IRRIGATION CHARACTERISTICS OF SOILS IN THE MAREEBA-DIMBULAH AREA OF NORTH QUEENSLAND

3. INFILTRATION CHARACTERISTICS OF THREE MAJOR SOIL TYPES

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SUMMARY

The infiltration characteristics of three soil types were examined using unbuffered ring infiltrometers. Both the measured rates and those corrected for lateral spread are given and penetration profiles are illustrated.

The use of various methods of irrigation are discussed on the basis of these results. Spray irrigation is recommended for Algoma loamy sand and Dimbulah sandy loam, whereas Walsh sandy clay loam could be efficiently irrigated by either spray or furrow methods.

I. INTRODUCTION

The first paper in this series (Keefer and Ward 1961) described three major soil types in the Mareeba-Dimbulah area of North Queensland and discussed their soil moisture characteristics. These soils are being utilized for the production of tobacco under irrigation. Studies on the infiltration capacities of the three soils were undertaken in order to assess their suitability for either spray or furrow irrigation.

Following the definitions of Richards (1954), in this paper the terms Infiltration Velocity and Intake Rate refer to rates in which no allowance is made for lateral water movement and the terms Infiltration Capacity and Infiltration Rate refer to rates that have been corrected for lateral spread.

II. METHODS

One of the aims of this work was to define those soils on which difficulty would be experienced in using furrow irrigation efficiently. A ponding method using an unbuffered ring infiltrometer was therefore selected as being most relevant to surface methods of irrigation. The method was essentially the same as that described by Stirk (1951) and outlined by Ward (1961).

Six tests (hereafter referred to as a trial) were run simultaneously on a particular date and for convenience were set out approximately 12 ft apart in two rows. The majority of the trials reported were conducted from February to August 1959 at various antecedent soil moistures. They were confined to an area of 1 square chain on the representative virgin sites previously described (Keefer and Ward 1961).

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A tube-type sampler was used to collect samples for the gravimetric determination of soil moisture. Antecedent soil moisture was determined at four positions in close proximity to each trial. On completion of each trial, the rings were left in position and the surface within each ring covered to prevent evaporation. Samples were then taken down the wetted profile within each ring after 24 hr on the Algoma, 48 hr on the Dimbulah and 72 hr on the Walsh soil types. These samples were used to determine the field capacity figures previously reported, the depth of penetration and also the fraction retained directly beneath the ring, using the method of Marshall and Stirk (1950). These authors discuss the limitations resulting from the use of such fractions to correct intake rates for lateral spread. It is probable that as a result of these limitations the infiltration rates reported in this paper are somewhat lower than actual rates.

III. RESULTS

(a) Walsh Sandy Clay Loam (Type 43)

The results for Walsh Sandy Clay Loam (Type 43) are presented in Table 1. For most of the tests antecedent soil moisture was approaching or below wilting point (4·5 per cent. at 0-6 in.)

TABLE 1

INFILTRATION DATA, WALSH SANDY CLAY LOAM

Date	Antecedent Soil Moisture (%)		Rate During Period (in./hr)							
	0–6 in.	0–18 in.	0–30 min		0–60 min		0–120 min		0–360 min	
			1*	2†	1*	2†	1*	2†	1*	2†
21.vi. 60	3·2	4·2	3·6	0·9	2·4	0·6	1·6	0·4	1·1	0·2
8.viii.59	3·5	5·5	3·2	0·7	2·1	0·5	1·5	0·3	1·1	0·2
21.vi. 59	3·7	5·5	4·2	1·1	2·9	0·8	2·0	0·5	1·4	0·4
30.vi. 59	4·1	4·8	4·4	1·1	2·9	0·7	2·0	0·5	1·4	0·4
18.v. 59	4·8	7·2	4·6	0·8	3·1	0·6	2·3	0·4	1·4	0·2
7.vii. 59	5·4	6·1	4·6	1·1	3·0	0·7	2·0	0·5	1·3	0·3
8.vi. 59	5·4	6·6	5·0	0·9	3·3	0·6	2·3	0·4	1·6	0·3
11.v. 59	6·7	8·5	3·2	0·8	2·1	0·5	1·4	0·4	0·8	0·2
2.vi. 59	10·4	8·9	3·8	0·7	2·5	0·4	1·7	0·3	1·1	0·2
13.iv. 59	18·5	16·1	3·5	0·2	2·3	0·2	1·5	0·1	1·1	0·1
Mean ..	6·6	7·3	4·0	0·8	2·7	0·6	1·8	0·4	1·2	0·2

*Actual mean figures for the particular trials (Intake Rate).

