STUDIES ON THE MOISTURE RETENTION CHARACTERISTICS OF LATERITE SOILS OF KERALA

BY

THULASIDHARAN, C. K.

THESIS

Submitted in partial fulfilment of the requirement for the Degree

Master of Science in Agriculture

Faculty of Agriculture
Kerala Agricultural University

Department of Agronomy
COLLEGE OF HORTICULTURE
Vellanikkara - Trichur
Kerala - India

1983

DECLARATION

I hereby declare that this thesis entitled "Studies on the moisture retention characteristics of laterite 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,
5 - 5 - 1983.

THULASIDHARAN, C.K.

Dr. R. VIKRAMAN NAIR,
Professor of Agronomy (KADP).

College of Horticulture,
Vellanikkara,
Dated: 5-5-1983

CERTIFICATE

Certified that this thesis entitled "Studies on the moisture retention characteristics of laterite soils of Kerala" is a record of research work done independently by Sri. THULASIDHARAN, C.K., under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

5/5/83

R. VIKRAMAN NAIR,
Chairman,
Advisory Committee.

CERTIFICATE

We, the undersigned, members of the Advisory Committee of Sri. Thulasidharan, C.K., a candidate for the degree of Master of Science in Agriculture with major in Agronomy, agree that the thesis entitled "Studies on the moisture retention characteristics of laterite soils of Kerala" may be submitted by Sri. Thulasidharan.C.K., in partial fulfilment of the requirement for the degree.

Chairman:

Dr. R. VIKRAMAN NAIR

Members:

Dr. E. TAJUDDIN

Dr. A.I. JOSE

Sri. P.V. PRABHAKARAN

Dr. V.K. VENUGOPAL

ACKNOWLEDGEMENTS

I wish to place on record my deep sense of gratitude and indebtedness to Dr. R. Vikraman Nair, Professor of Agronomy, College of Horticulture, Vellanikkara, Chairman of my Advisory Committee, for suggesting the problem, his masterly guidance, constant encouragement and sincere help throughout the course of this investigation and preparation of the thesis.

I am greatly thankful to Dr.E. Tajuddin, Professor of Agronomy, Communication Centre, Mannuthy; Dr. A.I.Jose, Professor and Head, Department of Soil Science and Agricultural Chemistry, College of Horticulture, Vellanikkara; Sri. P.V. Prabhakaran, Associate Professor, Department of Agricultural Statistics; Dr. V.K. Venugopal, Associate Professor, Soil Science and Agricultural Chemistry; members of the Advisory Committee and to Sri. T.P.George, Professor and Head, Department of Agricultural Engineering, College of Horticulture, Vellanikkara for their valuable advice and critical suggestions for the proper conduct of the research work.

It is my previlege to thank Dr. C.Sreedharan, Professor and Head, Department of Agronomy, College of Horticulture, Vellanikkara for his sustained interest and constant help during the study.

Sincere thanks are also due to Sri. P.K.Asokan, Dr. J.Thomas, Dr.P.V.Balachandran, Assistant Professors

(Agronomy), other staff members of the Department of Agronomy, and my friends and colleagues for their sincere help in the preparation of the manuscript. I would like to unveil my deep sense of gratitude to Sri. K. Valsaji, Assistant Soil Survey Officer, Bench Mark Survey, Trivandrum; Sri. A.K.Narayanan, Assistant Soil Survey Officer, Cannanore; Sri. S. Haridas, Assistant Soil Survey Officer, Calicut; Sri.N. Krishna Murthy, Assistant Soil Survey Officer, Trichur and other staff of the Soil Survey Unit of the Department of Agriculture for their valuable help and sincere co-operation during the survey and soil sample collection.

Thanks are also due to Dr. P.K.Gopalakrishnan, Associate Dean, College of Horticulture, and Dr. P.C. Sivaraman Nair, Director of Research, Kerala Agricultural University, for providing the necessary facilities for conducting the work.

My special thanks are to Sri. L.J. Martis, Personnel Manager, Institutional Training Section, Syndicate Bank for granting study leave for the completion of the course.

The award of the research fellowship by the Kerala Agricultural University is gratefully acknowledged.

THULASIDHARAN, C.K.

CONTENTS

LIST OF TABLES

FIGURE

1. Soil moisture characteristic curve for the 2 mm sieved fraction in laterite soil

Introduction

INTRODUCTION

A knowledge of the moisture retention properties of soil is important in deciding on the irrigation schedules of crops as it is the major aspect that contributes to the quantity of water that can be retained in the soil in a form that is available to plants. It is, however, very well established that there are difficulties in strictly quantifying the available water content in soil based on moisture characteristic studies. Yet, it forms the presently available basis for estimating the quantity of water that would be available to plants.

Many of the soil properties are known to influence the moisture retention, the most important being the content of organic colloids and texture. In the laterite soils with a distinct abundance of gravel, the content of this component also will have a strong bearing. Similar studies on moisture characterisation have been widely reported including many of the soils of India. Relating moisture retention with contents of organic matter and texture also has been attempted in several reported studies and mathematical models to predict moisture retention based on the above soil properties have been arrived at. Predictably, no two models are identical as, in addition to the particle size distribution, the quality of fine fractions, especially of the colloidal components will influence the quantity of water that can be retained.

The present study was taken up on similar lines to define the moisture retention pattern of laterite soils of Kerala which extend to about 60 per cent of the geographical area of the State. As had been indicated earlier, the laterite soils are distinct in that there is an over-riding predominance of gravel in them. Again, the gravel in laterite soils is considered to be secondary formations from clays and are likely to retain considerably more of moisture than the primary mineral particles of comparable size. As such, water retention by this component and its relative proportion also are to be taken into account while deciding on the total water retention by the profile.

In this study, samples of 15 soil profiles representing five typical series of five districts of the state were used. The districts were selected based on the relative extent of laterite soils in them. Separate samples were drawn at intervals of 30 cm from each profile upto a depth of 150 cm.

The broad objectives of the study are summarised below.

1. To study the moisture retention characteristics of laterite soils of Kerala at varying levels of matric potential.

2. To arrive at the degree of relationship of the moisture retention with gravel content, content of organic carbon and particle size distribution and to work out prediction models.

3. To work out available water content of laterite soils to aid in irrigation scheduling.

Review of Literature

REVIEW OF LITERATURE

A review of the work done on the retention and availability of soil moisture, the relation between moisture retention characteristics, texture and organic carbon content of soil is summarised below.

Concepts of soil moisture availability

One of the earliest investigations on the relation between soil moisture constants and availability of water to plants was made by Veihmeyer and Hendrickson (1934) who summarised their findings as follows:

"Our studies with grape vines, peach, apricot, apple and pear trees in field plots and containers and with sunflowers show there is no one percentage of moisture above the permanent wilting percentage at which plants grow better than at any other and which, therefore could be considered optimum for plant growth".

Contrary to this, Richards and Wadleigh (1952) summarised their interpretation of numerous experiments as follows:

"From the irrigation and soil moisture experiments, it is apparent that there is considerable evidence that significant differences in growth rates occur along with varying degrees of moisture range. Throughout the moisture depletion process the soil moisture stress increases continuously and such experimental evidence supports the hypothesis that the growth rate of various plants decreased markedly in the available moisture range and that vegetative growth is completely inhibited by the time the soil moisture is depleted to the permanent wilting range".

Kramer (1944), Veihmeyer and Hendrickson (1950) and Kelley (1954) investigated the problems of soil moisture in relation to plant growth and developed the concept known as available moisture. The lower limit of available water has been fixed as moisture at permanent wilting percentage or 15 atmosphere moisture and upper limit as field capacity or 1/3 atmosphere moisture.

Veihmeyer and Hendrickson (1927) had maintained over a number of years that water was equally available to plants between field capacity and permanent wilting percentage. But more detailed studies of soil water phenomena on physical grounds, tension and conductivity revealed that this view was untenable. The weight of the experimental evidences of Staple and Lehane (1941), Aiyers and Campbell (1951), Army and Kozluski (1951), Richards and Wadleigh (1952), Bernstein and Pearson (1954) and Kelley (1954) supported this view. The soil moisture content and the energy with which it is associated with the soil has been proved to be a continuous function by Childs (1940). The soil moisture constants when fitted into the moisture tension curves showed that they are only arbitrary points. Since they do not fit into the curve at any dividing point, their use was not supported by the modern theories of soil water relations. However they are useful from the agronomical stand point to convey some ideas which have come to carry a particular meaning by long usage.

Moisture retention in relation to texture

Studies by Wilcox (1939) conducted at Dominion Experiment Station showed a high correlation between per cent of silt plus clay and moisture holding capacity. Joachim and Kandiah (1947), while studying 33 Ceylon soils observed that a high correlation existed between clay content and water holding capacity. Jamison and Kroth (1958) studied the available moisture capacity in relation to texture in several Missouri soils. They showed that the available water capacity decreased with clay and increased with silt content. They also observed that coarse silt (0.05 to 0.02 mm) increased the available water capacity more than fine silt (0.02 to 0.002 mm).

Vigneron and Desaumettes (1960) obtained a good correlation between the moisture equivalent and texture, the correlation coefficient between the texture and the moisture equivalent was the highest when the structure was completely destroyed. Grohman and Medina (1962) indicated that the greater part of the soil moisture available to plants was held under a tension of less than 8 atmospheres and the moisture holding capacity depended largely on the clay content.

Investigations on the surface soil of major soil types of Natal sugar belts of South Africa showed that a high correlation exists between field capacity and wilting point moisture on the one hand and clay and silt plus clay content on the other (Maud, 1962). Israelsen and Hansen (1962) summarised some representative moisture retention properties of soils based on texture. According to them, for the textural class, clay loam the field capacity, wilting point and available water content on percentage dry weight basis range between 23-31, 11-15, and 12-16 respectively with the means of

27, 13 and 14. Longwell *et al.* (1963) working on the moisture characteristics of Tennesse soils concluded that as the clay content increased, the available water holding capacity decreased, but the decrease was not proportionate to the amount of clay. As the sand content increased, the moisture storage capacity decreased.

Salter and Williams (1965) discussed the available moisture capacities and moisture release characteristics of soils. Moisture contents at field capacity and at permanent wilting point increased as the soil became finer in texture, but the medium textured soils held the greatest volume of available water. Canarache (1965) observed high correlation between clay content and field capacity or available water capacity of soils studied. Modgal (1965) showed that a major portion of the available water is removed when the soil attains a tension of one atmosphere and water retentivity of the clay is the highest while that of sand is the lowest at a particular tension. Ali *et al.* (1966) presented soil moisture tension curves for a few typical soils of India and obtained highly significant and positive correlations between silt plus clay content and moisture percentages at 1/10, 1/3 and 15 atmospheres. A similar observation was reported in several studies for different soils (Subba Rao, 1960; Kandaswamy, 1961; Varkey, 1963; Velayudham, 1964; Rabindra, 1966; Rajagopal, 1967; Sekhon and Arora, 1967; Augustine Selvaseelan, 1970; Ramanathan, 1974 and Talati et al. 1975).

