PHYSICAL PROPERTIES OF SUGAR BELT SOILS WITH PARTICULAR REFERENCE TO MOISTURE RELEASE CHARACTERISTICS

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Abstract

Results of determinations for particle size distribution, bulk density, porosity and moisture retention over the available moisture range are tabulated for 21 different soil series. Moisture characteristic curves are plotted for seven soil series which broadly represent the various soil conditions that occur. Moisture release characteristics of these soils are discussed.

Introduction

Investigations into the physical properties of sugar belt soils have been reported by Hill [3,4], Hill and Sumner[5] and Maud.[8] These data generally refer to determinations at a single sampling site so that little is known of the range of physical conditions occurring within soil series. Thus further information on the soils already studied is often of value and data for other soils are urgently required.

For several years, work has been in progress at the Experiment Station on the characterization of important physical properties of soils commonly found in the sugar industry. The primary purpose of this paper is to report results that have been obtained, for easy reference by others dealing with these soils.

In order to seek an understanding of the physical suitability of different soil types for crop growth, much emphasis has been placed on moisture release properties in these studies. Hill[4] has demonstrated the importance of soil physical properties in irrigation. He found that cane growing on a Windermere clay was far more susceptible to drought and showed a greater response to frequent irrigation than cane growing on a Clansthal sand.

Important factors determining the potential moisture supply of a soil are:

(1) amount of water retained by the soil that is available to the crop (moisture held between field capacity and wilting point),
(2) degree of availability or ease with which this moisture can be removed from the soil, and
(3) depth of soil available for root growth.

The influence of rooting depth has been avoided as far as possible in this paper in order to simplify comparisons between different soils, but the importance of this factor should not be overlooked.

Experimental procedure

Soil series were sampled according to the diagnostic horizons. All results presented in tables 1-3 refer to undisturbed soil core samples. The sampler used consists of a steel cylinder bearing a metal sleeve and cutting edge and was constructed according to the design of Dagg and Hosegood.[8] The sample fits neatly into the sleeve as the cylinder is hammered into the soil. The sleeve acts as a sample retainer and facilitates easy handling of soil cores.

The following core sizes and apparatus were used for the different ranges in tension:

Tension (bars)	*Core size*	*Apparatus*
0,075 — 0,100	7,7 cm deep by 9,5 cm diam.	Asbestos tension trays (Jamison and Reed[6])
0,33	Generally as above but some of 2,5 cm deep by 7,5 cm diam.	One bar ceramic plate and pressure membrane apparatus.
1,0 — 15	2,5 cm deep by 7,5 cm diam.	15 bar ceramic plate and pressure membrane apparatus.

Core samples were saturated with water under a suction of approximately 0,75 bar in order to obtain as complete a saturation of the soil as possible. After remaining submerged for at least 15 minutes samples were transferred to the moisture tension apparatus. For low tension work on the asbestos trays, samples were allowed to equilibrate for 48 hours at each tension before being weighed. On the ceramic plate and pressure membrane extractors readings were taken twice daily on a burette which was connected to the outflow tube on the extractor. If the reading was constant for an eight hour period the samples were regarded as being at equilibrium with the applied pressure.

Particle size distribution was determined by the Bouyoucos hydrometer method[1] using sodium hexametaphosphate as dispersing agent. In tables 1-3 clay % represents the fraction less than 0,002 mm, silt % the 0,002 — 0,02 mm fraction and sand % the 0,02, to 2,0 mm fraction. Fine, medium and coarse sand fractions were actually determined, but for the sake of brevity only total sand percentage is given.

Results

All results given in tables 1-3 are averages for data from a minimum of two cores. Where core samples were taken at more than one depth within a particular horizon and the results were similar, averages have been given.

