

EFFECT OF SOIL MANAGEMENT ON SOME PHYSICAL PROPERTIES OF A RED YELLOW PODZOLIC TEA SOIL

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An evaluation of the effect of some selected soil management practices on the physical properties of tea soil showed that shortly after old seed-tea is uprooted in order to replace it with clonal tea the saturated infiltration rate, total pore space and percentage macropore space were relatively high (15 cm h⁻¹, 67.55 and 39.25 respectively). In soil that was left bare after such uprooting these soil physical properties had deteriorated. Growing grasses after uprooting old tea for the purpose of soil reconditioning increased organic carbon content, percentage macropore space and infiltration rate (6.70, 46.78, 21.6 cm h⁻¹) respectively. In soil that was under clonal tea for a period of about 17 years the bulk density was higher and the total and macropore volume were lower than in the soil from which seed-tea had been uprooted a few days before making the measurements. Available water capacity was higher in the soil under grasses and the soil under clonal tea than in the soil that remained bare after uprooting old tea. Available water capacity was linearly related to organic carbon content and curvilinearly related to total pore space. The relationship between infiltration rate and macropore space was exponential.

INTRODUCTION

The deterioration in soil physical properties under continuous cultivation of arable crops in both temperate and tropical soils is well documented (Page and Willard, 1946; Van Bavel and Schaller, 1950., Pereira *et al.*, 1954; Wilkinson and Aina, 1977; Le Mare, 1972). However, the soil under continuous cultivation with a perennial crop like tea is believed to be protected sufficiently by the crop canopy and surface litter derived from the large amounts of leaf fall (Visser, 1960) so that deterioration in soil physical properties and fertility is expected to be minimal. Such a belief is augmented by reviewers (Harris *et al.*, 1966) who concluded that grasses and perennial crops with extensive root systems, a continuous supply of readily decomposable organic matter and effective protective coverage improve physical properties such as soil aggregation. Nevertheless, the soil under tea may remain exposed to various degrees depending on the "jat" of tea and spacing used. There is, in addition, inevitable soil exposure for a period of four to six months once in two to four years when most of the canopy is removed by pruning. The nature of the terrain in which tea is grown in Sri Lanka, the system of planting of old seedling tea (up and down the slope), soil exposure and manual weed control by the use of scrapers have all resulted in loss of top soil due to erosion (Holland and Joachim, 1933; Hasselo and Sikurajapathy, 1965). Soil erosion leading to degradation in soil fertility has been reflected even in low rates of nutrient transformation (Sandanam *et al.*, 1978).

In commercial tea plantations many cultural practices such as forking, incorporation of green manures, mulching *etc.* are designed to improve the physical properties and fertility of the soil. In addition, when old tea is uprooted for re-planting with high yielding clonal tea the soil is reconditioned by growing a grass for a period of at least 18 months. Some cultural practices have been reported to reduce soil compaction (Eden, 1940) and soil reconditioning with grasses has been

shown to increase water stable aggregates (Tolhurst, 1959) and to increase yield in soils with low organic matter content (Sandanam *et al.*, 1976), but no detailed information is available on the effects of management practices on soil physical properties. The present investigation was therefore undertaken to examine the changes in physical properties brought about in a tea soil under some selected management practices.

MATERIALS AND METHODS

Sites and soil management

The investigation was conducted in tea fields adjacent to the laboratories of the Tea Research Institute of Sri Lanka (1500 metres above mean sea level). Some important characteristics of the soil and details of type of soil management are given in Table 1. Treatment A (Bare plot) was in an area which was left exposed for about three years without any ground cover, the weeds being manually removed. It was forked, (an operation where a digging fork, with three tines each 30 cm long, is driven into the soil and the fork levered forward without turning over) at a spacing of about 30 cm about three months prior to making the measurements. Treatment B was in a field which carried seedling tea for about sixty years; the old tea was uprooted, the soil was reconditioned with Guatemala grass (*Tripsacum laxum*) and planted with clonal tea in 1961. In 1978 the tea was pruned for the fourth time about six weeks before making the measurements. In this treatment the leaf litter on the surface had been washed away after pruning, soil erosion had taken place and feeder roots were visible on the soil surface. Treatment C was in a plot with same history as B but where the leaf litter (about 3 cm thick) had remained *in situ*. Soil under treatment D has carried seedling tea for about 70 years. The tea was uprooted and the soil thoroughly disturbed to remove tea roots about three weeks before making the measurements. Soil under treatment E carried seedling tea for about 65 years. The tea was uprooted, and the soil kept under Mana grass (*Cymbopogon confertiflorus*) for two years for soil reconditioning. Soil in treatment F had the same history as E but had been under Guatemala grass for two years.

