THE INFILTRATION CAPACITIES AND PERCOLATION RATES FOR SOME NATAL SUGAR BELT SOILS[1]

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Summary

The infiltration capacities and percolation rates of ten soil series found at Tongaat are presented and certain aspects of the determination discussed. This includes the effects of antecedent soil moisture and soil compaction on the results obtained.

Introduction

With our ever increasing need for greater efficiency in farming practices, and in view of the increasing use being made of supplementary irrigation in the production of sugar cane crops in certain parts of Natal, a knowledge of the rates at which certain soils will accept overhead irrigation water is urgently required. It is hoped that this data will be useful in the planning of irrigation schemes where application rates are in question.

Infiltration capacity is defined as the maximum rate at which a given soil absorbs water. This is distinct from percolation, which relates to the downward flow of water due to gravity in the zone of aeration of the soil, once water has gained access to the soil. Thus total water absorbed by the soil in the first hour of operation is presented as infiltration capacity, whilst the more reproducible percolation rates have been taken as infiltration from the second hour until the end of the determination. The reason for the selection of a one hour initial period, is because much of the irrigation applications at Tongaat run for one hour.

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Methods

The infiltration capacities and percolation rates for the various soil series encountered at Tongaat have been measured, using the double ring infiltrometer after Thompson and du Toit (1962). Although this method was intended for use on subsoil horizons, investigations showed that results on top soils were fairly reproducible.

The length of duration of the determination was also investigated and it soon became apparent that, for these soils, steady percolation rates were reached within half-an-hour of commencing the experiment. Runs of 4 hours were then selected since this time period enabled two reliable determinations to be made in one day.

The effects of various soil factors such as temperature, compaction and antecedent soil moisture were also studied, and results are detailed below.

Results and Discussion

Some workers have reported that changes in soil temperature have affected infiltration but during the twelve-month period of this study, the quite considerable variations in temperature experienced, did not seem to influence the results to any significant extent.

The average infiltration capacities and percolation rates for the ten soils studied are presented in table 1. Owing to the host of variables which influence infiltration, it is not surprising that results vary considerably and therefore, an estimate of variation to be expected in work of this nature is also presented. In table 1 it can be seen that differences in infiltration capacities between A- and truncated A-horizons vary quite considerably in certain soils, whilst percolation rates were not as variable. This is illustrated in figures 1 and 2, where infiltration capacities are represented by dotted lines.

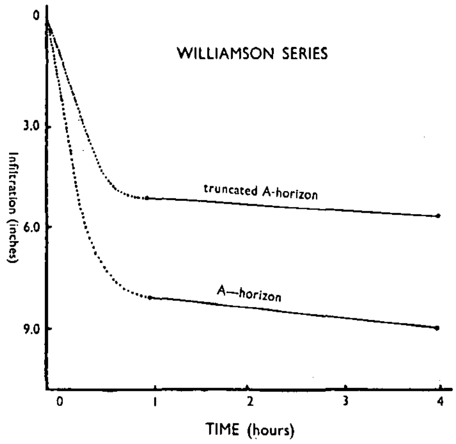

FIGURE 1

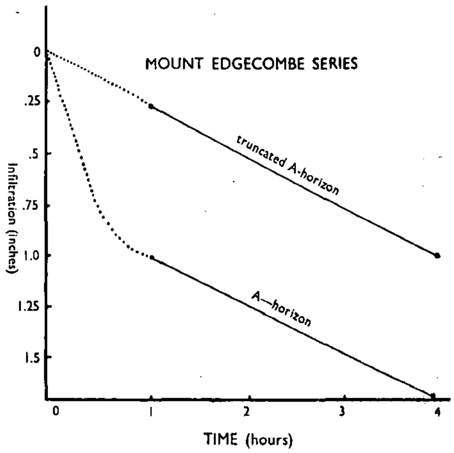

FIGURE 2

TABLE 1

Infiltration Capacities and Percolation Rates for A- and Truncated A- Horizons in Some Sugar Belt Soils

