A PRELIMINARY REPORT ON WATER AVAILABILITY IN SOME NATAL SUGAR BELT SOILS[1]

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Summary

The departure of actual evapotranspiration from potential evapotranspiration of sugar cane plants growing in five-gallon drums containing six different soil series is indicated at different soil moisture contents and under varying meteorological conditions.

Capillary conductivities of the two extreme soil types have also been presented and the concept of water availability has received some consideration.

Introduction

Whilst some very useful data on the water requirement of sugar cane in Natal have been collected by Thompson *et al* (1963), no evidence has been presented to show the availability of soil moisture to sugar cane as influenced by soil moisture content and meteorological conditions. It is therefore the aim of this paper to indicate the departure of actual from potential evapotranspiration in different soils and to discuss the concept of water availability with special reference to the physical condition of the soil.

Methods

Sixty drums containing ten natural monoliths of each of six soil series found at Tongaat were collected. Each drum within a series contained the same weight of soil, and soils were brought to field capacity with respect to moisture. Transplants of very similar size cane shoots of N:Co.376 were made from the field to the drums, and when the plants were 1 ft. high (from soil surface to growing point) the drums were transferred from the germination greenhouse to the selected site, a plan of which is presented in figure 1.

The drums were then sealed by means of plastic sheeting which was secured to the drum with adhesive tape and to the stem of the sugar cane plant with cotton wool and tape. Loss of weight by the drum could then be attributed solely to transpiration by the plant. By means of a portable gallows and scale, rapid weighing of the drums was facilitated. All drums were brought to field capacity and the loss of weight measured daily between 7 a.m. and 3 p.m. Only drums recording very similar weight losses were accepted for the experiment and several discards were made.

The site of the experiment was selected and the row of drums stood in the middle of a fifty-acre field on which the ratoon cane was approximately 2 ft. in height. As the surrounding cane grew the row of drums, which substituted a row of cane, was raised out of the ditch into which they were placed, in order to maintain an even foliage height. These precautions were taken with the view to minimising localised advective energy effects.

In the choice of a five-gallon drum, the volume of soil from which the plant could draw water was sufficiently small that the roots thoroughly permeated the soil; this small volume, however, can offer a limitation to transpiration. It is for this reason that results after a six-week period were discarded, although inspection revealed that at this stage the root development had not quite reached the bottom of the drums.

Initially it was hoped that a wide range in soil moisture contents could be accommodated within the ten drums of any one soil series. Later, however, it was decided to split the moisture treatments into two sets of five drums, one set at field capacity and the other at some stage drier than field capacity.

Actual and potential transpiration was then measured in conjunction with evaporation from a class A pan and total incoming solar radiation on a Gunn-Bellani solarimeter. During the course of the experiment the dry drums reached permanent wilting point and were then brought to field capacity whilst those drums previously maintained at field capacity were