Abrol et al. (1968) considered that silt was the major factor contributing to the moisture held at 1/3 atmosphere in soil samples and profiles in semi arid region. Clay showed a significant positive correlation with water content at 15 atmosphere. There was a linear increase in the available water capacity with increasing silt plus clay content upto about 50 per cent. Beyond this or in samples containing more than 25 per cent clay, available water capacity tended to decrease.

Abrol and Bhumbla (1968) reported the moisture retention and storage characteristics of three profiles from the University Research Farm, Hissar. Available moisture calculated from the surface 120 cm was closely related to the silt fraction and the available water capacity increased with an increase in the silt plus clay content upto 50 per cent. The maximum available water capacity resulted when the silt content was more than 50 per cent of the total clay plus silt. The relationship between mechanical composition and available water capacity is shown by the regression equation, A.W.C. = 24.62 - 0.2081 (per cent clay) + 0.0417 (per cent silt) - 0.1748 (per cent fine sand)

It has been suggested that the particle size distribution can be conveniently used to predict the available water capacity of the soils.

Zawadski (1970) observed that the potential available moisture retention increased quickly to 35 per cent at 30 per cent silt plus clay and then decreased slowly to 15 per cent at 75 per cent silt plus clay.

Knisaari (1971) investigated the influence of texture on some soil moisture constants and observed that the clay content of the soil had a strong influence on the 15 atmosphere percentage even when the clay percentage was less than 20. The closest correlation between the available water capacity and the amount of clay was obtained when the clay percentage was less than 30. He got a close correlation between the available water capacity and the particle size fractions of 2 - 60 μ. A close negative correlation was also obtained between the content of 2 - 60 μ fractions and the amount of water retained at moisture tension between 0.3 and 1.3 bar. Pandhare et al. (1974) opined that the depletion of

50 per cent of available moisture occurred at less than 3 bars in certain soils.

Moisture retention values at 1/3 bar ranged from 14.1 to 17.5 per cent from 0 - 20 cm to 160 - 180 cm depth in Kharagpur profile while the range is from 16.0 to 31.1 per cent between layers of similar depth in Balampur profile (Prasad and Datta, 1975). According to them, the higher values of retention and the wider range is a function of the silt content. Pandhare et al. (1974) reported that as the clay content of the soil increased, there was an increase in soil moisture retention at different tensions and the clayey soils which had more than 60 per cent clay recorded soil moisture range greater than 10. A similar view was reported by Jovandic and Hakl (1977).

Velayudham and Raj (1977) found that progressive increase in clay content did not increase available range of water and they indicated the favourable effect of silt content. The 1/3 and 15 atmosphere moisture contents of the soils were positively correlated with the content of clay, clay plus silt and silt in the black alluvial soils of Karnataka and were negatively correlated with the sand content. This view was supported by Jadhav et al. (1977) on a few clay loams and sandy clay loams of Marathwada.

Olivin and Ochs (1978) observed that in soils containing at least 8 to 10 per cent of clay, the moisture contents corresponding to field capacity increased linearly with clay content; but the available water content decreased. For PF values between 4.2 and 4.6 (soil moisture tension between 15.54 and 39 bars) water retention was correlated with the proportion of the particles less than 0.02 mm while for the PF range 4.6 to 6.0 (soil moisture tension between 39 and 980 bars), the effect of particles less than 0.002 mm predominated (Moreno *et al.*, 1978). Haridasan (1978) presented the soil water characteristic curves of three laterite profiles from Kasaragod, Muttathody and Sullia. The water characteristic curves of sieved fractions indicated that 8 to 13 per cent (by weight) of water can be held in laterite profiles between 0.1 and 15 bars. Since these soils contained more than 50 per cent (by weight) of gravel throughout the profile, he concluded that the quantity of water that can be stored in the field will be only half this quantity (4 to 8 per cent by weight) and that such a correction for the presence of gravel in laterite soil is necessary in calculating the storage capacity of the profile in the field.

Riley (1979) presented regression equations that related easily available water (0.1 to 1.0 bar), strongly held available water (1.0 to 15 bar), and total available water (0.1 to 15 bar) to soil texture and values of R^2 ranged from 0.40 to 0.61, 0.65 to 0.78 and 0.76 to 0.88 for three categories of available water.

Mohsin and Syeedullah (1981) studied the influence of texture on the available moisture of 130 samples from 23 profiles of 11 major soils groups of Bihar. For soil texture ranging from sand to loams, silt loam had the highest range of available moisture whereas that ranging between sandy clay loam and clay, silty clay had the highest. Prediction equations relating the available moisture to textural separates had been developed for four textural classes.

The main conclusions from the above review on the relation between moisture retention and soil texture may be summarised as follows:

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

(ii) The relation between available water content and content of fine fractions 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 consistent positive correlation between the content of silt and available water content.

Moisture retention in relation to organic carbon

As early as 1959, Haalbach observed an increase in the wilting point values in artificially prepared horticultural soils with increasing amounts of organic matter. Salter and Williams (1963) studied the effect of farm yard manure on the moisture characteristics of a sandy loam soil. They concluded that annual applications of 20 tonnes farm yard manure $acre^{-1}$ for 7 to 8 years significantly increased the available water capacity of a sandy loam soil and the volume of water released at low tensions. On the other hand, Rajagopal (1967) working on Tamil Nadu soils observed that organic carbon content had no bearing on the moisture constants and moisture characters due to the predominant effect of clay on the soil moisture retention. Biswas and Ali (1967) found that influence of organic carbon on permanent wilting point was not significant in laterite and lateritic soils. The same authors (1969) reported that on black, alluvial, laterite and brownish soils that differed in their organic carbon content, available water and water retention at any particular suction were higher in soils of high organic carbon content. They also concluded that the effect of organic carbon was treater in coarse textured soils than in fine textured soils. Rid (1968), in his studies ploughed farm yard manure into two sandy soils at a depth of 50 cm. In the soil with 3 per cent clay, the layers provided with organic matter retained extra 5 per cent by volume of water but water content remained unchanged in the other soil layers and in the soil with 6 to 7 per cent clay. Similar results were reported by Kuntse (1968). Bertramson and Rhodes (1939) found that the organic matter had no influence on the moisture holding capacity of heavy soils of Nebraska.

Singh et al. (1976) investigated the moisture retention characteristics of lateritic soil as influenced by organic amendments. Their study revealed that the retained moisture was higher in soil amended by organic amendments than in control. They attributed the greater moisture retention by the amended soil to the organic carbon content.

A close relationship of organic matter content with moisture storage capacity, wilting point and available moisture was reported by Loyonet (1977). According to Hollis *et al.* (1977) large proportion of the variations in the available water and retained water capacities is due to the difference in the organic carbon content. Incubation experiments by Mello *et al.* (1979) showed that when castor bean meal was added at 20 to 100 tonnes hectare $^{-1}$, water retention capacities of four soils were increased.

Riley (1979) presented regression equations that relate easily available water (0.1 to 1.0 bar), strongly held available water (1.0 to 15 bar) and total available water (0.1 to 15 bar) to soil organic matter content.

The moisture retention characteristics of a terra rossa soil of Cyprus was studied by Orphanos and Stylianov (1980). The field capacity determined in the field was highest (33.9 per cent on soil dry weight basis) in the top 15 cm layer but was essentially uniform (30.4 to 31.4 per cent) in deeper layers. They correlated the higher field capacity values in the top 15 cm layer with the higher organic matter content. In a similar work on some selected tropical soils, Zusevic (1980) found that the permanent wilting percentages of eight light tropical soils from Venezuela were higher in samples with higher organic matter content.

Mohsin and Syeedullah (1981) studied the influence of organic carbon on the available moisture of 11 major soil groups of Bihar. Organic carbon and 1/10 and 1/3 bar percentages were positively correlated. According to them, the favourable effects of organic carbon on the available moisture is attributed to textural changes because organic carbon increased with fine sand (0.385) and silt (0.194) and decreased with clay (0.397).

To summarise the main conclusions from the review, it was generally observed that moisture retention and content of available water were positively correlated with the organic carbon content. However, there were also reports of a lack of such a relation presumably because the favourable effect of organic matter was masked by the dominant effect of the content of the fine fractions and also because the inherent difference in organic carbon content was associated with textural changes.

Materials and Methods

MATERIALS AND METHODS

The study was conducted in the College of Horticulture, Vellanikkara during the period from April 1981 to May 1982.

1. Soil

Five laterite soil series established by the soil survey unit of the Department of Agriculture were selected for the study. Three profiles from each soil series located in Cannanore, Calicut, Trichur, Kottayam and Trivandrum districts were collected. In Cannanore district, the series selected was Arathil located at Pariyaram, in Calicut district, Kunnamangalam series at Malapparamba, in Trichur district, Vellanikkara series at Vellanikkara, in Kottayam district, Arpukkara series at Gandhinagar and in Trivandrum district, Trivandrum series at Sreekaryam. Morphological descriptions of the typifying pedon of each series are given in Appendix 1.

2. Sampling procedure

Pits of 1.5 m depth were dug at the three different locations of each of the five series of laterite soil. 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 and these samples were used for moisture retention studies.

Bulk densities of the soil at different depths were found out using core samplers of 10 cm length and 4.4 cm diameter. The core samplers were hammered into the soil from the top of the pit vertically down after removing the top 5 cm soil layer of each depth.

The gravel percentage of each sample was determined separately by weighing the 2 mm sieved soil fraction and gravel, of the samples taken for bulk density determination after oven drying.

3. Moisture retention measurements

Moisture retention studies of the collected soil samples passing through a 2 mm sieve were made at 0.3, 1, 3, 5, 10 and 15 bar pressures using the pressure plate apparatus. For this, the samples were saturated overnight in rubber rings and placed in the pressure plate till they reached equilibrium with the applied pressure (24 to 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°C. One bar pressure plate was used to determine the field capacity and fifteen bar plate for the rest. Moisture retention studies were replicated thrice for each sample. The moisture retention of gravel from these samples was separately found out at 0.3 and 15 bar pressures by a procedure similar to that of soil. One sample of gravel from each sample was used for this purpose. The overall mean retention by gravel was then calculated. The moisture retention by the soil at 0.3 and 15 bars including the gravel was found out by incorporating the mean retention of gravel at 0.3 and 15 bars along with their proportionate contents in the soil. The moisture retention at 0.3 and 15 bars including gravel on volume basis was calculated by multiplying the values on weight basis including gravel with the bulk density of the sample.

