
Deviation from regression	49.24	18	2.74	

** Significant at 1 per cent level

Appendix 7. Analysis of variance for the multiple regression equation of moisture content at 15 bars including the retention by gravel, particle size distribution including gravel and organic carbon content.

Source	Sum of squares	df	Mean squares	F
Total	200.92	24		
Regression	186.29	6	31.05	38.33**
Deviation from regression	14.63	18	0.81	

** Significant at 1 per cent level

MOISTURE RETENTION CHARACTERISTICS OF RED AND FOREST SOILS OF KERALA

BY

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ABSTRACT OF A THESIS

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ABSTRACT

The investigation was undertaken in the College of Horticulture, Vellanikkara, during the period from November 1983 to September 1984. Soil samples were collected from Cannanore, Calicut and Trivandrum districts for red soil and Trivandrum, Trichur and Wynad districts for forest soil. Moisture retention studies were done at six applied pressures, viz. 0.3, 1, 3, 5, 10 and 15 bars and these values were correlated with contents of textural separates and organic carbon using multiple regression analysis. The study revealed that moisture retention by 2 mm sieved soil was higher for forest soil than red soil at all the six tensions. The moisture contents on weight basis at 0.3 bar for the two soils were 24.85 and 10.45 per cent, respectively. The corresponding values at 15 bars were 18.15 and 7.21 per cent.

In both the soils, the contents of fine fraction (clay and silt) showed significant positive correlation with moisture retention while the correlation with fine sand was significant and negative. Organic carbon was found to have no bearing on moisture retention as indicated by the lack of significant correlation at any of the tensions studied.

The gravel fraction in the case of forest soil was found to retain moisture and the values at field capacity and permanent wilting point were 10.8 and 9.46 per cent, respectively. The moisture retention of the soil including gravel amounted to 26.90 per cent at field capacity and 20.2 per cent at permanent wilting point, on volume basis.

Prediction equations were developed to estimate the moisture retention at 0.3 and 15 bars of the 2 mm sieved soil from a knowledge of the contents of organic carbon and textural constituents. In the case of forest soil, another set of prediction models was also worked out to arrive at the moisture retention including gravel at these soil moisture constants.