† Corrected figures using the mean correction factor for the particular trials (Infiltration Rate).

Line for Wilting Point lies below the figures for 30.vi.59.

Most of the trials were conducted for 6 hr. The average fraction retained directly beneath the ring after a 6-hr run was 0·21 ± 0·03. That is, almost 80 per cent. of the amount applied spread laterally. The lowest fraction retained (0·07) was in the trial conducted on April 13, 1959, when soil moisture was close to field capacity. This trend of lowest fractions retained at highest soil moisture levels was also noted on the other soil types.

For each trial the coefficient of variability for intake rates over the first hour was calculated. The mean coefficient of variability for all trials on this soil type was 17·2 ± 3·4 per cent.

Field observations indicated that the clay loam to loam B horizon commencing at 12-15 in. had a much lower infiltration rate than the A horizon. On June 21, 1960, six holes were dug to 12 in. and tests conducted on this horizon. At the same time six tests were run in the usual manner on the surface. The mean intake rate over a 6-hr period was 0·2 in. per hr on the B horizon, compared with 1·1 in. per hr on the A horizon.

(b) Algoma Loamy Sand (Type 32)

As indicated in Table 2, Algoma Loamy Sand (Type 32) was approaching or below wilting point (2·2 per cent. at 0-6 in.) for the majority of the trials.

TABLE 2

INFILTRATION DATA, ALGOMA LOAMY SAND

Date	Antecedent Soil Moisture (%)		Rate During Period (in./hr)							
			0–30 min		0–60 min		0–120 min		0–360 min	
	0–6 in.	0–24 in.	1*	2†	1*	2†	1*	2†	1*	2†
20.vii. 59	0·9	1·2	28·4	4·0	24·7	3·5	21·0‡	2·9	15·8‡	0·8
13.vii. 59	1·2	1·5	25·8	3·6	23·2	3·2	20·0‡	2·8	16·7‡	0·8
14.viii.59	1·3	1·4	13·6	1·9	12·6	1·8	11·5‡	1·6	10·0‡	0·5
28.viii.59	1·3	1·5	24·2	3·4	20·3	2·8	17·0‡	2·4	11·7‡	0·6
18.viii.59	1·3	1·5	10·4	1·5	9·4	1·3	8·6	1·2	7·3	0·4
19.v. 59	1·3	1·7	22·0	3·1	20·9	2·9	19·5	2·7	16·8	0·8
13.v. 59	1·6	1·9	17·2	2·4	16·1	2·3	14·2	2·0	13·7	0·7
14.iv. 59	2·6	3·7	20·4	2·9	19·4	2·7	17·5‡	2·5	13·3‡	0·7
4.vi. 59	3·1	2·7	25·6	3·6	25·2	3·5	19·0	2·7	15·9	0·8
24.ii. 59	3·5	3·6	14·6	2·0	13·8	1·9	12·6	1·8	10·0‡	0·5
6.iv. 59	6·3	5·9	28·2	4·0	24·4	3·4	20·0‡	2·8	15·0‡	0·8
9.iii. 59	6·4	5·6	20·4	2·9	18·2	2·5	16·0‡	2·2	13·3‡	0·7
Mean ..	2·6	2·7	20·9	2·9	19·0	2·7	16·4	2·3	13·2	0·7

*Actual mean figures for the particular trials (Intake Rate).
† Corrected figures using a mean correction factor of 0·14 (Infiltration Rate).
‡ Obtained by extrapolation.
Line for Wilting Point lies below the figures for 13.v.59.