Soil Group	Soil Series	A-horizon (T) or Truncated A-horizon (S)	Infiltration Capacity in./hr.	Percolation Rates in./hr.
Table Mountain Sandstone . .	Cartref	T S	15 0 ± 6.0 12 0 ± 4 0	9.0 ± 3.0 8.8 ± 2.0
Dwyka Tillite	Williamson	T S	8.0 ± 3 0 5.0 ± 2 0	0.35 ± 0 2 0.27 –
LowerEcca Shale	Milkwood Kraal . . .	T S	3.0 ± 2 0 1.7 ± 0 5	1.6 ± 0 8 1.3 ± 0 6
Middle Ecca Sediments	Mount Edgecombe . . .	T S	1.0 ± 0 5 0.25 –	0 25 – 0.25 –
Middle Ecca Sediments	Avoca	T S	2.0 ± 1.0 1.0 ± 0.5	0.36 – 0.30 –
Karroo Dolerite.	Shortlands	T S	5.0 ± 3.0 3.5 ± 1.0	4.0 ± 1.0 3.5 ± 1 0
Recent Sands	Clansthal	T S	11 0 ± 5.0 9.7 ± 3.0	8.4 ± 2 0 8.4 ± 2.0
Recent Sands	Fernwood	T S	9 0 ± 4 0 6 0 ± 2.0	6 4 ± 2 0 3 0 ± 1.5
Alluvium	Blackburn	T S	6 0 ± 3.0 3.4 ± 2.0	2.6 ± 1.5 2.0 ± 1 5
Middle Ecca Sediments	Windermere	T S	2.5 ± 1.0 1.5 ± 1.0	0 55 – 0.50 –

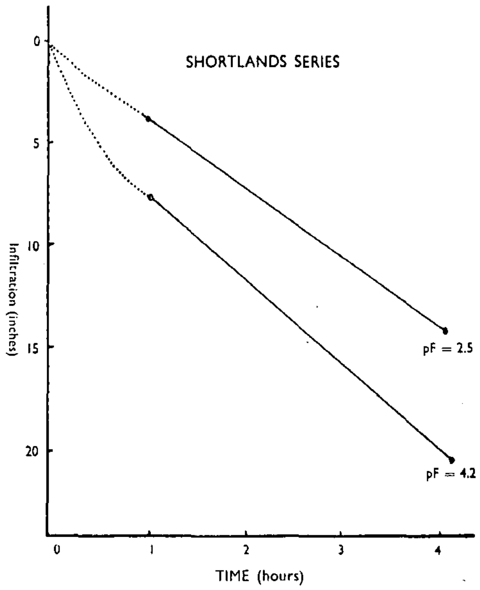

FIGURE 3

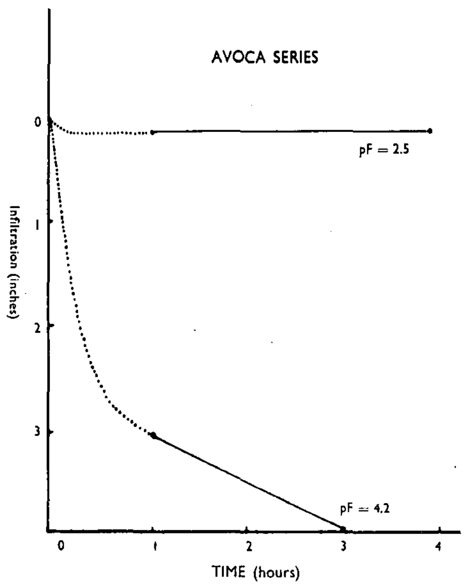

FIGURE 4

TABLE 2

The Influence of Antecedent Soil Moisture on Infiltration Capacities and Percolation Rates of Some Coastal Soils

Soil Series	pF	Infiltration Capacity in./hr.	Percolation Rate in./hr.
Williamson	4 2	10 0	0 50
	3 0	8 5	0 35
	2 5	0 3	0 27
Clansthal	4 2	16 0	13.0
	3 0	13 0	7 5
	2 5	9 0	4 0
Shortlands	4 2	8 7	4.0
	3 0	4 8	4.0
	2 5	3 8	3 5
Avoca	4 2	3 0	0 5
	3 0	1 0	0 1
	2 5	0 1	nil

TABLE 3

The Influence of Soil Compaction on Infiltration of Water into Two Soils

Soil Series		Compaction at pF 3.0 (lb./sq. in.)	Infiltration Capacity (in./hr.)	Percolation Rate (in./hr.)
Avoca	1	150	5 0	4.0
	2	300	0 5	0.2
Windermere	1	220	4 5	3 0
	2	500	0 7	0.6

The influence of antecedent soil moisture on infiltration rates has been reported by Tisdall, 1951. Since irrigation applications are made on soils in various states of moisture content, this aspect was also investigated. It was found that the higher the antecedent soil moisture content, the lower the infiltration capacity. However, as can be appreciated this factor had little effect on percolation rates. Table 2 and figures 3 and 4 illustrate this point.

Compaction in sugar belt soils is a problem which deserves detailed investigation on its own and this all-important factor was found to govern the infiltration of water into soils. Since infiltration depends to a certain extent on soil porosity and to a large extent on the pore-space geometry (that is, the pore size distribution), soil compaction, which is the reduction in pore space between the solid particles, plays a major role in infiltration and water movement. During the course of this work it was found that soil compaction was by far the most important factor influencing infiltration, and the magnitude of this effect is illustrated in table 3. Soil compaction is best measured by bulk density determinations, but for this work compaction was measured as resistance to penetration of a penetrometer, graduated in pounds per square inch.