Soil physical properties studied and the techniques employed

Infiltration rate was measured with double ring cylinder infiltrometers (diameter 30.5 cm) according to the method outlined by Haise *et al.*, (1956). Three measurements were taken at each site. Other physical properties were determined with soil at 0-15 cm depth. Water retention characteristics were estimated with core samples (diameter 5.35 cm and height 6.0 cm). Water retention at 1/3 to 15 bar suctions was estimated using a pressure plate apparatus and that at suctions lower than 1/3 bar estimated using hanging water column. Bulk density was determined according to the core method of Blake (1965) using core measuring 5.35 cm in diameter and 6.0 cm in height. Particle density was determined by the method outlined by Blake (1965) using a pycnometer. Particle size analysis was carried out by the pipette method as outlined by Day (1965). Total pore space was estimated by using the relationship:

$$\text{Total pore space} = 100 (D_p - D_b)/D_p$$

Where D_p is particle density, D_b bulk density. Macro pore space as a percentage of the total pore space was estimated using the relationship:

$$100 \frac{(\text{TPS} - \theta)}{\text{TPS}}$$

TPS

TABLE 1 — *Physical properties of the soil under different management practices*

Treat- ments	Sand %	Soil Texture		Organic carbon %	Density parti- cle Bulk	Density (g cm ⁻³) Bulk	Pore Total	Space Macro	Infiltration		Water retention (w/w)		Avail- able water cm/30 cm
		Silt %	Clay %						Satu- rated cm h ⁻¹	Cumu- lative cm	0.1 bar	15 bar	
A	30.51	21.91	47.58	5.55	2.64	1.04	60.60	33.48	10.4	69.3	38.76	27.92	3.38
B	31.55	20.23	48.22	6.50	2.74	0.97	63.26	21.02	2.7	38.0	51.50	34.87	4.84
C	32.91	23.72	43.37	6.75	2.68	0.96	64.18	27.59	5.8	44.0	48.41	28.54	5.72
D	33.00	17.02	49.98	5.95	2.65	0.86	67.55	39.25	15.0	94.5	47.72	33.68	3.62
E	31.83	18.54	49.63	6.70	2.66	0.88	66.92	46.78	21.6	117.6	40.47	24.10	4.32
F	27.15	23.59	49.26	6.80	2.63	0.84	68.06	35.00	15.5	88.4	52.67	34.73	4.52
LSD (P=0.05)	1.93	3.30	2.07	0.40	0.002	0.07	2.60	5.72	2.70	23.0	4.19	0.82	0.99

A — Bare plot; B — Soil under clonal tea without leaf litter; C — Soil under clonal tea with leaf litter;

D — Soil deep-forked after uprooting old seed tea; E — Soil under Mana grass; F — Soil under Guatemala grass

*Means of 6 determinations; others are means of 3 determinations.

where TPS is the total pore space and θ is the volumetric water content at 100 cm water tension, since a pore size 1.5×10^{-3} mm corresponding to 100 cm suction is frequently chosen for separating 'large' from 'small' pores (Marshall, 1959). Organic carbon was determined by the method of Walkley and Black (1934). For statistical analysis the three measurements taken of each physical property at each site were considered as three replicates and the analysis carried out on six treatments with three replicates for each.