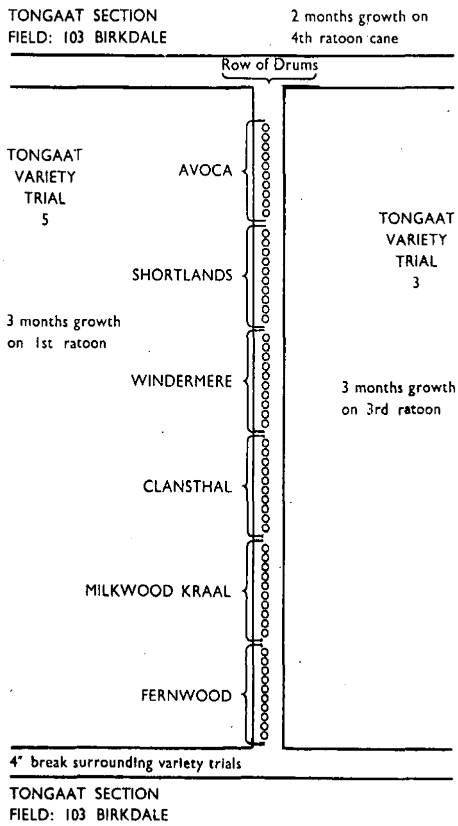

FIGURE 1 : Plan showing outlay of Water-Availability Experiments

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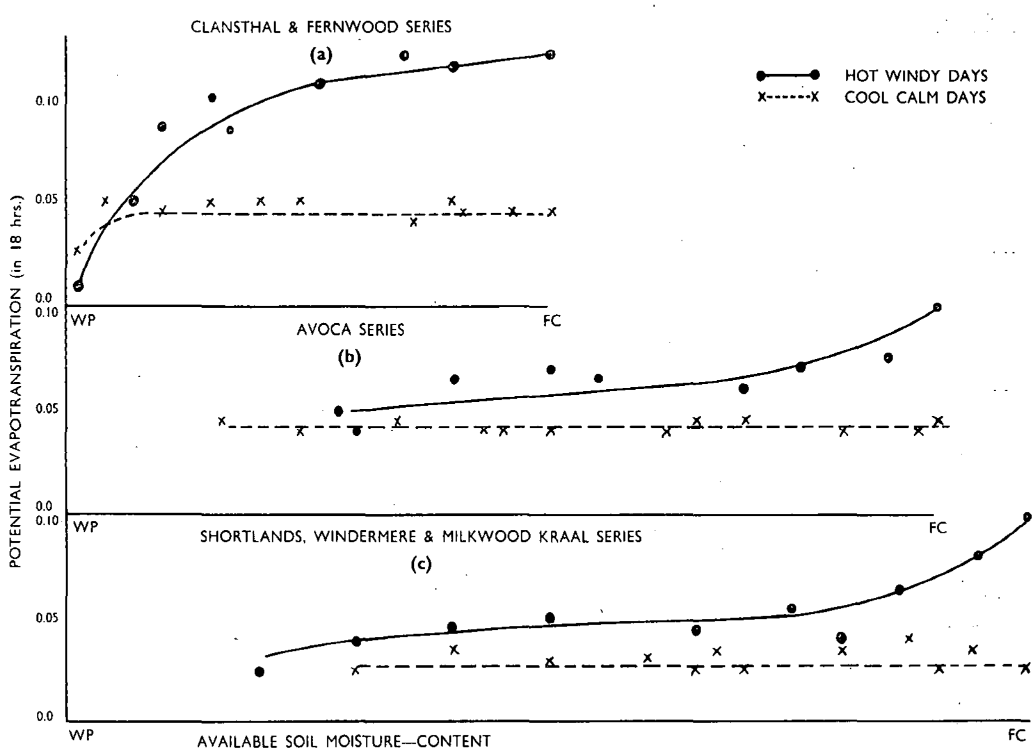

FIGURE 2 : Departure of Actual Evapotranspiration from Potential Evapotranspiration as influenced by Soil Moisture Content and Meteorlogical Conditions

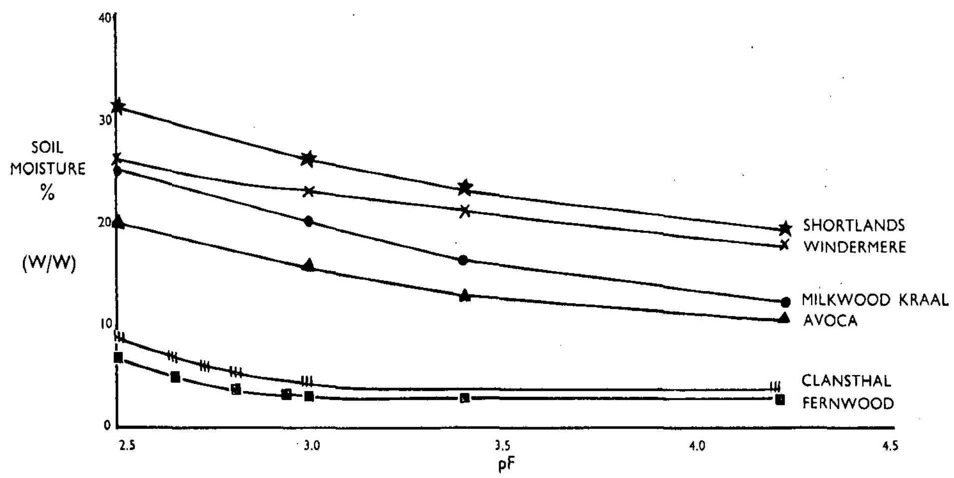

FIGURE 3 : Moisture characteristics for Shortlands ★ Windermere X Milkwood Kraal ● Avoca ▲ Clansthal ⧻ and Fernwood ■ series

TABLE 1

Some daily transpiration rates for sugarcane plants growing in wet and dry soils, with corresponding meteorlogical data.