Total pore space was calculated from the bulk density using an assumed particle density of 2,65 g/cm^3 (U.S.S. Lab. Staff[9]). Macropore space is defined here as the pore space occupied by pores of

TABLE 1

Physical properties of red soils

Soil Form	Series	Depth (cm)	Texture Clay %	Silt %	Sand %	BD (g/cm³)	TPS (%)	MPS (%)	Moisture % (W/W) 0,075 bar	0,10 bar	0,33 bar	1,0 bar	4 bar	15 bar	AMC (mm/cm, 0,1 –15 bar)	AMC (mm/cm, 0,1 –1 bar)
Hutton	Clansthal	0–30	7	3	90	1,50	43,4	30,8	9,8	8,4	6,0	4,8	—	2,7	0,85	0,54
		30–120	8	2	89	1,58	40,4	27,2	9,8	8,4	5,7	4,1	—	2,3	0,96	0,68
(red porous	Shorrocks	0–70	15	3	82	1,59	40,8	24,9	10,5	10,1	7,6	6,3	4,8	4,0	0,97	0,60
soil		70+	31	3	66	1,69	37,1	8,0	17,6	17,2	14,9	14,0	12,3	11,0	1,05	0,54
without visible	Shorrocks	0–18	11	5	84	1,45	45,3	23,3	17,0	15,2	9,0	7,5	7,1	4,8	1,50	1,12
struc-		18–100	22	4	74	1,58	40,6	16,0	16,5	15,6	12,1	11,6	10,6	8,4	1,14	0,63
ture)	Shorrocks	0–30	21	6	71	1,39	47,5	21,4	20,2	18,8	12,1	10,2	—	7,3	1,60	1,20
		30–90	29	12	59	1,39	47,7	18,4	22,7	21,2	17,4	14,8	—	11,3	1,38	0,89
	Shorrocks	15–90	22	7	69	1,48	44,2	12,2	22,2	21,6	18,1	16,3	14,2	11,8	1,45	0,78
Short-lands	Glendale	0–25	39	13	47	1,31	50,6	15,8	27,4	26,6	21,6	19,3	16,8	15,1	1,50	0,96
		25–100	45	19	36	1,30	51,0	17,4	26,8	25,9	23,2	21,8	20,4	18,4	0,98	0,53
(red soil with	Shortlands	0–30	63	13	18	1,27	52,1	10,9	33,1	32,4	—	28,3	—	23,7	1,10	0,52
blocky		30–120	74	11	12	1,26	52,4	15,3	30,0	29,5	—	26,6	—	23,0	0,82	0,37
struc-	Shortlands	10–90	62	19	17	1,27	52,1	11,7	32,6	31,8	28,9	27,3	24,7	22,8	1,14	0,57
ture)	Shortlands	10–75	55	14	29	1,33	49,8	4,6	34,3	34,0	31,2	28,7	26,5	26,3	1,38	0,70

BD = bulk density TPS = total pore space MPS = macro-pore space AMC = available moisture capacity.

diameter greater than 30 microns. This was determined from the air filled pore space at the 0,10 bar tension using the relationship

$$r = \frac{2 \times 10^{-6}\, x}{\text{M.S.}}$$

where r = upper limiting radius (cm) of pores which can remain full of water when matric suction (M.S.) in bars is applied.
x = surface tension of water erg g^{-1}

The macropore space gives a measure of the permeability of the soil to air and water.

The 0,1 bar tension has been used as a measure of the upper limit of moisture availability (field capacity) for all soils. From saturated plots in the field, field capacity was found by von der Meden[10] to correspond fairly closely to the 0,1 bar moisture content of soils over a wide range of texture. However, there was a tendency in sands for field capacity to be more closely approximated by the 0,075 bar tension. Nevertheless the 0,1 bar tension has been used throughout for the sake of comparing moisture release from different soils.

Due largely to their shrink-swell nature, black clays do not lend themselves to moisture retention studies in the laboratory. Moisture is released slowly from the soil sample and there is no clear-cut end point at which moisture release ceases, particularly at higher tension. Shrinking with drying out of the sample can also result in poor contact between soil and ceramic plate or pressure membrane.

Discussion

Moisture held between field capacity (say 0,1 bar tension) and 15 bars is classically regarded as available moisture. Gardner[2] is of the opinion that active crop growth generally takes place within the range of 0,1 to 1 bar. This belief is supported and would apply particularly to irrigated conditions. Thus it is thought that the 0,1 to 1 bar A.M.C. (available moisture capacity) provides a more realistic index of the moisture supplying power of a soil than does the 0,1 to 15 bar A.M.C. Both values have nevertheless been given in the tables.