RESULTS AND DISCUSSION

The particle size distribution in the soils under different treatments (Table 1) showed slight differences. These variations were larger in the sand and silt fractions. The soil under all the treatments however, fall into the textural class of clay. Organic carbon content appeared to be higher in the soils carrying clonal tea and grasses than in the others. The lower organic carbon content in the bare plot and in the plot from which old seed-tea had been uprooted and the higher values in soil under tea and grasses show the loss of organic matter under exposure, its enrichment under grass and its maintenance under a good cover of clonal tea as in treatments B and C. The extensive feeder root system of well managed tea, 90 per cent of which is confined to the first 30 cm of soil (Eden, 1940), and large amounts of leaf fall (Visser, 1960) probably contribute to the maintenance of soil organic matter. Deterioration in organic matter content under old seed-tea has, therefore, to be attributed to soil exposure as a result of wide spacing of low 'jat' tea, planted up and down steep slopes (20-70°) leading to excessive soil erosion.

TABLE 2 — Relationships between available water capacity (AWC) saturated infiltration rate (SI) and some physical properties

Regression equation	Correlation coefficient	% variation explained
Y (AWC) = - 4.147 + 1.341 OC	0.806	65
Y (AWC) = - 472.74 + 14.80 TPS - 0.114 TPS ²	0.818	67
Y (AWC) = - 17.386 - 0.0349 Sand - 0.2478 Clay	0.691	48
Y (AWC) = - 5.070 + 0.090 Silt + 1.191 OC	0.852	73
Y (AWC) = - 8.207 + 0.112 Sand + 1.429 OC	0.854	73
Y (SI) = - 24.226 + 0.759 MPS + 1.622 OC	0.982	96
Y (SI) = - 36.339 + 0.383 TPS + 0.687 MPS	0.984	97
Y (SI) = - 86.115 + 2.014 TPS - 5.202 OC	0.721	52
Y (SI) = - 71.729 - 0.0517 Sand + 1.774 Clay	0.629	40
Y (SI) = - 76.907 + 0.052 Silt + 1.826 Clay	0.629	40
Y (SI) = - 105.696 - 1.826 Sand - 1.774 Silt	0.629	40

TPS = Total pore space

OC = Organic carbon

MPS = Macro pore space

Total pore space was least in the bare plot, perhaps because of compaction brought about by exposure and the beating action of rain drops (Millington, 1965; Jones and Wild, 1975) and is reflected in the higher bulk density in this treatment compared with others. It is also to be noted that the bulk density in soil under grass was lower than that in soil under clonal tea, reflecting compaction in the soil under tea brought about by treading by the workers in the process of harvesting tea at frequent intervals (once in 7-10 days). The similarity in bulk density in treatment D with that in soil under grasses in probably due to the thorough disturbance of the soil in the process of uprooting old tea. Of more interest is the macro pore space which