4. Determination of available water

Available water of the soil samples was determined by finding the moisture held between 0.3 and

15 bar 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 from the water retention by the sieved soil, its proportion, the mean retention by gravel and its proportion. These retention values were then calculated on volume basis by multiplying the water retentions of these 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 and 15 bars on volume basis.

5. Particle size distribution analysis

International pipette method as proposed by Piper (1942) was used to find out the mechanical composition of 2 mm sieved soil fraction. 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

Organic carbon content of the 2 mm sieved soil samples was determined by Walkley and Black method (Jackson, 1958).

7. Statistical analysis

Multiple regression analysis as described by Snedecor and Cochran (1967) was conducted to correlate the organic carbon content and texture, with the moisture retention capacity of the sieved soils. Prediction models were developed to predict the field capacity and wilting coefficient of sieved fraction in laterite soils from a knowledge of values of organic carbon and texture. Moisture characteristic curve was arrived at for laterite soil from the mean moisture retention of all the samples. From the calculated values of water content including gravel on weight basis at 0.3 and 15 bars, correlation coefficients of water content at these tensions, contents of gravel, organic carbon and other soil fractions were separately worked out. Prediction equations for predicting the water contents at these tensions from these components were also arrived at.

Results

RESULTS

In this chapter, the results of the present study are given.

1. Moisture retention by profiles

1.1 Moisture retention by the 2 mm sieved soils

Data on the moisture retention values at six different tensions varying from 0.3 to 15 bars are presented in Table 1. The data show in general, a trend of decreasing moisture retention with increasing tension. The mean moisture percentage at field capacity was 25.2 and the mean values for the different series varied from 16.1 to 29.4. Similarly, the mean permanent wilting point was 19.4 and the range of mean values for the different series was from 11.6 to 23.6. On the other hand, the percentage of available water ranged between 4.5 and 7.8 with the mean value of 5.8.

A comparison between the series showed no consistent remarkable difference in the moisture retention but for the Arpukkara series in which the moisture retention was comparatively low at all tensions.

Table 1. Moisture retention by 2 mm sieved soil (percentage by weight)

a) Arathil series

Depth cm	Soil moisture tension (bars)						Available water
	0.3	1	3	5	10	15	
0 - 30	31.9	29.8	28.3	25.0	23.4	23.5	8.4
30 - 60	28.3	28.0	26.6	23.0	23.7	23.1	5.2
60 - 90	28.4	28.8	27.2	23.7	24.4	23.3	5.1
90 -120	28.8	29.3	27.4	25.0	25.5	24.7	4.1
120 -150	27.9	28.4	26.4	24.6	24.2	23.5	4.4
Mean	29.1	28.9	27.2	24.3	24.2	23.6	5.5

b) Kunnamangalam series

Depth cm	Soil moisture tension (bars)						Available water
	0.3	1	3	5	10	15	
0 - 30	29.6	28.3	25.6	22.9	21.8	20.7	8.9
30 - 60	30.9	28.9	27.4	25.6	23.8	23.3	7.6
60 - 90	29.6	27.8	26.4	24.3	22.9	22.2	7.4
90 -120	29.3	27.1	25.1	24.4	22.7	20.8	8.5
120 -150	27.3	26.1	23.1	22.2	21.1	20.7	6.6
Mean	29.4	27.7	25.5	23.9	22.5	21.6	7.8

24

c) Vellanikkara series

Depth cm	Soil moisture tension (bars)						Available water
	0.3	1	3	5	10	15	
0 - 30	17.9	16.8	15.0	14.2	13.5	13.2	4.7
30 - 60	20.8	19.9	19.1	18.6	17.5	17.1	3.7
60 - 90	25.5	24.1	22.5	22.1	20.3	20.6	4.9
90 -120	25.8	24.2	23.5	22.6	20.8	20.4	5.4
120 -150	26.3	24.4	23.2	23.3	21.2	21.2	5.1
Mean	23.2	21.9	20.7	20.2	18.7	18.5	4.7

d) Arpukkara series

Depth cm	Soil moisture tension (bars)						Available water
	0.3	1	3	5	10	15	
0 - 30	12.0	9.8	8.6	8.3	7.9	7.3	4.7
30 - 60	13.8	12.9	11.4	11.0	10.4	10.0	3.8
60 - 90	16.7	15.7	14.2	13.9	13.1	12.8	3.9
90 -120	15.6	15.0	13.7	13.3	12.2	11.7	3.9
120 -150	22.3	19.7	18.1	17.7	16.4	16.3	6.0
Mean	16.1	14.6	13.2	12.8	11.9	11.6	4.5

e) Trivandrum series

Depth cm	Soil moisture tension (bars)						Available water
	0.3	1	3	5	10	15	
0 - 30	25.4	23.1	20.7	19.7	18.5	19.4	6.0
30 - 60	28.5	27.4	25.2	24.4	23.3	21.9	6.6
60 - 90	27.7	26.4	24.9	24.2	23.0	21.6	6.1
90 -120	29.1	27.2	25.8	24.9	23.7	22.4	6.7
120 -150	29.7	27.9	26.8	25.9	24.9	23.1	6.6
Mean	28.1	26.4	24.7	23.8	22.7	21.7	6.4

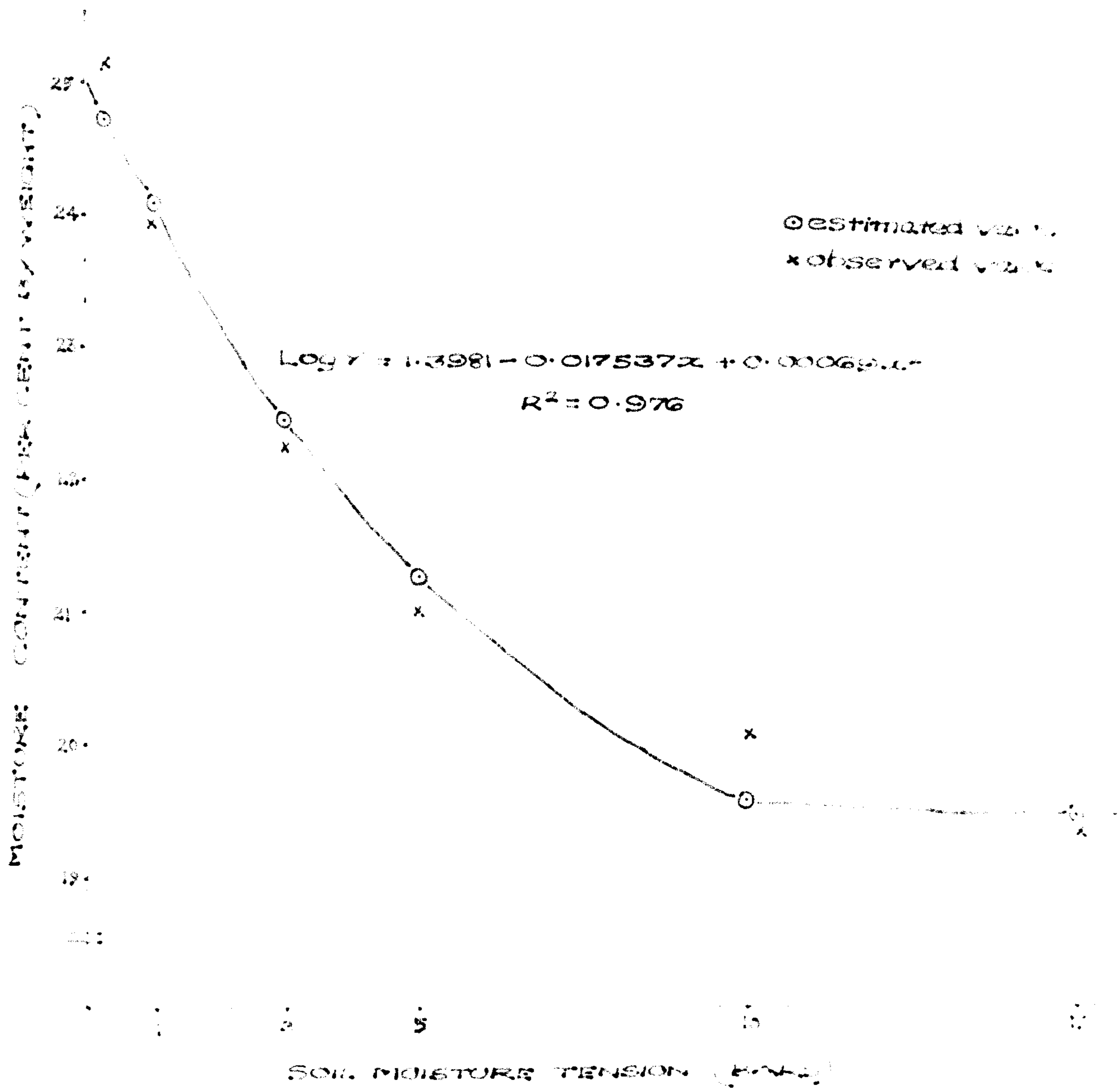
f) Overall mean moisture retention by the 2 mm sieved fractions at different tensions (percentage by weight)

Depth cm	Soil moisture tension (bars)						Available water
	0.3	1	3	5	10	15	
0 - 30	23.4	21.6	19.6	18.1	17.0	16.8	6.6
30 - 60	24.5	23.4	21.9	20.6	19.7	19.1	5.4
60 - 90	25.6	24.6	22.9	21.7	20.8	20.1	5.5
90 -120	25.7	24.6	23.1	22.0	20.9	20.0	5.7
120 -150	26.7	25.3	23.5	22.7	21.6	20.9	5.8
Mean	25.2	23.9	22.2	20.9	20.0	19.4	5.8

When the tension was increased from 0.3 bar to 1 bar, 22.15 per cent of the total available water was removed, while 28.55 per cent was removed when the tension was raised from 1 to 3 bars. Similarly, when the tension was increased from 3 to 5 bars, 20.76 per cent of the total available water was removed and 17.6 per cent of the same was depleted when the tension was changed from 5 to 10 bars. Only 10.8 per cent of the total available water was depleted when the tension was increased from 10 to 15 bars. Thus it can be observed that most of the available water was removed when the pressure reached 3 bars (50.7 per cent). An attempt was made to arrive at a suitable prediction model for moisture characterisation and of the several models tried, an exponential quadratic one was found to be the best fit for the sieved fraction (Fig.1).

A comparison of the moisture retention at different tensions with depth shows that there was a trend of progressive increase in the mean values of field capacity and permanent wilting point while the available water was more in the topmost layer of the profile. This trend was however not consistent.

FIG.1. MOISTURE CHARACTERISTIC CURVE FOR THE 2mm SIEVED FRACTION IN LATERITE SOIL



The trend was nearly the same in all the five series excepting Arathil series in which the reverse trend was noticed in the case of moisture retention especially at low tensions and in the case of percentage available water.