Type of day	Evap. in.	Rad. ml.	Date	Transpiration Rates (in./8 hrs.)											
				Clansthal		Fernwood		Avoca		Shortlands		Windermere		Milkwood Kraal	
				W*	D	W	D	W	D	W	D	W	D	W	D
Hot	0.10	14.0	18.11.63	0.110	0.100	0.105	0.105	0.110	0.07	0.100	0.06	0 095	0.04	0.110	0.06
Hot	0.10	17.3	19.11.63	0.120	0.125	0.115	0.110	0.100	0.06	0.105	0.06	0.100	0.065	0.105	0.07
Cool	0.02	6.8	20.11.63	0.040	0.040	0.050	0.045	0.035	0.035	0.030	0.035	0.030	0.035	0.035	0.030
Cool	0.02	8.0	6.12.63	0.045	0.030	0.040	0.040	0.025	0.030	0.035	0.028	0.040	0.030	0.030	0.030

* W = Soil at field capacity D = Soil drier than W.

allowed to dry off. In this way a moisture stress cycle was completed for all plants. For the month and a half duration of the experiments meteorological conditions fell into two classes. Firstly, very hot windy days resulting in very high potential evapotranspiration conditions and, secondly, cool calm overcast days when potential evapotranspiration was comparatively low.

pF curves for the six soils were determined using the 15 Bar Ceramic plate extractor after Richards (1954) whilst capillary conductivities were calculated from the pressure plate outflow method after Gardner (1956). Undisturbed cores at 6-inch intervals down the profile to a depth of 2 feet from some ten different sites of a single soil series were equilibrated and moisture content - pF relationships averaged from the results obtained. The field capacity values corresponding to pF = 2.5 correlate very well with those measured with the soil *in situ*.

The influence of soil moisture content and potential evapotranspiration conditions on actual transpiration in the various soils is shown below.

Results and Discussion

The average transpiration rates for the sugar cane plants for a certain number of days are shown in table 1. Evaporation from the class A pan and solar radiation were also recorded. Transpiration rates are expressed in inches per 8 hours.

In table 2 and figure 2 results have been averaged for hot days and for cool days and are shown against the soil moisture contents for the various soils. Whilst data within treatments were reproducable, it must be borne in mind that not sufficient evidence has been collected from this experiment to more than merely illustrate the type of transpiration behaviour that can be expected under various conditions.

Gardner (1960), Philip (1957), and Covey and Bloodworth (1962) have considered the availability of moisture in soils from the dynamic view point and Gardner's equation describing the flow of water through the soil to the plant root in the course of transpiration has been verified, at least qualitatively, by Denmead (1961). This equation shows that increases in soil suction are proportional to transpiration rate and inversely proportional to the capillary conductivity of the soil.

TABLE 2

Average Transpiration Rate for Hot and Cool Days at varying Soil Moisture Content

Soil Group	Soil Series	Moisture Content as a Deficit from Field Capacity † %	Transpiration Rate in./8 hrs. hot days	Transpiration Rate in./8 hrs. cool days
Recent Sands (5% available water)	Clansthal and Fernwood	0.4	—	0.045
		0.9	—	0.045
		1.0	0.115	0.050
		1.4	—	0.040
		1.5	0.120	—
		2.0	—	0.045
		2.4	0.105	—
*TFC on hot days	=0.120″	2.6	—	0.050
		3.0	—	0.050
TFC on cool days	=0.045″	3.3	0.085	—
		3.5	0.100	0.050
		4.0	0.085	0.045
		4.3	0.050	—
		4.6	—	0.050
		4.9	0.001	0.025
Dolerite	Short-lands, Winder-mere and Milkwood Kraal	0.6	0.080	0.035
		1.0	—	0.030
		1.3	—	0.040
M.E. Shale		1.4	0.065	—
		2.0	0.040	0.035
L.E. Shale (10% available water)		2.5	0.055	—
		3.0	—	0.025
		3.3	—	0.035
		3.5	0.045	0.025
		4.0	0.050	0.030
TFC on hot days	=0.100″	5.0	0.045	0.030
		6.0	0.050	0.035
TFC on cool days	=0.030″	7.0	0.040	0.025
		8.0	0.025	—

* TFC is the transpiration rate when the soil is at field capacity and has been assumed to be the potential transpiration rate.

† The recent sands hold 5 per cent available water, thus 0.4 per cent deficit is almost field capacity, whilst 4.9 per cent deficit is almost at the permanent wilting percentage. The same principle applies for other soils.