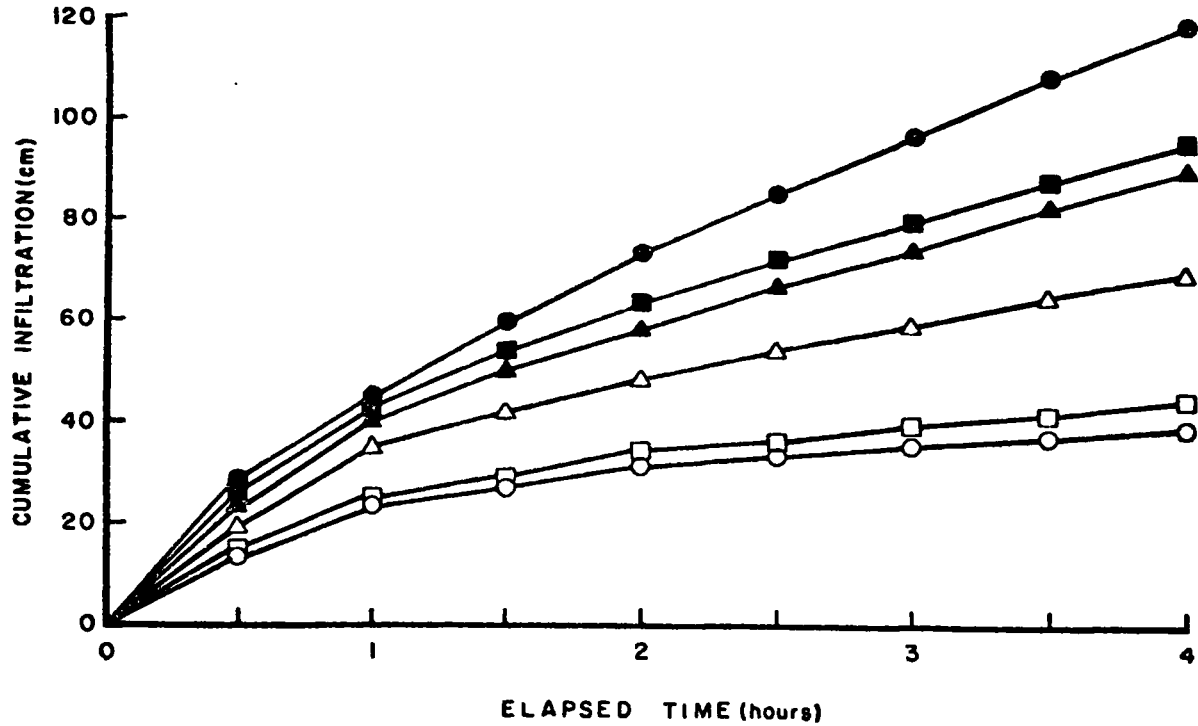


Fig. 1. — Effect of soil management treatments on cumulative infiltration.

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|-----------------------------|-----------------------|---------------------|
| ○—○ Tea without leaf litter | ■—■ Uprooted tea area | ▲—▲ Guatemala grass |
| □—□ Tea with leaf litter | △—△ Bare area | ●—● Mana grass |