1.2 Moisture retention by gravel

Studies on the moisture retention by gravel were made at 0.3 and 15 bars only. The data for the five series are presented in Table 2a, b, c, d, e and overall mean in Table 2 f. The moisture contents at these tensions were much lower than those of fine fractions. Yet, there was a decrease in moisture retention with an increase in the tension. The overall mean moisture percentage at 0.3 bar was 8.8 while the mean values for the different series were between 6.1 and 12.9. Similarly, the mean moisture percentage at 15 bars ranged from 5.2 to 9.2 for the different series with an overall mean of 7.2. The mean available water content in the gravel varied between 0.7 per cent and 3.8 per cent for the different series with an overall mean of 1.6 per cent.

A comparison between the series showed no conspicuous difference in the moisture retention by gravel.

Table 2. Moisture retention by gravel (percentage by weight)

a) Arathil series

Depth cm	Soil moisture tension (bars)		Available water
	0.3	15	
0 - 30	8.8	8.2	0.6
30 - 60	8.7	6.7	2.0
60 - 90	7.3	5.9	1.4
90 -120	7.4	6.7	0.7
120 -150	10.5	9.3	1.2
Mean	8.5	7.4	1.1

b) Kunnamangalam series

Depth cm	Soil moisture tension (bars)		Available water
	0.3	15	
0 - 30	4.9	4.1	0.8
30 - 60	5.4	4.7	0.7
60 - 90	7.8	6.9	0.9
90 -120	7.9	6.4	1.5
120 -150	4.6	4.1	0.5
Mean	6.1	5.2	0.9

c) Vellanikkara series

Depth cm	Soil moisture tension (bars)		Available water
	0.3	15	
0 - 30	6.2	4.9	1.4
30 - 60	7.9	6.0	1.9
60 - 90	9.9	8.4	1.5
90 -120	9.7	8.6	1.1
120 -150	11.6	10.2	1.4
Mean	9.0	7.6	1.4

d) Arpukkara series

Depth cm	Soil moisture tension (bars)		Available water
	0.3	15	
0 - 30	6.4	5.9	0.5
30 - 60	6.5	5.7	0.8
60 - 90	8.1	7.8	0.3
90 -120	6.4	5.7	0.7
120 -150	8.2	6.8	1.4
Mean	7.1	6.4	0.7

e) Trivandrum series

Depth cm	Soil moisture tension (bars)		Available water
	0.3	15	
0 - 30	9.9	6.9	3.0
30 - 60	12.8	9.3	3.5
60 - 90	13.8	9.9	3.9
90 -120	11.1	8.6	2.5
120 -150	17.3	11.3	6.0
Mean	12.9	9.2	3.7

f) Overall mean retention by gravel

Depth cm	Soil moisture tension (bars)		Available water
	0.3	15	
0 - 30	7.3	5.9	1.4
30 - 60	8.3	6.5	1.8
60 - 90	9.4	7.8	1.6
90 -120	8.5	7.2	1.3
120 -150	10.4	8.4	2.0
Mean	8.8	7.2	1.6

An increase in mean retention at the two tensions, and in the percentage available water was observed with depth. However, a comparison with the mean values of the different series indicated wide variations in the trend and it may be concluded that the observed differences in the overall mean value were only incidental.

2. Soil properties

2.1 Organic carbon

Data on the organic carbon percentages of the five series and their overall mean contents are presented in Table 3.

The overall mean organic carbon content was 0.65 per cent while the mean values for the different series ranged between 0.55 and 0.95 per cent. The organic carbon percentage was the highest in the topmost layer of 0 to 30 cm in all the series and it decreased with depth. The overall mean organic carbon content of surface layer (0 to 30 cm) was 1.30 per cent which dropped to 0.33 per cent at the lowermost layer (120 to 150 cm). Though, in the carbon content of the lowest layer there was little difference between the

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

Depth cm	Arathil series	Kunnamangalam series	Vellanikkara series	Arpukkara series	Trivandrum series	Overall mean
0 - 30	2.30	1.06	1.05	0.79	1.28	1.30
30 - 60	1.14	0.73	0.55	0.60	0.45	0.69
60 - 90	0.58	0.58	0.48	0.50	0.38	0.50
90 -120	0.44	0.45	0.36	0.44	0.36	0.41
120 -150	0.31	0.33	0.33	0.34	0.35	0.33
Mean	0.95	0.63	0.55	0.55	0.56	0.65

series, that of the surface showed variation from 0.79 per cent in Trivandrum series to as much as 2.3 per cent in Arathil series.

2.2 a) Texture of 2 mm sieved fraction

The mechanical composition of the 2 mm sieved soil fraction of the different series and their overall mean are presented in Table 4.

The mean clay content of 2 mm sieved soil was 41.8 per cent while the mean values for the different series ranged between 31.9 and 53.1 percentages. Similarly, the mean silt contents for the different series varied from 8 per cent to 17.6 per cent with an overall mean of 12.5 per cent. Data on the fine sand contents showed that its mean content varied between 17.5 per cent and 31 per cent while the mean content was 23.6 per cent. As in other cases, the mean coarse sand content also showed variation and it ranged from 11.7 per cent to 28.9 per cent for the different series with its overall content as 22.1 per cent. The textural variations between the series were not conspicuous and consistent.

Table 4. Textural composition of the 2 mm sieved soil (percentage)

a) Arathil series

Depth cm	Clay	Silt	Fine sand	Coarse sand	Textural class
0 - 30	43.6	18.4	20.6	17.4	Clay loam
30 - 60	43.3	18.4	23.6	14.7	Clay loam
60 - 90	61.4	20.4	14.9	3.3	Clay
90 -120	54.5	16.9	13.1	15.5	Clay
120 -150	62.9	13.9	15.3	7.8	Clay
Mean	53.1	17.6	17.5	11.7	Clay

b) Kunnamangalam series

Depth cm	Clay	Silt	Fine sand	Coarse sand	Textural class
0 - 30	44.4	20.9	21.1	13.5	Clay
30 - 60	57.8	13.3	17.5	11.4	Clay
60 - 90	54.8	3.5	18.4	25.2	Clay
90 -120	50.7	8.3	19.9	21.1	Clay
120 -150	51.7	6.1	23.3	18.9	Clay
Mean	51.9	10.5	20.1	18.0	Clay

c) Vellanikkara series

Depth cm	Clay	Silt	Fine sand	Coarse sand	Textural class
0 - 30	39.4	14.0	22.0	24.6	Clay loam
30 - 60	43.5	10.0	16.4	30.1	Clay
60 - 90	40.6	14.2	20.6	24.7	Clay loam
90 -120	33.1	15.7	22.7	28.5	Clay loam
120 -150	43.3	11.6	17.6	27.6	Clay
Mean	39.9	13.1	19.9	27.1	Clay loam

d) Arpukkara series

Depth cm	Clay	Silt	Fine sand	Coarse sand	Textural class
0 - 30	17.3	7.5	37.0	38.2	Sandy loam
30 - 60	26.0	7.9	33.2	32.9	Sandy clay loam
60 - 90	34.7	11.9	28.7	24.8	Sandy clay loam
90 -120	34.6	7.6	32.2	25.6	Sandy clay loam
120 -150	47.2	5.3	24.1	23.4	Sandy clay
Mean	31.9	8.1	31.0	28.9	Sandy clay loam

e) Trivandrum series

Depth cm	Clay	Silt	Fine sand	Coarse sand	Textural class
0 - 30	42.1	12.6	28.1	17.2	Sandy clay
30 - 60	33.8	13.7	30.7	21.8	Sandy clay loam
60 - 90	27.8	14.5	29.1	28.6	Sandy clay loam
90 -120	21.6	15.4	28.8	34.1	Sandy clay loam
120 -150	36.2	10.5	30.1	23.2	Sandy clay loam
Mean	32.3	13.4	29.3	24.9	Sandy clay loam

f) Overall mean textural composition

Depth cm	Clay	Silt	Fine sand	Coarse sand	Textural class
0 - 30	37.4	14.7	25.8	22.1	Clay loam
30 - 60	40.9	12.7	24.3	22.2	Clay loam
60 - 90	43.8	12.9	22.3	21.3	Clay
90 -120	38.9	12.8	23.3	24.9	Clay loam
120 -150	48.3	9.5	22.1	20.2	Clay
Mean	41.8	12.5	23.6	22.1	Clay loam

A comparison of the contents of fine fractions (clay plus silt) in different series showed that the Arathil series contained the highest amount (70.7 per cent) with the Arpukkara series the lowest (40.02 per cent). The overall mean contents of fine fractions showed an increase in their contents with depth while there was no consistent trend of change with depth for the different series.

b) Particle size distribution including gravel

The particle size distribution including gravel was also found out by incorporating the weights of gravel and sieved soil of each sample. These data are presented in Table 5.

The contents of gravel varied from 40.8 to 83.4 per cent while the mean of all the series was 62.5 per cent. The Kunnamangalam series showed a comparatively higher content of gravel (78.3 per cent) while the reverse was true for Arpukkara series (53.2 per cent).

2.3 Bulk density

Data on the bulk density values for the different series together with their overall mean

Table 5. Particle size distribution including gravel (percentage)

a) Arathil series

Depth cm	Clay	Silt	Fine sand	Coarse sand	Gravel
0 - 30	18.6	7.8	8.6	6.9	57.9
30 - 60	19.2	8.1	10.9	6.9	54.9
60 - 90	17.2	6.5	4.5	0.9	70.8
90 -120	15.4	4.4	3.7	4.3	72.3
120 -150	16.9	3.4	4.1	2.1	73.5
Mean	17.5	6.0	6.4	4.3	65.9

b) Kunnamangalam series

Depth cm	Clay	Silt	Fine sand	Coarse sand	Gravel
0 - 30	10.5	4.9	5.1	3.3	76.1
30 - 60	11.3	3.4	3.5	2.1	79.7
60 - 90	9.3	0.6	3.0	3.9	83.4
90 -120	10.7	1.9	4.2	4.5	78.7
120 -150	13.6	1.6	6.1	4.9	73.7
Mean	11.1	2.5	4.4	3.8	78.3

c) Vellanikkara series

Depth cm	Clay	Silt	Fine sand	Coarse sand	Gravel
0 - 30	23.6	8.2	12.3	15.0	40.8
30 - 60	19.9	4.8	9.1	13.6	52.5
60 - 90	16.5	5.9	7.9	9.7	59.9
90 -120	16.7	8.7	11.6	12.3	50.9
120 -150	11.9	3.1	4.8	7.4	72.9
Mean	17.7	6.2	9.1	11.6	55.4

d) Arpukkara series

Depth cm	Clay	Silt	Fine sand	Coarse sand	Gravel
0 - 30	9.1	3.8	18.9	19.7	48.6
30 - 60	12.6	3.9	16.2	16.9	51.2
60 - 90	15.3	5.7	12.7	10.4	55.9
90 -120	15.9	3.6	14.8	11.6	54.1
120 -150	19.5	3.4	10.1	10.6	56.4
Mean	14.4	4.1	14.5	13.8	53.2

e) Trivandrum series

Depth cm	Clay	Silt	Fine sand	Coarse sand	Gravel
0 - 30	17.9	5.7	12.3	7.7	56.6
30 - 60	11.8	5.0	10.6	7.8	64.9
60 - 90	9.6	6.1	12.4	11.9	60.0
90 -120	10.3	7.1	13.9	18.1	51.9
120 -150	12.2	3.5	10.8	8.2	65.3
Mean	12.3	5.5	11.9	10.7	59.7

f) Overall mean particle size distribution including gravel

Depth cm	Clay	Silt	Fine sand	Coarse sand	Gravel
0 - 30	15.9	6.1	11.4	10.5	56.0
30 - 60	14.9	5.1	9.3	9.5	60.6
60 - 90	13.6	4.9	8.1	7.4	66.0
90 -120	13.8	5.2	9.6	10.2	61.6
120 -150	14.8	3.0	7.2	6.7	68.4
Mean	14.6	4.9	9.1	8.8	62.5

for the whole samples are presented in Table 6.