Conclusions

From the results of this work it can be said that infiltration capacity and percolation rate determinations made with a double ring infiltrometer serve only as a rough guide to irrigation potential for a given soil series. No attempt has been made to classify soils on either criterion since results will depend entirely on the physical condition of the soil in question.

However, from this work has emerged the interesting point that a possible method for assessing a general physical condition of any given soil, is by infiltration studies. This concept merits further investigation.

Attempts to correlate these results within field values obtained by means of a portable runoff lysimeter will be reported at some later date.

Acknowledgment

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References

Thompson, J. C., and du Toit, A. A. (1962). Personal communication.

Tisdall, A. L. (1951). Antecedent soil moisture and its relation to infiltration. Aust. J. Agric. Res. 2, p. 342-348.

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Mr. G. D. Thompson (in the chair): For the first time at one of our congresses the inter-relationship between atmospheric and soil factors has been demonstrated. Transpiration, evaporative demand and soil moisture must be treated together and studied for each of our soil series.

It is rather surprising to note that the field determinations of field capacities for all the series, which differed quite markedly in texture, were all at pF 2.5.

Dr. Sumner: Yes, in the circumstances we had expected a variation of about 2.4 to 2.8.

Mr. Hill: All the soils were fairly compact and we used undisturbed soil cores, which probably influenced our values, but we did attain very close agreement between infield results and those obtained in the laboratory.

Dr. Sumner: The packing of the sand, either square or hexagonal, could give a variation between the infield method and the retention method in the laboratory, if disturbed soil samples are used.

Mr. Gosnell: In the first paper, in Table 2, the potential transpiration rate on the two sandy soils is .120 and .045 inches on hot and cool days respectively, whereas on a clay soil it is .100 and .030 inches. This seems to indicate that potential evapotranspiration, defined by Penman as being primarily dependent on atmospheric factors alone, is now also dependent on soil factors.

Mr. Hill: I assume the potential transpiration rate was the same in all soil types but it is possible that in the experiment the plants in the Clansthal/Fernwood soil series were slightly more mature than those in the Shortlands/Windermere/Milkwood Kraal soil series, although transplanted at the same stage. This might have contributed to the slight difference.

Mr. Gosnell: In Figure 4, capillary conductivity/available moisture relationship, when the tension rose above .8, did the capillary conductivity of Clansthal drop below that of Shortlands?

Mr. Hill: I do not think so.

Dr. Sumner: Still referring to Figure 4, from the textural nature of the soils, one would expect the capillary conductivity of Clansthal sand to be less than that of Shortlands clay, at high tensions, since the Shortlands, at the wilting point, holds far more water than the Clansthal. At the medium tension, the capillary conductivity of Clansthal should be of the same order as Shortlands.

Mr. Hill: I am not sure of that. From the values we have, except at field capacity, the differences at medium tensions were ten times lower in the Shortlands than the Clansthal.

Mr. du Toit: Surely the presence of trash must be considered, in respect to its effect on run off.

Dr. Sumner: There are different kinds of trash — different thicknesses, different degrees of decomposition etc., which we have not taken into account here, but which could possibly account for differences in results. But until the various qualities of trash are classified it will be very difficult to evaluate statistically. I hope the agronomists will help us over this.

Mr. Thompson: We have results on record — generally the minimum amount of trash gives the biggest response of cane. On an 11 per cent. slope on the Waldene series, over six months, 16 per cent. of the rainfall ran off bare soil but only 2 per cent. where there was a trash layer from a 35 tons cane per acre crop.

Dr. Sumner: It depends also on the rate of application of the water and infiltration capacity.

Mr. Thompson: Certainly. We were dealing with rainfall and Mr. Hill and Dr. Sumner were dealing with precipitation from irrigation rainers.

Mr. Hill: We conducted an experiment similar to the Waldene on our soils. With a constant application of one inch an hour on Shortlands, which has a good structure, infiltration capacity and percolation rate, and on a slope of 1 in 2.3, we measured no run off at all.

Mr. Thompson: The Waldene series has a poor infiltration capacity.

Mr. Hill: Our measurements show the Waldene series to have a fairly high infiltration capacity but low percolation rate.

Professor Orchard: You cannot generalise about this, particularly in view of the different conditions, or types, of trash.

Professor Scott has made run off measurements from an experiment that has gone on for nearly thirty years on veld. Rough veld that has never been burned or cut has a much higher run off than burned or cut veld. It provides such a thick covering that the water does not penetrate, hardly wets the soil, and eventually runs off in small channels. Similarly a thick trash layer could possibly give a big run off, whereas a thin one might improve infiltration.

Mr. Thompson: With regard to advection, I would suggest to Mr. Hill that in the particular work he was doing the roughness parameter would be more important than the height of crop. Even where advection is not important the roughness of the crop, affecting the wind function as it does, can be particularly important in establishing the amount of evaporation that takes place.