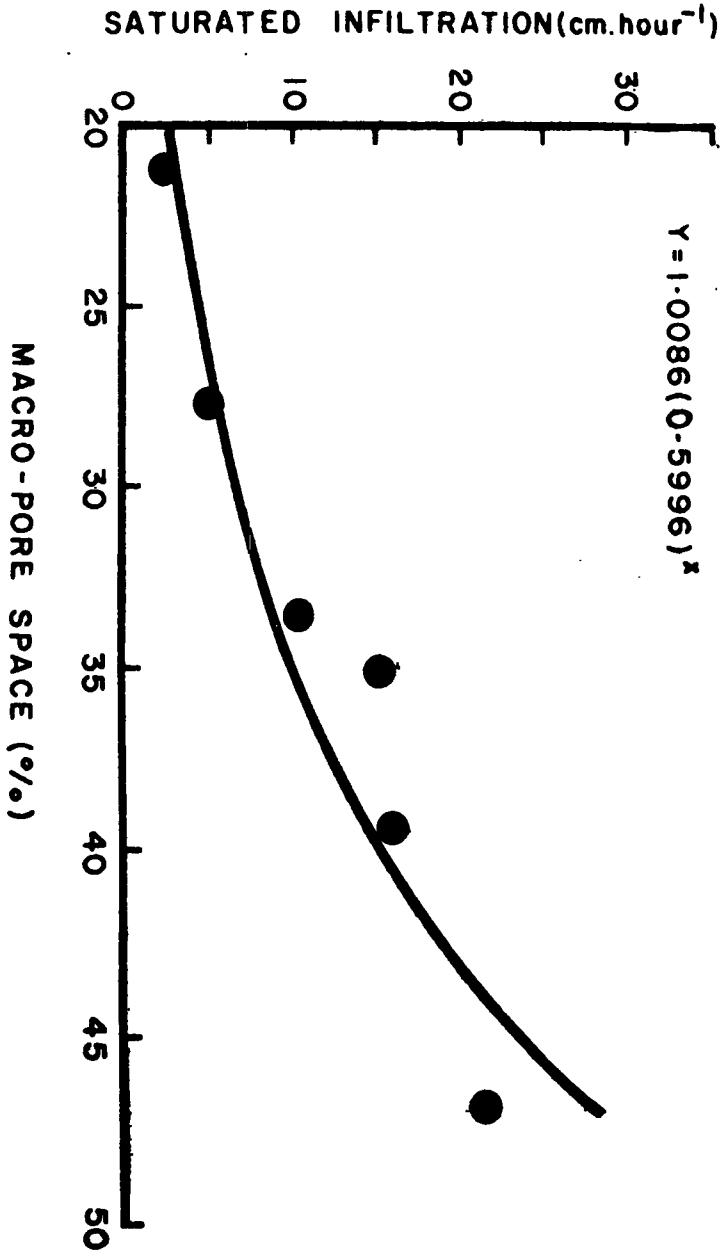


Fig. 2. — Relationship between macro pore space and Saturated Infiltration rate

was higher in the soil under grasses and in soil from which tea had been uprooted shortly before measurements were made, than in the bare plot and the soil under clonal tea. Generally shortly after cultivation most soils contain an abundance of large pores (Skidmore *et al.*, 1975). The macro pore space in the bare soil, however, was higher than that in the soil under tea probably due to the forking done in the bare plot a few months before the measurements were made. In the soil which was under tea for 17 years, the percentage macro pore space was only 21-27% of the total pore space whereas in the soil under grasses it ranged from 35 to 46% of the total pore volume. It appears reasonable to assume that the magnitude of macro pore space in treatments B and C would have been similar to that in treatments D, E and F at the time of uprooting and after soil reconditioning and before planting clonal tea. Therefore, the reduction in macro pore space in the soil under tea has to be attributed to management practices which cause soil compaction. The high macro pore volume content in the soil from which tea had been uprooted (Treatment D) indicates that the soil is inherently good structured and has desirable physical properties as pointed out by Eden (1951). Under continuous cultivation with tea, however, even with sufficient protection afforded by the canopy and leaf fall, soil compaction apparently impairs pore space relationship which is considered a criterion for predicting water storage capacity of the soil, water availability to plants and to provide information about the management practices to be used (Nagpal *et al.*, 1972; Sills *et al.*, 1973). Although the organic content of soils under treatments B, C, E and F were higher than that in treatments A and D, the total pore space was similar in all the treatments and the percentage macro pore space also did not appear to be related to organic matter content (Table 1). It thus appears that factors other than aggregation as influenced by organic matter, such as natural consolidation, compaction brought about by implements and treading, root activity etc., have an influence on the volume percentage of macro pores. Such observations have been reported in other soils (Cary and Hayden, 1973; De Kimpe and Mehuys, 1979).

The saturated infiltration rate (Table 1) and cumulative infiltration (Fig. 1) were higher in soil under Mana grass and similar in soils under Guatemala grass and in the soil from which old tea had been uprooted (treatment D). It was lowest in the soil under tea without leaf litter. The similarity in infiltration in the soil from which old tea had been uprooted and that in the soil under Guatemala grass and the higher infiltration in soil under Mana grass seems difficult to explain, since in earlier investigations the amount of roots produced by Guatemala grass far exceeds that produced by Mana grass (Sandanam *et al.*, 1976). A possible explanation could be that the surface characteristics of soil were more desirable under Mana grass which has a higher C/N ratio than Guatemala grass and therefore serves as a soil protectant for a longer period of time. In view of the fact that the soil under clonal tea had been reconditioned with grass before planting tea despite which the rate of infiltration was low in these two soils, it appears that the improvement in physical properties brought about by loosening the soil by deep-forking and subsequently by reconditioning with a grass disappears after a few years of cultivation as reported for other tropical soils (Pereira *et al.*, 1954). The benefits of grass fallow resides in improvement in nutritional status rather than to any significant improvement in physical properties has also been reported (Wilkinson, 1975). The deterioration in the rate of infiltration in soil under clonal tea with surface litter is probably due to soil compaction by treading and the still lower rate in the soil under clonal tea, without leaf litter, could be a combined effect of treading and surface sealing brought about by reorientation of dispersed particles by rain-drop impact. The higher saturated infiltration rate in the bare plot than in the plots under tea is perhaps due to loosening of the soil by forking and due to the soil not being compacted by treading.