The highest mean bulk density of 1.89 g cc^{-1} was noted in the Kunnamangalam series where the gravel content was comparatively high. In all the others, it was in the range from 1.42 g cc^{-1} to 1.60 g cc^{-1}. The overall mean bulk density for the entire samples worked out to 1.5 g cc^{-1}. Lack of a consistent change in bulk density with depth was also observed.

3. Moisture retention including gravel

3.1 Moisture retention and available water including gravel on weight basis

The gravel fraction was separately run in the pressure plate apparatus and the mean retention of moisture at 0.3 and 15 bars was found out and the available water was also determined. Moisture retention at 0.3 and 15 bars and available water content of soil including the mean retention by gravel on weight basis were calculated from the overall mean retention by gravel and from individual values of gravel contents of samples. The data for the different series are presented in Table 7.

The mean content of available water was 3.1 per cent, with 14.4 per cent and 11.3 per cent as the

Table 6. Bulk densities of the different series (g cc^{-1})

Depth cm	Arathil series	Kunnamangalam series	Vellanikkara series	Arpukkara series	Trivandrum series	Overall mean
0 - 30	1.32	1.80	1.43	1.57	1.52	1.53
30 - 60	1.40	1.72	1.60	1.33	1.53	1.52
60 - 90	1.49	1.96	1.66	1.33	1.45	1.58
90 -120	1.52	1.83	1.74	1.40	1.47	1.59
120 -150	1.44	1.75	1.58	1.44	1.39	1.52
Mean	1.43	1.89	1.60	1.42	1.47	1.55

Table 7. Moisture retention including gravel on weight basis for different series (percentage by weight) at 0.3 and 15 bars

Depth cm	Arathil series			Kunnamangalam series			Vellanikkara series		
	0.3	15	Available water	0.3	15	Available water	0.3	15	Available water
0 - 30	18.4	13.9	4.5	13.8	10.4	3.4	14.2	10.8	3.4
30 - 60	17.5	14.1	3.4	13.3	10.6	2.7	14.1	11.4	2.7
60 - 90	14.3	11.7	2.6	12.3	9.7	2.6	15.3	12.2	3.1
90 -120	14.3	11.9	2.4	13.2	10.1	3.1	16.9	13.3	3.6
120 -150	13.9	11.4	2.5	13.6	10.7	2.9	13.6	11.0	2.6
Mean	15.7	12.6	3.1	13.2	10.3	2.9	14.8	11.7	3.1

(Contd.)

Table 7 (Contd.)

Depth cm	Arpukkara series			Trivandrum series			Overall mean		
	0.3	15	Available water	0.3	15	Available water	0.3	15	Available water
0 - 30	10.5	7.3	3.2	15.8	12.4	3.4	14.5	10.9	3.6
30 - 60	11.2	8.6	2.6	15.7	12.4	3.3	14.4	11.4	3.0
60 - 90	12.3	9.6	2.7	17.3	12.9	4.4	14.3	11.2	3.1
90 -120	11.9	9.2	2.7	18.0	13.9	4.1	14.8	11.7	3.1
120 -150	13.8	10.6	3.2	15.9	12.6	3.3	14.2	11.3	2.9
Mean	11.9	9.1	2.9	16.6	12.8	3.7	14.4	11.3	3.1

mean moisture retention at 0.3 and 15 bars, respectively. Though the available water content was comparatively higher in the top 0 to 30 cm layer of all the series excepting Trivandrum and Vellanikkara series, there was no consistent change in the moisture retention values with depth. The mean available water percentage ranged from 2.9 to 3.7 for the different series.

Similarly, the moisture retention at 0.3 and 15 bars also showed variations for the different series. This variation at 0.3 bar was between 11.9 per cent and 16.6 per cent while the same at 15 bars was between 9.1 per cent and 12.8 per cent for the different series.

3.2 Moisture retention and available water including gravel on volume basis

Moisture retention and available water on volume basis including the retention by gravel were found out by multiplying the corresponding values on weight basis including retention by gravel of the sample with the bulk density of each sample. Data on these are furnished in Table 8.

Table 8. Moisture retention including gravel on volume basis for different series (percentage by volume) at 0.3 and 15 bars

Depth cm	Arathil series			Kunnamangalam series			Vellanikkara series		
	0.3	15	Available water	0.3	15	Available water	0.3	15	Available water
0- 30	24.3	18.4	5.9	24.8	18.7	6.1	20.3	15.3	5.0
30 -60	24.4	19.8	4.6	22.8	18.2	4.6	22.6	18.3	4.3
60 -90	21.3	17.5	3.8	24.0	18.9	5.1	25.4	20.3	5.1
90-120	21.7	18.2	3.5	24.1	18.5	5.6	29.4	23.2	6.2
120-150	19.9	16.5	3.4	23.9	18.8	5.1	21.4	17.4	4.0
Mean	22.4	18.1	4.3	23.9	18.6	5.3	23.8	18.9	4.9

(Contd.)

Table 8 (Contd.)

Depth cm	Arpukkara series			Trivandrum series			Overall mean		
	0.3	15	Available water	0.3	15	Available water	0.3	15	Available water
0 - 30	16.4	11.4	5.0	24.1	18.8	5.3	22.3	16.6	5.7
30 - 60	14.9	11.4	3.5	24.0	19.0	5.0	21.8	17.4	4.4
60 - 90	16.3	12.8	3.5	24.8	18.5	6.3	22.6	17.7	4.9
90 -120	16.6	12.9	3.7	26.5	20.4	6.1	23.6	18.6	5.0
120 -150	19.9	15.3	4.6	22.2	17.5	4.7	21.5	17.2	4.3
Mean	16.8	12.8	4.0	24.3	18.8	5.5	22.4	17.5	4.9

The mean content of available water was 4.9 per cent, with 22.4 and 17.5 per cent as the mean moisture retention at 0.3 and 15 bars respectively. Though the available water content was comparatively higher in the top 0 to 30 cm layer of all the series excepting Trivandrum and Vellanikkara series, there was no consistent change in the moisture retention with the depth of the profiles. A comparison between the mean values of the different series showed variations ranging from 4 to 5.5 in the percentage of available water on volume basis. The moisture retention at 0.3 bar ranged from 16.8 per cent to 24.3 per cent while the same at 15 bars was between 12.8 per cent and 18.9 per cent.

4. Correlation studies

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

Results of the correlation studies of moisture percentages at different tensions of the 2 mm sieved fractions with organic carbon and texture are presented in Table 9.

The clay fraction showed significant positive correlation with the moisture contents at different

Table 9. Correlation coefficients of moisture percentages of 2 mm sieved soil at different tensions with organic carbon and textural fractions.

Tensions (bars)	Organic carbon	Clay	Silt	Fine sand	Coarse sand
0.3	0.1330	0.4316**	0.0178	-0.4615**	-0.4870**
1	0.1508	0.4740**	0.3530**	-0.4642**	-0.4952**
3	0.1247	0.4940**	0.1480	-0.4867**	-0.4659**
5	0.0005	0.4300**	0.2830**	-0.4688**	-0.3864**
10	0.0290	0.4380**	0.3370**	-0.3662**	-0.4200**
15	0.0394	0.5022**	0.3178**	-0.5531**	-0.4729**

** Significant at 1 per cent level

tensions and the same trend was shown by silt fraction excepting at 0.3 and 3 bars where the relationship was not significant. The coarse fractions, fine sand and coarse sand showed significant negative correlations with the moisture retention values at all the tensions. The correlations between the moisture retention values at different tensions and the organic carbon were not significant at any of the six tensions from 0.3 to 15 bars.

Prediction equations were developed to predict the moisture percentage at 0.3 and 15 bars from organic carbon content and texture of sieved fraction. 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)

$$Y_1 = -80.9088 + 0.7647\ x_1 + 1.1465\ x_2 + 1.2407\ x_3 + 0.8974\ x_4 + 0.9429\ x_5 \quad (R^2 = 0.38)$$

b) Moisture percentage at 15 bars (Y_2)

$$Y_2 = -12.9880 - 0.3575\ x_1 + 0.4033\ x_2 + 0.5214\ x_3 + 0.1344\ x_4 + 0.2714\ x_5 \quad (R^2 = 0.41)$$

where x_1 = Organic carbon per cent

x_2 = Clay per cent

x_3 = Silt per cent

x_4 = Fine sand per cent and

x_5 = Coarse sand per cent

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

Inter correlations among textural separates including gravel, organic carbon and moisture retention at 0.3 and 15 bars were worked out and are presented in Tables 10 and 11. The moisture percentages at 0.3 and 15 bars showed significant positive correlations with the fine fractions (clay and silt). The gravel showed significant negative correlations with the moisture content at both the tensions and the effects of coarse sand and fine sand were non-significant. Similarly, the influence of organic carbon was also non-significant at both the tensions.

All the components except the organic carbon showed significant negative correlations with the gravel content.

Prediction equations were developed to find out the moisture retention at 0.3 and 15 bars utilising the date of organic carbon and particle size separates

Table 10. Inter correlations of moisture content at 0.3 bar with organic carbon and textural separates including gravel.