Dr. Cleasby: In connection with the experiment on the availability of water in soils, it must be appreciated that it was done with rather small cane in five gallon drums. If Mr. Thompson would now produce a reasonably cheap lysimeter the experiment could be carried out on fully-grown cane in the fields.

Mr. Thompson: We are trying to develop relatively cheap weighing lysimeters.

Also, we now have a neutron probe for measuring soil moisture in the field so we do not necessarily have to wait for the development of the lysimeters.

Gravitational water should receive more attention than it is getting. The available moisture-holding capacity of our soils can be as low as 1½ or 2 inches in the effective rooting zone and that amount of water can be used in six days by the crop. Gravitational water passing through this zone would also be used and contribute significantly to the requirements of the crop.

Mr. Hill: On certain soil types, gravitational water might decrease potential evapotranspiration through water logging effect. Soil root zone aeration is of prime importance.

Dr. Sumner: When you get below pF 2.5, it is difficult to measure the water being used by the crop from the gravitational pool as against the capillary pool of water in the soil.

Mr. Grice: What should be the depth of subsoiling in relation to water losses?

Mr. Hill: As long as subsoiling breaks the plough pan it is doing its job.

Mr. de Robillard: Mr. Hill mentions measurements for run off and infiltration, the first referring to loss of water and the second to moisture acceptance. Is the soil with an infiltration of ten inches an hour the same one with a run off of 50 per cent? If you apply rrigati on at one inch an hour you will therefo re lose 50 per cent, or half an inch, and yet the soil sho uld be able to take ten inches.

Mr. Hill: It appears that the principles of run off apply where the infiltration capacities of the soils are in the order one to two inches an hour. Over two inches we do not mention run off, but the compaction of the soil is also involved.

Dr. Sumner: The method we used for measuring infiltration probably gave an over-estimate of infiltration capacity, as defined by the difference between precipitation and run off.

Rain falling on a bare soil surface causes compaction for a centimetre or so on top of the soil, cutting down infiltration so that you get run off. The way to get a value for infiltration capacity which is fairly well related to the natural infiltration capacity of the soil is with rainfall simulators. They are not very portable, are costly and are tricky to operate and therefore the coverage that can be made in a given time is much less than that with the double ring infiltrometer. The answer is to correlate the values for a double ring infiltrometer with the rainfall simulator and then use the double ring infiltrometer. We are working on a rainfall simulator at the moment but it is not yet operating satisfactorily.

Mr. Wilson: Mr. Hill's earlier remark about breaking the plough pan makes me wonder why we bother to plough at all if subsoiling will give us the necessary penetrability and percolation rate.

Mr. Hill: A rugged plough going deep beyond the plough pan might be sufficient on its own, without subsoiler or anything else.

Mr. Pearson: Will not your deep ploughing simply give you a greater pan, so that you will be creating a worse situation, only deeper?

Dr. Cleasby: We have to get rid of our old crop so we have to plough. I would not advocate deep ploughing on soils where you have a reasonable depth of soil for roots to explore but on others it could be used as a possible method of making more soil.

Mr. Wood: In the Capillary Conductivity Table, the rates of removal are all extremely small. How does this fit in with the transpirational requirements of the plant?

Dr. Sumner: Capillary conductivity is a measure of the rate of replenishment of water between two points of different tensions. The exploration of the soil by the roots is such that water, at a point where there are no roots, will not have to move far to gain access to one. Although the figures are very small the replenishment of water seems to be adequate to meet crop demands.

Mr. Gosnell: Referring to Mr. Hill's paper on infiltration. Firstly, has he been able to calibrate the penetrometer? Secondly, in Tables 2 and 3 the percolation rate appears to have been affected by antecedent soil moisture in the Williamson and Clansthal series. Thirdly, the percolation rate appears to have been affected by the compaction. Was compaction measured on the surface or at lower depths ?

Mr. Hill: The Procter penetrometer has not yet been calibrated with the bulk density because with the Procter penetrometer you need to know the moisture content of the soil, but the bulk density is measured when the soil is oven dry. No undisturbed soil cores were taken for this purpose.

As regards compaction, the penetrometer merely indicates the firmness of the surface crust or any subsequent layer down to about 6 inches.

Dr. Sumner: In answer to Mr. Gosnell's question as to why the percolation rate varied, particularly with the Williamson series. The points for percolation rates and infiltration capacities with varying pF values, were measured at different sites, and consequently there were variations in the condition of the soil.

Dr. Roth: The soil must not be considered on its own when growing sugar cane is being discussed. After all, cane can be grown in a water culture, without any soil, provided it is given correct nutrition. The chemical, biochemical and microbiological aspects of the soil must also be taken into consideration.