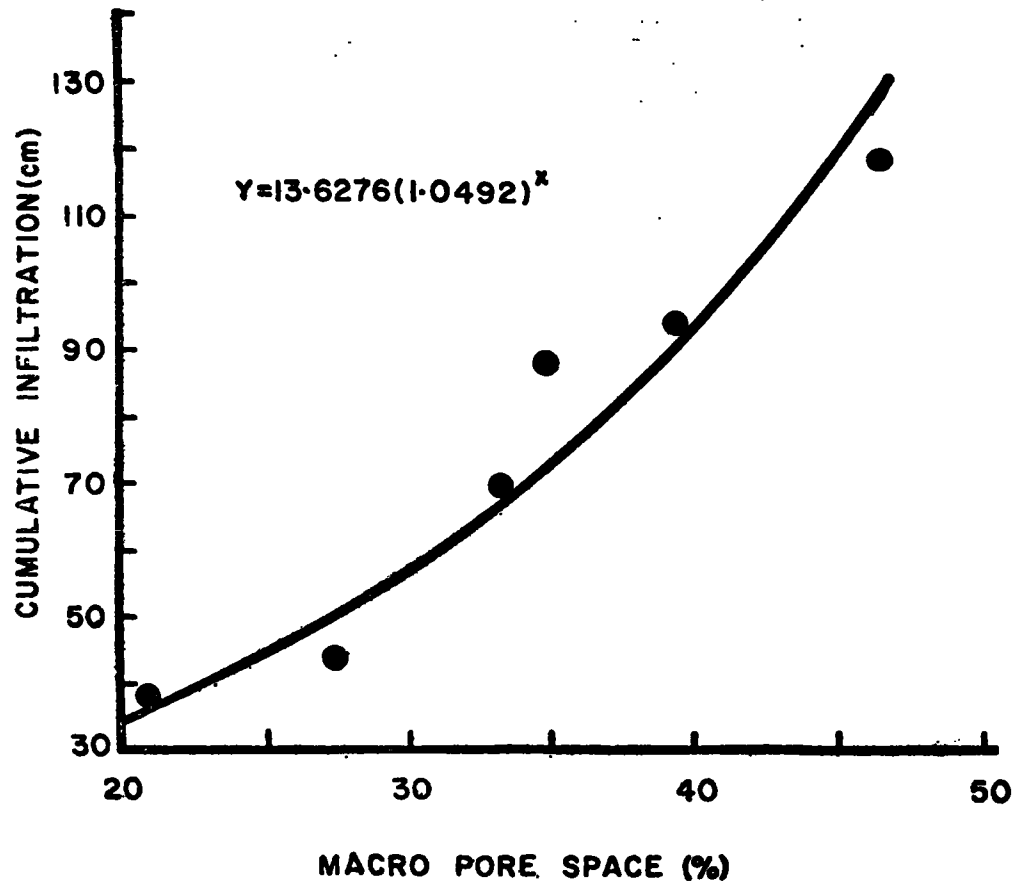


Fig. 3 — Relationship between macro pore space and Cumulative Infiltration

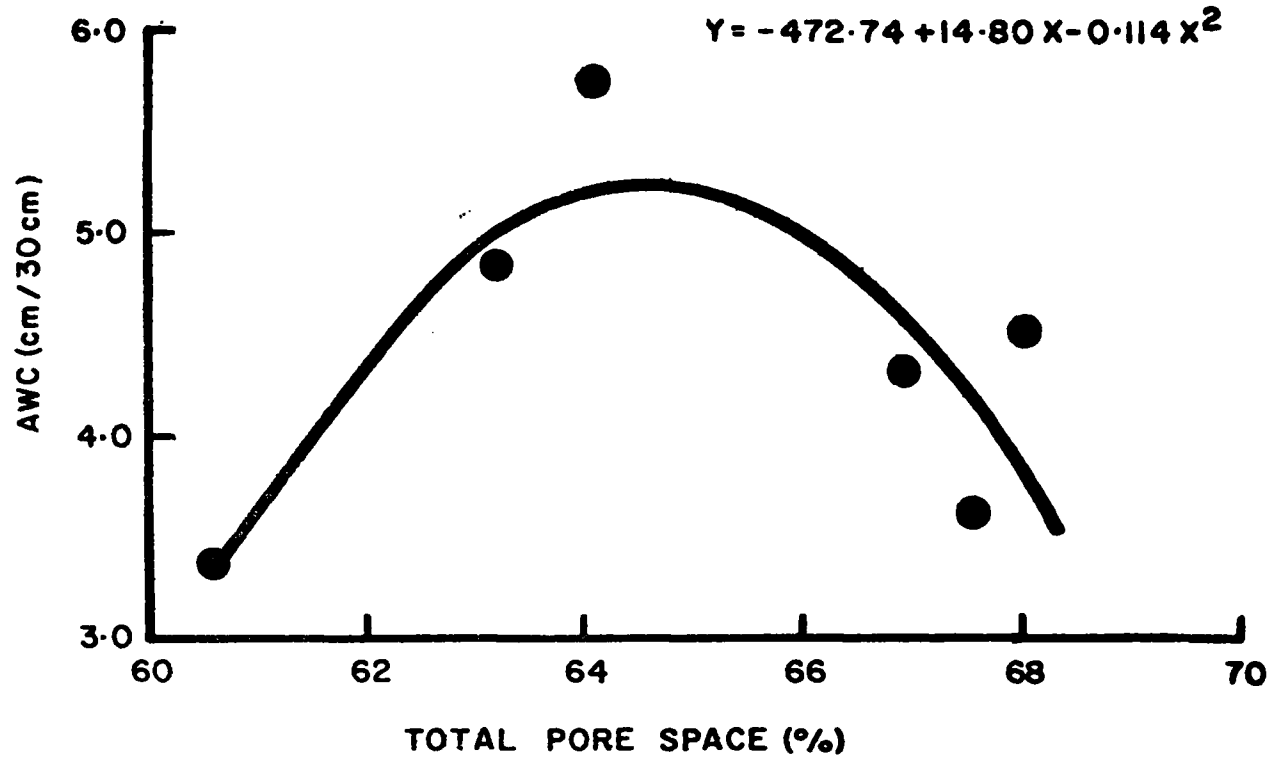


Fig. 4. — Relationship between total pore space and Available Water Capacity (AWC)

An examination of the relationships between field capacity, permanent wilting percentage, available water capacity, saturated infiltration rate and soil physical properties such as texture, total pore space, macro pore space, organic carbon content etc. revealed a linear relationship between organic carbon content and available water capacity and a curvilinear relationship between total pore space and available water capacity (Table 2 and Fig. 2). The saturated infiltration rate and cumulative infiltration were exponentially related to macro pore space (Fig. 3 and 4). Multiple regression analyses on soil physical properties and available water capacity or saturated infiltration rate improved the correlation in many cases (Table 2). However, the correlation was high only in the case of saturated infiltration as affected by macro pore space and organic carbon content or as affected by total pore space and macro pore space with a predictability of 96 and 97% respectively. Nevertheless, since the data are limited, these relationships cannot be unreservedly used to predict available water capacity or infiltration rate in tea soil under different management systems.

ACKNOWLEDGEMENTS

The authors wish to gratefully acknowledge the help offered by Mr. T. Thevadasan, Officer-in-Charge of the Statistics Division in carrying out the statistical analysis, Messrs D. J. M. Hettiarachi and D. L. Coonghe for preparing the figures and Mr. P. W. Uduwawala for typing the manuscript.

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