	Moisture percentage at 0.3 bar	Organic carbon	Clay	Silt	Fine sand	Coarse sand	Gravel
Moisture percentage at 0.3 bar	1.0000	0.1579	0.3273**	0.6525**	0.1917	0.0874	-0.4321**
Organic carbon		1.0000	0.1202	0.1420	-0.0189	-0.0738	-0.0487
Clay			1.0000	0.4838**	0.1705	0.1022	-0.6219**
Silt				1.0000	0.0438**	0.3530**	-0.7203**
Fine sand					1.0000	0.7885**	-0.8249**
Coarse sand						1.0000	-0.7559**
Gravel							1.0000

** Significant at 1 per cent level

Table 11. Inter correlations of moisture content at 15 bars with organic carbon and textural separates including gravel.

	Moisture percentage at 15 bars	Organic carbon	Clay	Silt	Fine sand	Coarse sand	Gravel
Moisture percentage at 15 bars	1.0000	0.0910	0.4550**	0.5760**	0.0479	-0.0213	-0.3169**
Organic carbon		1.0000	0.1202	0.1420	-0.0189	-0.0738	-0.0487
Clay			1.0000	0.4838**	0.1705	0.1022	-0.6219**
Silt				1.0000	0.4838**	0.3530**	-0.7203**
Fine sand					1.0000	0.7885	-0.8249**
Coarse sand						1.0000	-0.7559**
Gravel							1.0000

** Significant at 1 per cent level

including gravel for laterite soil. These equations are given below. The analyses of variance are given in Appendices 4 and 5.

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 and

x_6 = Gravel per cent

5. Available water on volume basis for different depths

The quantity of available water on volume basis for varying depths and gravel contents have been worked out based on the mean available water content

Table 12. Calculated available water content on volume basis for different depths and gravel contents (cm)

Depth of soil cm	Gravel content (per cent)							
	10	20	30	40	50	60	70	80
30	2.49	2.30	2.10	1.91	1.71	1.52	1.32	1.13
60	4.99	4.66	4.21	3.82	3.43	3.04	2.65	2.26
90	7.48	6.98	6.31	5.72	5.14	4.55	3.97	3.38
120	9.97	9.31	8.41	7.63	6.85	6.07	5.29	4.51
150	12.46	11.64	10.52	9.54	8.57	7.59	6.62	5.64

and mean bulk density of 1.5 g cc^{-1}. These data are presented in Table 12. It would be observed from the Table that the available water contents on volume basis to a depth of 150 cm are 12.46 cm and 5.64 cm for soils having gravel contents 10 per cent and 80 per cent respectively.

Discussion

DISCUSSION

The results obtained in the study are discussed in this chapter.

The soils selected for the study included those from fifteen typical laterite profiles covering five districts of Kerala. Three profiles each from a soil series established in a district were utilised for the study. Samples were drawn from five depths at intervals of 30 cm from each profile. Moisture retention studies of 2 mm sieved fraction were carried out in triplicate at six tensions in each sample.

Data on the moisture retention values at different tensions from 0.3 to 15 bars are presented in Table 1. There was a general decreasing trend in the retention values with increasing tension. As expected, a progressive decrease in the quantity of water extracted with increasing applied pressures was noticed. There was little consistent difference between series or between depths in the profile in the extraction pattern. As such, the values were pooled and the overall mean values are presented (Table 1f). A prediction equation was also arrived at and a quadratic model between soil moisture tension and logarithm of moisture content was found to be the best fit. The graphical presentation is given in Fig. 1.

With the objective of predicting the gravimetric water content of the sieved fraction of the soil with the content of organic carbon and texture, correlation coefficients were worked out between water content at 0.3 and 15 bars and the content of organic carbon and textural constituents. Data presented in Table 9 indicate significant positive correlation between clay contents and moisture contents at both the tensions. In the case of silt, there was significant positive correlation at 15 bars only. The correlation between organic carbon and moisture retention was not significant and those of fine sand and coarse sand with retention were significant and negative. As the organic colloids contribute to moisture retention, significant positive correlation was expected with the organic carbon content. The lack of a significant correlation probably indicates that the total organic matter content of the soil tested was so low as to exert significant influence on retention and that it is being masked by the over riding effects of clay and silt. In the case of silt, statistical significance was noted only at 15 bars indicating again the dominant influence of clay at lower tensions.

One notable feature of the moisture retention by the soil under study was the relatively high water content at 15 bars. Based on mechanical analysis, the soil was grouped under the textural class, clay loam. The reported standard values for the gravimetric water content of this textural class for field capacity and wilting coefficient are in the range from 23 to 31 and 11 to 15 per cent and the overall mean retention, 27 and 13 per cent respectively. (Israelsen and Hansen, 1962). The retention values of the soils in the present study showed overall average values of 25.2 and 19.4 per cent at 0.3 and 15 bars respectively. It may, however, be noted that in a study involving laterite soils, Haridasan (1978) reported field capacity and wilting coefficient values comparable to those of the present study. Indications are that some properties of the laterite soil enable it to retain higher amounts of water especially at higher tensions.

As expected, the relation of fine sand and coarse sand fractions with moisture retention at these tensions was significant and negative.

Correlation coefficients were also worked out for water retention at all the tensions, the contents of organic carbon and the various size fractions of soils. The same trend as in the case of 0.3 and 15 bars was noted in these cases also, with the influence of clay being significant and positive at all the tensions. The influence of silt was significant at all the tensions excepting at 0.3 and 3 bars. An increasing influence of silt fraction in deciding the moisture retention at increasing tensions is again indicated.

Multiple regression equations to predict the moisture contents at 0.3 and 15 bars from the contents of organic carbon and textural constituents were worked out and these are as follows.

a) Moisture percentage at 0.3 bar (Y_1)

$$Y_1 = -80.9088 + 0.7647\, x_1 + 1.1465\, x_2 + 1.2407\, x_3 + 0.8974\, x_4 + 0.9429\, x_5 \quad (R^2 = 0.38)$$

b) Moisture percentage at 15 bars (Y_2)

$$Y_2 = -12.9880 - 0.3575\, x_1 + 0.4033\, x_2 + 0.5214\, x_3 + 0.1344\, x_4 + 0.2714\, x_5 \quad (R^2 = 0.41)$$

where x_1 = Organic carbon per cent

x_2 = Clay per cent

x_3 = Silt per cent

x_4 = Fine sand per cent and

x_5 = Coarse sand per cent

The coefficients of determination were 38 per cent and 41 per cent respectively, which were rather low for a physical measurement like water retention. The involvement of the differences in packing density on deciding moisture retention and the experimental error induced mainly by the smallness of samples can be attributed to the low predictability.

The available water content (difference in water content at 0.3 and 15 bars) calculated from the overall mean value of field capacity and wilting coefficient was 5.8 per cent on weight basis. This value also is low comparing with standard values for the textural class (12 to 16 per cent). The comparatively higher wilting coefficient values appear to be the reason for this. However the reported values for laterite soil (Haridasan, 1978) tally with the observed values.

Moisture retention by gravel

Laterite soils in general are characterised by a high content of gravel. The samples used for the present study also had high gravel content with mean values ranging from 53.2 per cent in Arpukkara series (Kottayam district) to 78.3 per cent to Kunnamangalam series (Calicut district). Though this fraction is sieved out and neglected in most of the moisture retention studies of soil, its retention and relative proportions were included in the present study taking into account its high proportion. The percentage of gravel was separately estimated on oven dry basis. From each sample of soil, one sample each of gravel was used to estimate the retention at 0.3 and 15 bars. The values ranged widely showing no consistent variation between series and with depths in the profile. Assuming that these variations arose mainly from the smallness of the sample used for estimation, the overall mean retention of all the samples was worked out. The values of mean retention at 0.3 and 15 bars by the gravel came to 8.7 per cent and 7.1 per cent respectively. A comparison with the retention values at corresponding tensions of the sieved fraction of soils would indicate that the retention by gravel is very low. In an earlier study by Haridasan (1978), similar results were obtained in laterite soils of Kasaragod, Kerala and based on the relatively low retention by gravel, it was suggested that retention by this component may be neglected (Haridasan, 1978). However, in the present study, taking into account the relatively large proportion of gravel, moisture retention by this component was also included on proportionate basis. It was found that in some soils in which the total gravel content was as much as 80 per cent, the retention by this component came to almost as much as that of the proportionate sieved fraction. Data on the moisture retention of soils including gravel are given in Table 7. As had been mentioned earlier, the mean water retention by gravel at 0.3 and 15 bars came to 8.7 per cent and 7.1 per cent respectively. Though these values are comparable to the reported values for the laterite soils of Kerala (Haridasan, 1978), these appear to be very high considering the relative surface area of particles more than 2 mm in size. The fact that laterite gravels are secondary formations and the probability that they may have pore spaces in them may explain these relatively high retention values.

Retention by soil including gravel

With the objective of finding out the relation of water retention at 0.3 and 15 bars with the contents of gravel, fine fractions and organic carbon, correlation coefficients were worked out (Tables 10 and 11). As would be evident from correlation coefficient values, percentage of gravel had significant negative influence in deciding moisture retention and the proportionate clay and silt contents had significant positive effects. The effect of organic carbon was non significant.

As mentioned earlier, for arriving at moisture retention including gravel, proportionate values of gravel and fine fraction were taken. Similarly, the values of gravel and fine fractions were also recalculated on proportionate basis.

Prediction equations to arrive at gravimetric water content of the soil including gravel at these two tensions were also worked out and the equations are given below.

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; and

x_6 = Gravel per cent

As in the case of gravimetric water content of sieved fractions, the predictability coefficients of these equations were also relatively low (49 and 41 per cent respectively). The reasons for this have been mentioned earlier.

The overall mean available water content on volume basis including gravel was found to be 4.86 per cent.

Available water content

One of the objectives of the study was to work out the available water content of the laterite soil on volume basis from measurements of bulk density, organic carbon and textural composition. For this purpose the bulk densities of all the samples were determined. The data presented in Table 6 indicate large fluctuations in the bulk density values presumably induced by the difference in the gravel content. Because of these wide variations, calculations of prediction equations between water content on volume basis and soil characters was not attempted. However, from the available data, such calculations were made and the overall mean values at 0.3 and 15 bars were found to be 22.3 and 17.5 per cent, respectively.

It is suggested that for arriving at available water content for scheduling irrigation, estimation of bulk density, gravel percentage, texture and organic carbon content may be done and the gravimetric water content determined from the prediction equations given. The available water content on volume basis may be separately worked out for each soil using the observed bulk density values.

While using prediction equations, the fact that the predictability is comparatively low may also have to be recognised.

Based on the overall mean values of the soil components and mean bulk density of 1.5 g/cc quantity of available water on volume basis for the different depths of soil were worked out. These are given in Table 12 to serve as a rough general guideline.