It is difficult to classify soils on the basis of moisture supplying power using A.M.C. alone without considering other factors, a very important one being the depth of soil. In this paper however, the soils sampled have been rated according to their moisture release properties in three broad categories.

Group 1: Highly favourable—
Shorrocks, Inanda, Trevanian and Glendale series.

Group 2: Intermediate—
Shortlands, Clansthal, Fernwood, Cartref, Glenrosa, Rosehill, Williamson, Windermere, Waldene and Avoca series.

Group 3: Poor—
Uitvlugt and Estcourt series, and all black clays.

Moisture characteristics of selected soils have been plotted in Figures 1 - 3 in order to demonstrate the variation in moisture release properties of different soil materials.

TABLE 2

Physical properties of black clays and one brown clay (Inanda series)

Soil Form	Series	Depth (cm)	Texture: Clay %	Silt %	Sand %	BD (g/cm^3)	TPS* (%)	MPS* (%)	Moisture % (W/W): 0,075 bar	0,10 bar	0,33 bar	1,0 bar	4 bar	15 bar	AMC (mm/cm, 0,1–15 bar)	AMC (mm/cm, 0,1–1 bar)
Arcadia (black swelling clay on rock)	Arcadia	0–20	73	10	15	0,91	—	—	—	49,7	48,5	46,1	41,0	35,2	1,32	0,53
		20–95	69	10	13	1,21	—	—	—	47,8	46,8	43,0	39,1	35,7	1,46	0,58
	Arcadia	0–30	46	14	40	1,30	—	—	36,2	36,1	33,8	32,1	30,5	27,0	1,18	0,52
	Rydalvale	0–30	59	15	22	1,27	—	—	34,4	33,8	32,3	31,2	—	23,1	1,12	0,33
		30–90	67	15	14	1,21	—	—	40,4	39,9	38,4	35,9	—	30,1	1,17	0,48
Rensburg (black swelling clay on mottled grey clay)	Phoenix	0–60	37	15	47	1,40	—	—	32,4	32,1	31,2	28,7	25,2	21,5	1,49	0,48
		60–120	37	12	49	1,48	—	—	30,8	30,5	29,4	28,1	25,9	22,4	1,19	0,36
Bonheim (black blocky clay overlying brown blocky clay)	Bonheim	0–23	59	9	29	0,98	—	—	61,5	60,9	55,4	54,8	45,2	38,6	2,19	0,60
		23–120	68	11	21	1,04	—	—	48,8	48,3	43,7	42,8	37,0	32,3	1,66	0,68
Stanger (black blocky clay overlying red blocky clay)	Stanger	0–25	68	8	20	0,98	—	—	—	53,7	51,8	48,8	41,9	35,9	1,74	0,48
		25–125	69	11	20	0,96	—	—	—	52,8	49,7	45,8	41,9	37,1	1,51	0,67
Inanda (dark brown humic topsoil overlying red porous subsoil)	Inanda	0–89	45	27	23	0,89	66,9	18,4	—	54,7	49,1	45,8	42,1	39,0	1,40	0,79
		89–132	52	18	24	1,09	59,8	12,5	—	43,6	41,4	38,7	36,1	34,2	1,00	0,54

*Not given for black clays since particle density is believed to differ markedly from 2,65 g/cm^3 for these soils.