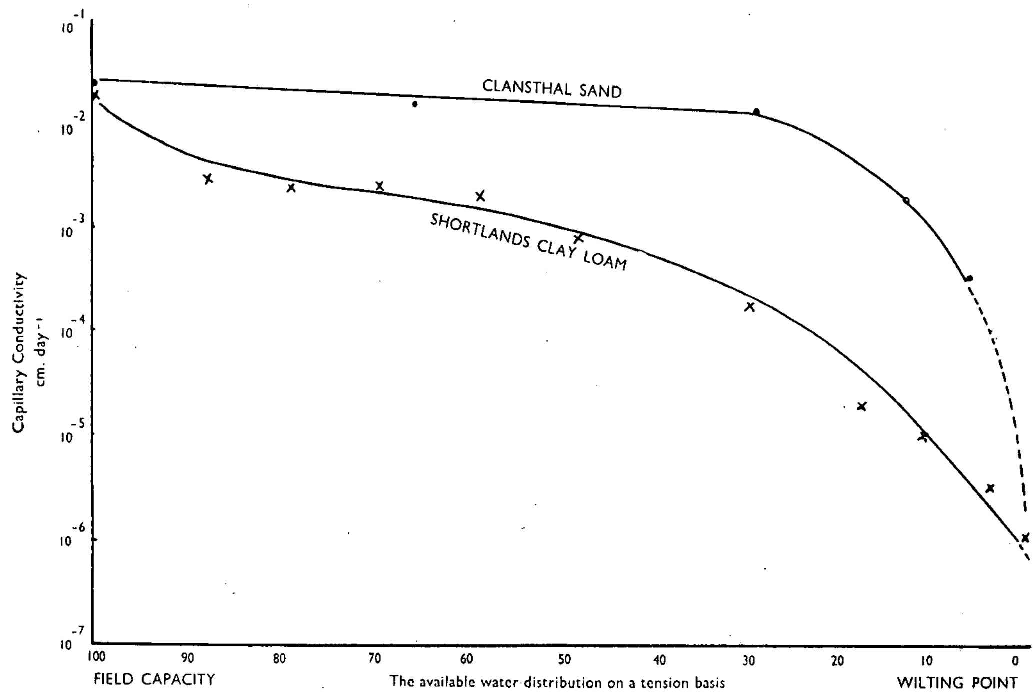

FIGURE 4 : Relation between capillary conductivity and available moisture

The capillary conductivities of soils decrease rapidly with increasing soil suction and thus we would expect transpiration rates to decline with decreasing soil moisture content and that this decline be evident at higher and higher soil moisture contents as the potential transpiration rate increases. From capillary conductivity considerations, the particular soil moisture content at which the decline in transpiration occurs will also depend on physical soil properties. In soils in which most of the water is held at low suction, such as the Clansthal, Fernwood, Cartref series, the decline should not be evident until most of the available water has been extracted. In soils in which suction increases rapidly as soil moisture content decreases, such as the Shortlands, Windermere and Milkwood Kraal series, the decline in transpiration should be noticeable at comparatively high soil moisture contents.

These points are illustrated by reference to the moisture characteristics of the six soils shown in figure 3, where it can be seen that the sands (Clansthal and Fernwood series) hold most of their available water at tensions less than pF = 3.0, whilst the heavier soils (Shortlands, Avoca, Windermere and Milkwood Kraal series) have their available water range approximately linearly distributed between pF = 2.5 and pF = 4.2 (corresponding to field capacity and wilting point, respectively).

These considerations have been illustrated by the results obtained, and the water transmitting properties of the soil are shown to play a major role in transpiration.

It is for this reason that capillary conductivities of the two extreme soils on a textural basis have been determined by integration of pressure plate outflow during laboratory determination of moisture characteristics. These results are shown in table 3, together with Gardner's data on a sandy loam from California. Of interest is the plot of capillary conductivity against the percentage distribution of available soil moisture (from the moisture content — pF relationship) which clearly shows the availability of the total available moisture range (figure 4).

From the results of this work, the importance of the soil factor in moisture use by sugar cane has emerged and it is hoped that these results together with those from future experiments will be useful in the ever increasing need for improving irrigation efficiency and control.

TABLE 3
Capillary Conductivity of Three Soils

Pressure Range atm.	Clansthal Natal cm. day^{-1}	Shortlands Natal cm. day^{-1}	Pachappa California cm. day^{-1}
0.2—0.3	3.7×10^{-2}	$2.1 \times 10{:}^{2}$	1.1×10^{-2}
0.3—0.4	1.6×10^{-2}	6.1×10^{-3}	4.5×10^{-3}
0.4—0.5	1.5×10^{-2}	6.0×10^{-3}	1.7×10^{-3}
0.5—0.6	2.5×10^{-3}	5.0×10^{-3}	8.4×10^{-4}
0.6—0.8	5.5×10^{-4}	4.1×10^{3}-	6.4×10^{-4}
0.8—1.0	—	9.3×10^{4}-	3.4×10^{-4}
1.0—2.0	—	2.5×10^{-4}	1.0×10^{-4}
2.0—4.0	—	4.0×10^{-5}	4.7×10^{-5}
4.0—8.0	—	1.1×10^{-5}	1.4×10^{-5}
8.0—14.0	—	6.4×10^{-6}	4.5×10^{-6}
14.0—16.0	—	1.0×10^{-6}	3.5×10^{-6}

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For discussion on this paper see page 123.