Summary

SUMMARY

A study was conducted at the College of Horticulture, Vellanikkara during the period from April 1981 to May 1982 to investigate the moisture retention characteristics of laterite soil of Kerala. Seventyfive soil samples were collected from fifteen profiles at five depths from different parts of Kerala covering Cannanore, Calicut, Trichur, Kottayam and Trivandrum districts. Moisture retention studies were done at six tensions, viz., 0.3, 1, 3, 5, 10 and 15 bars. The moisture retention characteristics were correlated with the organic carbon content and texture of the soil by multiple regression analysis. The results of the study are summarised below.

1. Moisture retention studies of the 2 mm sieved fractions indicate that most of the available water was removed at a tension less than 3 bars. More than 50 per cent depletion of available water occurred at this tension of three bars. There was no consistent change in the moisture retention values either series-wise or depth-wise at all the tensions.

The mean contents of moisture in sieved soil at 0.3 and 15 bars were 19.4 per cent and 25.2 per cent, respectively.

2. The organic carbon content of the surface layer showed variations from 0.79 per cent to 2.3 per cent between series. Organic carbon was found to have no bearing on the moisture retention indicated by its correlation being nonsignificant with moisture retention at all the tensions.

3. The content of clay showed significant positive correlation with the moisture content of the sieved fraction at all the tensions ranging from 0.3 bar to 15 bars. The effect of silt was significant and positive at tensions higher than 3 bars only.

4. Significant negative correlation was obtained between the contents of coarse fractions (fine and coarse sand) of the sieved soil and moisture retention at different tensions.

5. Prediction equations were developed to predict 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.

6. The content of gravel showed wide variations from 53.2 per cent in Arpukkara series to as high as 78.3 per cent in Kunnamangalam series. The overall mean content was 62.5 per cent.

7. The gravel fraction in the soil was also found to retain moisture amounting 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 available water in the sieved portion in which the available water was 5.8 per cent.

8. The mean moisture retention including gravel on weight basis was 14.4 per cent at 0.3 bar and 11.3 per cent at 15 bars. On volume basis, moisture content including gravel at field capacity was 22.3 per cent. The value corresponding to permanent wilting point on volume basis including retention by gravel was 17.5 per cent.

9. Moisture retention including gravel on weight basis showed significant positive correlations with the contents of fine fractions (clay and silt)

at 0.3 and 15 bars. The content of gravel was found to have significant negative influence on the moisture retention at these tensions.

10. Prediction equations were developed to arrive at the moisture retention at 0.3 and 15 bars including that of gravel from the knowledge of the contents of gravel, organic carbon and textural constituents.

11. A procedure for arriving at the available water content from the determinations of bulk density, contents of gravel, organic carbon and textural fractions is suggested.

12. Based on the overall mean values of the soil components and mean bulk density of 1.5 $g\ cc^{-1}$ quantity of available water on volume basis for the different depths of soil were worked out, to serve as a rough general guideline.

References

REFERENCES

Abrol, I.P., Khosla, B.K. and Bhumbla, D.R. (1968). Relationship of texture to some important soil moisture constants. *Geoderma*. *2*: 33-39.

Abrol, I.P. and Bhumbla, D.R. (1968). Moisture retention studies in soils of Hissar. *Proc. Symp. Water Management*: 9-18.

Aiyers, A.D. and Campbell, R.B. (1951). Freezing point of water in a soil as related to salt and moisture contents of the soil. *Soil Sci.* *72*: 201-206.

Ali, M.H., Chatterjee, R.K. and Biswas, T.D. (1966). Soil moisture tension relationships of some Indian soils. *J. Indian Soc. Soil Sci.* *14* (1): 51-63.

Army, T.J. and Kozluski, T.T. (1951). Availability of soil moisture for active absorption in drying soil. *Plant Physiol.* *26*: 353-361.

Augustine Selvaseelan (1970). *Clay mineralogy of red soils of Tamil Nadu*. M.Sc.(Ag) dissertation submitted to Tamil Nadu Agricultural University. pp. 88.

Bernstein, L. and Pearson, G.A. (1954). Influence of integrated moisture stress achieved by varying the osmotic pressure of culture solutions on the growth of tomato. Soil Sci. 77: 355-367.

Bertramson, B.R. and Rhodes, H.D. (1939). The effect of cropping and manure application on some physical properties of a heavy soil of Eastern Nebraska. Soil Sci.Soc. Amer.Proc. 3: 32-41.

Biswas, T.D. and Ali, M.H. (1967). Moisture retention studies in Indian soils. Indian J. agric.Sci. 37 (10): 322-331.

Biswas, T.D. and Ali, M.H. (1969). Retention and availability of soil water as influenced by organic carbon. Indian J. agric. Sci. 39 (6): 582-588.

*Canarache, A. (1965). The relationships between clay content and water capacity of soils. Anal. Inst. Cent. Cerc. agric. sect. Pedol. 32: 25-39.

Childs, E.C. (1940). The use of soil moisture characteristics in soil studies. Soil Sci. 50: 239-253.

Grohman, F. and Medina, H.P. (1962). Moisture characteristic of the main soil types of the State of Sao Paulo. Bragantia. 21: 289-295.

Haridasan, M. (1978). Soil water characteristic curves and hydraulic conductivity of some laterite and red sandy loam soils of Kasaragod area. Proc. Plantation Crops Symposium. 1: 179-186.

*Haslbach, J. (1959). The determination of wilting point of some kinds of horticultural soils. S. born vys Skol. Zemed. Lesn. Brne. 40 (A): 65-75.

Hollis, J.M., Jones, R.J.A. and Palmer, K.C. (1977). The effect of organic matter and particle size on the water retention properties of some soils in the west midlands of England. Geoderma. 17 (3): 225-238.

Israelsen, O.W. and Hansen, V.E. (1962). Irrigation principles and practices. Johnwiley and Sons, Inc. New York, London, Sydney, 3rd Ed.pp.412.

Jackson, M.L. (1958). Organic matter determinations for soils. In: Soil chemical analysis. Prentice Hall of India Private Limited, New Delhi, 2nd Ed. pp. 205-226.

Jadhav, G.S., Ingle, V.N., Varade, S.B. and Pawar, K.R. (1977). Moisture retention and available water capacity of Marathwada soils. J. Indian Soc. Soil Sci. 25 (4): 439-441.

Jamison, V.C. and Kroth, E.M. (1958). Available moisture storage capacity in relation to textural composition and organic matter content of several Missouri soils. Soil Sci. Soc. Amer. Proc. 22 (3): 189-192.

Joachim, A.W.R. and Kandiah, S. (1947). Studies on Ceylon soils XVII. The physical and physico chemical characteristic of the major soils types of Ceylon. Trop. Agriculturist. 103:71-84.

*Jovandic, P. and Hakl, Z. (1977). The dependance of retained and available water capacity on texture and humus content in pseudogleyed and lessive soils of Bosnia. Radovi Poljoprivrednog Fakulteta Univerziteta u Sarajevu.25 (28): 3-15.

Kandaswamy, P. (1961). Soil moisture constants in relation to physical properties of Madras soils. M.Sc. (Ag) dissertation submitted to Madras University. pp.104.

Kelley, W.D. (1954). Requirement and availability of soil water. Adv. Agron. 6: 67-94.

*Knisaari, S.(1971). The influence of texture on some soil moisture constants. Acta Agralia Fennica. 123: 217-222.

Kramer, P.J. (1944). Soil moisture in relation to plant growth. *Bot. Rev.* **10**: 525-559.

*Kuntze, H.(1968). Influence of organic matter on water regime characteristics in mineral soils. *Landw. Forsch.* **21**: 128-137.

Longwell, T. Jr., Parks, W.L. and Springer, M.E.(1963). Moisture characteristics of Tennesse soils. *Tenn. agric. Exp. Stn. Bull.* **367**: 46-47.

Loyonet, G.I. (1977). Interaction between water relations, organic matter and amorphous substances in soils on basaltic materials in a humid tropical climate. *Agronomie Tropicale.* **32** (2): 115-120.

*Maud, R.R.(1962). Soil moisture relationship of some Natal sugar belt soils. *Proc. 30th Congr. S. Afr. Sug. Tech. Ass*: 119-122.

*Mello, F.A.F., Silveira, R.I., Arzolla, S. and Hellmeister, S.R. (1978). Effects of organic matter on the moisture retention capacity of four soils of the Piraciaba, Brasil. *Luizde Queiroz.* **35**: 45-50.

Modgal, C. Suresh.(1965). Studies on moisture retention curves of soils. *Indian J. Agron.* **10** (4): 410-412.

Mohsin, M.A. and Syeedullah, M. (1981). Influence of texture and organic carbon on available moisture of soils. Rajendra Agricultural University Journal of Research. 3 (1): 1-12.

*Moreno, F., Martin, J. and Arrue, J.L. (1978). Relationships between texture and water retention in the pF range 4.2 - 6.0 in soils of western Andalusia. Anales de Edafologiay Agrobiologica. 37 (3): 335-344.

Olivin, J. and Ochs, R. (1978). The moisture properties of the soils and the moisture supply for perennial oil plants in West Africa. Oleagineux. 33 (1): 1-12.

Orphanos, P.I. and Stylianov, Y. (1980). The soil moisture characteristics of a terra rossa soil. Technical paper, Agricultural Research Institute, Cyprus. 19: 19-22.

Pandhare, A.V., Lakhdive, B.A. and Bathkal, B.G.(1974). Soil moisture retention in some soils of Vidharba. Indian J. Agron. 19 (2): 89-91.

Piper, C.S. (1942). Soil and plant analysis. Hans publishers, Bombay, 1st Ed. pp. 366.

Prasad, J. and Dutta, B. (1975). Study of moisture retention to available water capacity and porosity in lateritic soils. Indian Agric. 19 (1): 45-50.

Rabindra, B. (1966). The influence of amount and nature of clay on physical and moisture constants in the major grown soils of Mysore State. M.Sc.(Ag) dissertation submitted to the University of Madras. pp. 103.

Rajagopal, A. (1967). The relationship of soil water with soil moisture constants. Madras agric.J. 54 (9): 470-475.

Ramanathan, G. (1974). Studies on physico chemical properties of soils of Tamil Nadu in relation to clay mineralogy. Ph.D. thesis submitted to the Tamil Nadu Agricultural University.pp.250.

*Richards, L.A. and Wadleigh, C.H. (1952). Soil physical conditions and plant growth. Agronomy. 2: 73-251.

*Rid, H. (1968). The movement of water in sandy soils after ploughing at a depth of 50 cm. Publ. Int. Ass. Sci. Hydrol./UNESCO Symp. Waginengen. 83: 401-406.

*Riley, H.C.F. (1979). Relationship between soil moisture holding properties and soil texture, organic matter content and bulk density. Forskning og Forski i Landbruchet. 30 (4): 379-398.

Salter, P.J. and Williams, J.B. (1963). The effect of farm yard manure on the moisture characters of a sandy loam soil. J. Soil Sci. 14: 73-81.