TABLE 3
Physical properties of grey soils

Soil Form	Series	Depth (cm)	Texture Clay %	Texture Silt %	Texture Sand %	BD (g/ cm^3)	TPS (%)	MPS (%)	Moisture % (W/W) 0,075 bar	0,10 bar	0,33 bar	1,0 bar	4 bar	15 bar	AMC (mm/ cm, 0,1 –15 bar)	AMC (mm/ cm, 0,1 –1 bar)
Cartref (grey sand on rock)	Cartref	0–30	9	5	88	1,44	45,7	30,4	11,9	10,7	7,7	7,1	—	3,0	1,10	0,52
		30–120	7	3	90	1,57	40,6	29,4	7,9	7,1	4,9	3,3	—	1,6	0,87	0,60
Fern-wood (deep grey sand)	Fern-wood	0–25	7	3	88	1,50	43,4	30,5	10,4	8,6	5,2	3,7	2,6	2,2	0,96	0,73
		25–100	6	4	90	1,55	41,5	29,6	8,4	7,6	3,3	2,5	1,7	1,1	1,01	0,79
Glenrosa (grey to dark grey top-soil merging via illu-vial clay to wea-thered rock)	Glenrosa	0–46	17	8	75	1,63	38,5	20,4	11,8	11,1	9,3	8,3	—	5,3	0,96	0,46
	Rosehill	0–30	38	14	47	1,54	41,9	10,7	20,6	20,3	18,2	16,4	—	12,1	1,26	0,60
		30–90	60	11	28	1,35	49,3	6,6	32,7	32,4	30,8	29,8	—	24,2	1,11	0,35
	Trevanian	0–46	33	5	62	1,49	43,9	10,6	21,5	20,2	16,0	13,6	11,9	10,3	1,47	0,98
		46–91	44	7	49	1,38	47,9	10,0	26,3	25,5	20,8	19,4	17,2	15,7	1,36	0,84
	William-son	0–46	18	10	72	1,71	35,5	15,5	13,4	12,7	10,7	9,8	8,7	6,7	1,00	0,50
	Winder-mere	0–30	51	23	25	1,29	51,5	14,1	29,4	29,1	27,8	26,0	—	20,6	1,10	0,40
Long lands (grey topsoil on porous layer of iron con-cretions overlying heavy clay subsoil)	Waldene	0–25	18	14	68	1,63	35,9	6,7	17,5	17,2	13,5	9,8	6,4	4,9	2,00	1,21
		43–110	62	14	24	1,60	46,2	3,6	26,6	26,3	24,5	23,2	21,5	20,0	1,02	0,50
Kroon-stad (deep grey sand or loam lying abruptly on slow-ly perme-able clay)	Avoca	0–60	20	11	69	1,68	37,5	14,9	—	14,2	—	—	—	6,6	1,28	—
		60–120	34	8	57	1,68	37,5	5,5	—	19,0	—	—	—	14,3	0,79	—
Estcourt (shallow grey sand or loam lying ab-ruptly on slowly per-meable clay)	Estcourt	0–22	22	7	71	1,74	34,3	8,7	15,2	14,7	12,8	10,3	9,0	6,9	1,36	0,77
		22–60	45	11	45	1,51	43,0	7,5	23,7	23,5	22,0	19,9	—	16,4	1,07	0,54
	Uitvlugt	0–28	6	4	90	1,72	35,1	18,2	10,7	9,8	7,3	5,1	—	3,4	1,11	0,81
		28–45	41	4	54	1,66	37,4	3,4	20,7	20,5	19,1	17,7	16,0	14,3	1,03	0,47

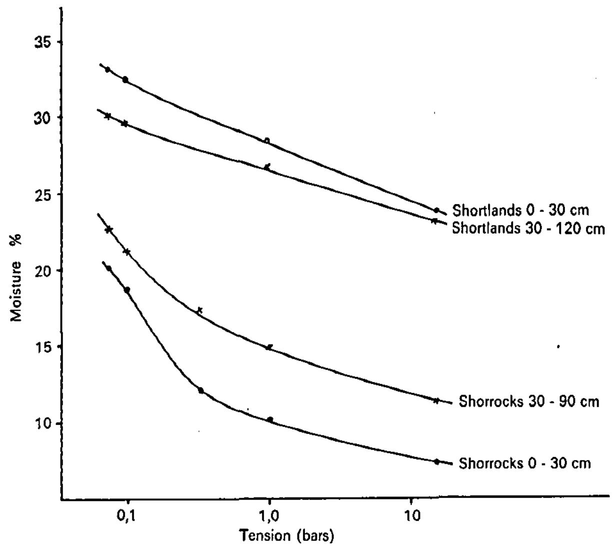

FIGURE 1: Moisture characteristics of Shorrocks and Shortlands series.