Salter, P.J. and Williams, J.B. (1965). The influence of texture on the moisture characters. soils II. Available water capacity and moisture release characters. J. Soil Sci. 16: 310-317.

Sekhon, G.S. and Arora, H.S. (1967). Moisture retention characteristics of some Punjab soils and their relation with the physico-chemical properties. J. Res. Punjab agric. Univ. 4: 330-337.

Singh, K.D., Kar, S. and Varade, S.B. (1976). Structural and moisture retention characteristics of lateritic soil as influenced by organic amendments. J. Indian Soc. Soil Sci. 24 (2): 129-131.

Snedecor, G.W. and Cochran, W.G. (1967). Statistical methods. Oxford and IBH Publishing Co., New Delhi. 6th Ed. pp. 593.

Staple, W.J. and Lehane, J.J. (1941). The wilting coefficient studies in Southern Saskatchewan. Sci. Agr. 21: 440-447.

Subba Rao, K. (1960). pF water relation in typical Indian soils. J. Soil Sci. 87: 174-178.

Talati, N.R., Attri, S.C. and Mathur, S.K. (1975). Moisture studies and their relationships with some of the soil characteristics. J. Indian Soc. Soil. Sci. 23(1): 12-17.

Varkey, G. (1963). Study of physical and chemical properties and categorisation of certain South Indian red soils. M.Sc.(Ag) dissertation submitted to the University of Madras. pp.85.

*Veihmeyer, F.J. and Hendrickson, A.H. (1927). Soil moisture conditions in relation to plant growth. Plant Physiol. 2: 71-78.

*Veihmeyer, F.J. and Hendrickson, A.H. (1934). Soil moisture constants and availability of water to plants. Am. Soil Survey Assoc. Bull. 15: 76-80.

*Veihmeyer, F.J. and Hendrickson, A.H. (1950). Soil moisture relationships and plant growth. Ann. Rev. plant Physiol. 285-294.

Velayudham, M. (1964). Soil moisture constants in relation to chemical properties of Madras soils. M.Sc.(Ag) dissertation submitted to the University of Madras. pp. 97.

Velayudham, M. and Raj, D. (1977). Available water capacity and its relationship with some soil factors. J. Indian Soc. Soil Sci. 25 (4): 439-441.

*Vigneron, J. and Desaumettes, J.R. (1960). The relationship between some soil characteristics. Trans. 7th Int. Congr. Soil Sci. 1: 114-121.

Wilcox, J.C. (1939). Soil moisture studies. Some factors affecting soil moisture holding capacity and its determination. Soil Agri. 20: 140-149.

Zavadski, S. (1970). The influence of mechanical composition of soils on soil moisture retention. Polish Journal of Soil Science. 3 (1): 11-16.

Zusevic, J.A. (1980). Seasonal changes of permanent wilting point in some selected tropical soil. Communications in Soil Science and plant analysis. 11 (9): 843-850.

* Original not seen

Appendices

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

a) Arathil series

Horizon	Depth (cm)	Description
Ap	0 - 14	Yellowish red (5 YR 5/6) dry, dark reddish brown (5 YR 3/3) moist, gravelly loam, moderate, medium granular structure, hard, friable, slightly stickly, roots fine, abundant gravels, moderate permeability.
B_1	14 - 51	Dark red (2.5 YR 3/6) moist, gravelly loams, moderate, medium, granular structure, friable, slightly sticky and plastic, roots fine, plenty, permeability moderate, clean smooth boundary.
B_2	51 - 116	Red (3.5 YR 4/6) moist, gravelly, clay loam, structureless, firm, sticky and plastic, few fine roots, bolders of various sizes, moderate slow permeability, gradual smooth boundary.
C	116+	Plinthite

Source : Office of the Assistant Soil Survey Officer, Cannanore.

b) Kunnamangalam series

Horizon	Depth (cm)	Description
Ap	0 - 19	Reddish brown (5 YR 5/4) gravelly clay loam; 5 YR 4/4 when moist; weak, medium granular structure, slightly hard, friable, slightly sticky, plastic, roots abundant; moderate permeability, clear, smooth boundary.
B_1	19 - 80	Yellowish red (5 YR 5/6) when moist, weak, gravelly clay loam; moderate medium to coarse granular structure; slightly hard, friable, slightly sticky, and plastic, plentiful roots; iron concretions many; moderate permeability, clear wavy boundary.
B_2	80 - 115	Yellowish red (5 YR 5/8) when moist, gravelly clay; moderate medium subangular blocky structure; friable, sticky and plastic; few roots, iron concretions many, moderately slow permeability; diffuse boundary.
B_3	115 - 150	Strong brown (7.5 YR 5/8) when moist, gravelly clay, massive structure, slightly firm, sticky and plastic, roots absent; iron concretions comparatively less

		few yellow and brown mottlings present; moderately slow permeability; diffuse boundary.
C	150	Quarriable type of laterite

Source: Office of the Assistant Soil Survey Officer, Calicut.

C) Vellanikkara series

Horizon	Depth (cm)	Description
A_1	0 - 8	Reddish brown (5 YR 4/4) clay loam, medium, moderate, subangular blocky structures; firm, slightly sticky and slightly plastic, plentiful roots, minute quartz gravels present, clear, smooth boundary; moderate permeability.
B_{21}	8 - 23	Dark reddish grey (5 YR 4/2) clay loam, moderately medium, subangular, blocky structure, firm, slightly sticky and slightly plastic, plentiful roots, minute quartz gravels present, clear, smooth boundary, moderate permeability.
B_{22}	23 - 120$^+$	Yellowish red (5 YR 4/6) silty clay, strong coarse subangular blocky structure, firm, sticky and plastic, few fine roots, minute quartz gravels, moderate slow permeability.

Source: Office of the Assistant Soil Survey Officer, Trichur.

d) Arpukkara series

Horizon	Depth (cm)	Description
A_1	0 - 10	Dark, reddish brown (2.5 YR 3/4) moist, gravelly clay loam, weak medium crumb, very friable, slightly sticky, slightly plastic, roots plenty, clear smooth boundary.
B_1	10 - 25	Dark red (2.5 YR 3/6) moist, gravelly clay loam, weak fine subangular blocky, very friable, slightly sticky, slightly plastic, very few roots, gradual smooth boundary.
B_2	25 - 30	Red (2.5 YR 4/6) moist, gravelly clay, weak medium subangular blocky, friable, sticky, plastic, roots rich, abrupt irregular boundary.
C	50 - 100+	Quarriable type of hard laterite with dark red (7.5 YR 3/6) and reddish yellow (5 YR 6/8) mottling.

Source: Office of the Assistant Soil Survey Officer, Kottayam.

e) Trivandrum series

Horizon	Depth (cm)	Description
Ap	0 - 27	Yellowish red (5 YR 5/6); gravelly loam, medium, weak, granular, moist, very friable; wet, slightly sticky and nonplastic; roots abundant; few iron concretions, permeability moderate.
B_1	27 - 55	Yellowish red (5 YR 4/8); gravelly clay loam; medium, moderate, subangular blocky; moist, firm; wet, slightly sticky; roots abundant; permeability moderately slow.
B_2	55 - 105	Yellowish red (5 YR 5/8), gravelly clay; coarse, strong subangular blocky structure; moist firm, wet, sticky and plastic, few faint and pure yellow and red mottlings; permeability very slow.
C	105 - 125$^+$	Yellowish red (5 YR 5/8) gravelly clay; massive, moist, firm, vermicular laterite; roots nil, many coarse and prominent yellow and red mottlings; permeability very slow.

Source : Office of the Assistant Soil Survey Officer, Trivandrum.

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

Source	Sum of squares	df	Mean squares	F
Total	468.89	70		
Regression	234.14	6	39.02	10.64**
Error	234.76	64	3.66	

** Significant at 1 per cent level

Appendix 3. Analysis of variance for the multiple regression equation of moisture content of the 2 mm sieved soil at 15 bars, organic carbon content and particle size distribution.

Source	Sum of squares	df	Mean squares	F
Total	299.58	70		
Regression	124.14	6	20.69	7.69**
Error	175.44	64	2.74	

** Significant at 1 per cent level

Appendix 4. Analysis of variance for the multiple regression equation of moisture content at 0.3 bar including the retention by gravel, organic carbon content and particle size distribution including gravel.

Source	Sum of squares	df	Mean squares	F
Total	2507.58	70		
Regression	970.65	5	194.13	8.21**
Error	1536.93	65	23.64	

** Significant at 1 per cent level

Appendix 5. Analysis of variance for the multiple regression equation of moisture content at 15 bars including the retention by gravel, organic carbon content and particle size distribution including gravel.

Source	Sum of squares	df	Mean squares	F
Total	1869.50	70		
Regression	782.57	5	156.51	9.35**
Error	1086.93	65	16.72	

** Significant at 1 per cent level

STUDIES ON THE MOISTURE RETENTION CHARACTERISTICS OF LATERITE SOILS OF KERALA

BY

THULASIDHARAN, C. K.

ABSTRACT OF A THESIS

Submitted in partial fulfilment of the requirement for the Degree

Master of Science in Agriculture

Faculty of Agriculture
Kerala Agricultural University

Department of Agronomy
COLLEGE OF HORTICULTURE
Vellanikkara - Trichur
Kerala - India

1983

ABSTRACT

An experiment was conducted at the College of Horticulture during the period from April 1981 to May 1982 to study the moisture retention characteristics of the laterite soil of Kerala. Seventyfive soil samples were collected from fifteen profiles at five depths from different parts of Kerala covering Cannanore, Calicut, Trichur, Kottayam and Trivandrum districts. Moisture retention studies were done at six tensions, viz., 0.3, 1, 3, 5, 10 and 15 bars. The moisture retention characteristics were correlated with the organic carbon content and texture of the soil by multiple regression analysis.

The study revealed that more than 50 per cent depletion of the available water in the sieved soil occurred at less than 3 bars. The mean moisture content of sieved soil at 0.3 and 15 bars were 19.4 per cent and 25.2 per cent respectively. From the study it was also observed that the organic carbon had no significant bearing on the moisture retention characteristics of the soils studied. The content of fine fractions

was found to be the determining factor which had positive influence on moisture retention. On the contrary, the effect of coarse fractions (fine and coarse sand) was negative and significant.

The gravel fraction in the laterite was found to retain available water which came to the magnitude of 27 per cent of that in the sieved fraction. The content of gravel was having a strong negative influence with the moisture retention characteristics. The moisture contents at 0.3 and 15 bars including gravel were found to be 14.4 per cent and 11.3 per cent respectively on weight basis.

Prediction equations were developed to determine the moisture retention at 0.3 and 15 bars of the 2 mm sieved fractions and of the soil including gravel from the contents of organic carbon and gravel and particle size distribution.