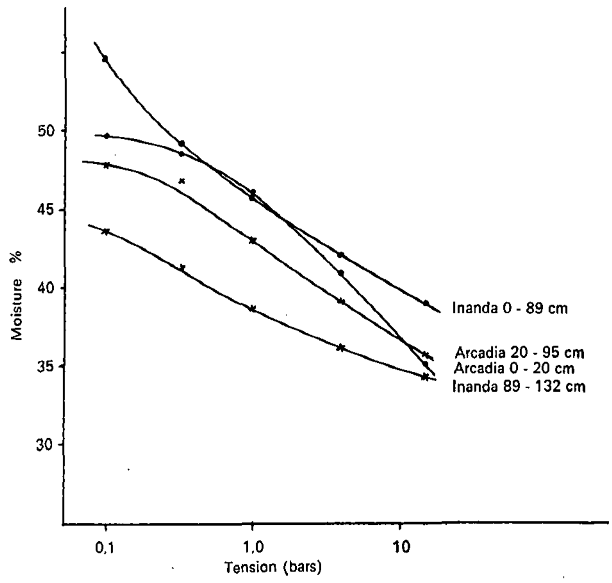

FIGURE 2: Moisture characteristics of Arcadia and Inanda series.

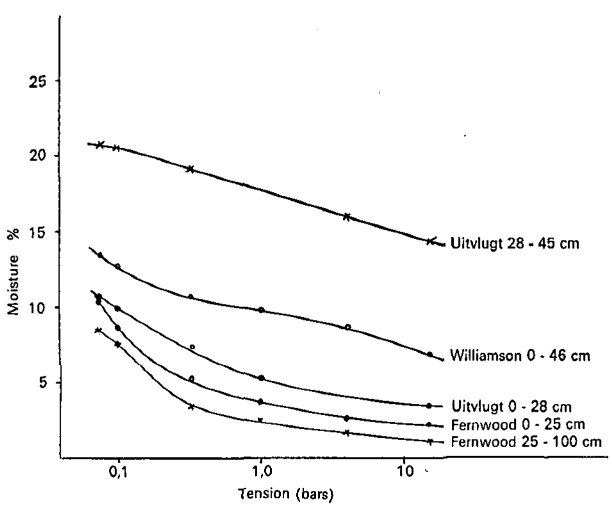

FIGURE 3: Moisture characteristics of Fernwood, Uitvlugt and Williamson series.

In Figure 1, Shorrocks series represents a soil of highly favourable moisture release properties. The soil is a porous unstructured loam which releases a large amount of moisture at low tensions. Approximately 70% of the moisture between 0,1 and 15 bars is held at tensions less than 1 bar. The porous humic topsoil of the Inanda series (Figure 2) also shows very favourable moisture release properties.

The Shortlands series (Figure 1) is a moderately structured red clay which releases water evenly over the whole available moisture range (0,1 to 15 bars). Only 47% of this moisture is held at tensions below 1 bar. Typical moisture characteristics of sands are represented by those of a Fernwood series in Figure 3. The total amount of moisture held is low but a large proportion of this is readily available to the plant. The curve for the Williamson series in Figure 3, is fairly typical of grey loamy soils.

In black clays such as the Arcadia series (Figure 2) a large proportion of the available moisture is held at high tensions so that much of it is not readily available to the crop. Wilting would be expected to occur on a black clay relatively soon after rain or irrigation. These soils are rich in montmorillonitic clay which imparts a shrink-swell character to the soil. This clay mineral has a very high surface area and pore spaces in the soil are predominantly small. These two properties largely lead to moisture being held tightly by the soil.

The marked difference in physical properties between the topsoil and the subsoil of the Uitvlugt series (duplex soil) is shown in Figure 3. While the topsoil shows the characteristics of a sand, the subsoil is a dense impermeable clay showing poor moisture release properties.

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