Most of the trials were run for 1 hr. For all tests conducted over this period, the mean fraction retained was 0·14 ± 0·03. To ascertain the change of rate with time over a longer period, some tests were run for periods of up to 6 hr, although this involved much heavier applications than would normally be used in irrigation practice. In these trials it was found that, as the total amount applied increased, the fraction retained decreased. A mean correction factor of 0·05 was used in correcting the 6-hr intake values in Table 2. It was considered that the 1-hr correction factor would be more applicable to the early stages of infiltration and this factor was used to correct all rates up to 2 hr.

By plotting on a log log basis the data from tests conducted for more than 1 hr it was found that the relationship approached a straight line.

The mean coefficient of variability for all trials (determined on 1-hr accumulated intake values) was 17·1 ± 8·8 per cent.

As pointed out by Keefer and Ward (1961), there are at least two phases of this soil type. The general area of the soil is a loamy sand through which run ridges of a coarse sandy phase. As far as possible, the coarse sandy phase was avoided in these studies, so even higher intake rates could be expected where this phase is involved.

(c) Dimbulah Sandy Loam (Type 41)

The results for Dimbulah Sandy Loam (Type 41) are presented in Table 3. For most of the trials the soil was approaching or below wilting point (2·6 per cent. at 0-6 in.)

TABLE 3

INFILTRATION DATA, DIMBULAH SANDY LOAM

Date	Antecedent Soil Moisture (%)		Rate During Period (in./hr)							
	0–6 in.	0–18 in.	0–30 min		0–60 min		0–120 min		0–360 min	
			1	2	1	2	1	2	1	2
12.viii.59	1·1	2·8	7·4	1·5	6·5	1·3	5·5‡	1·1	4·2‡	0·4
3.viii.59	1·3	2·8	6·8	1·4	6·0	1·2	5·6	1·1	5·2	0·5
21.v. 59	1·4	1·9	7·6	1·5	6·9	1·4	6·6	1·3	6·2	0·7
27.vii. 59	1·4	2·6	7·6	1·5	6·6	1·3	5·5‡	1·1	4·2‡	0·4
29.vi. 59	1·7	2·9	8·0	1·6	7·2	1·4	6·8	1·4	6·4	0·7
12.v. 59	1·9	2·9	6·0	1·2	5·2	1·0	4·8	0·9	4·7	0·5
10.vi. 59	2·8	3·5	12·4	2·5	11·4	2·3	10·4	2·1	8·4	0·9
3.vi. 59	4·4	4·7	13·2	2·5	12·1	2·4	11·3	2·3	9·8	1·0
19.ii. 59	4·5	5·5	15·4	3·1	14·1	2·8	12·5‡	2·5	10·0‡	1·1
10.iii. 59	4·6	5·4	12·6	2·5	11·6	2·5	10·0‡	2·0	7·5‡	0·8
7.iv. 59	5·2	7·7	9·6	1·9	8·5	1·7	7·4‡	1·5	5·4‡	0·5
18.iii. 59	7·3	8·5	12·4	2·5	11·2	2·2	10·0‡	2·0	8·0‡	0·9
Mean ..	3·1	4·3	10·0	1·9	8·9	1·8	8·3	1·6	6·6	0·7

1. Actual mean figures for the particular trials (Intake Rate).

2. Corrected figures using a mean correction factor of 0·20 (Infiltration Rate).

‡ Obtained by extrapolation.

Line for Wilting Point lies below figures for 12.v.59.

Six trials were run for periods of 1 hr, and other trials were run for periods of up to 6 hr to ascertain the change of rate over a longer period. For the 1-hr tests the average fraction retained was 0·20 ± 0·02. This correction factor was used to correct all values up to 2 hr in Table 3. As the length of runs increased, it was again found that the fraction retained decreased and for the 6-hr values a mean correction factor of 0·11 was used.

The mean coefficient of variability for all trials on this soil type (determined on 1-hr accumulated intake values) was 18·5 ± 6·4 per cent.

(d) Comments

The infiltration rates for all soil types are summarized in Figure 1, which shows the change in infiltration rate with time over the first 3 hr. On all soil types there is a very marked decrease within the first half hour. On the Walsh soil type a comparatively steady rate is reached after the first hour and in a trial conducted on June 21, 1960, this rate was found to remain relatively constant for 12 hr. In the case of Dimbulah Sandy Loam the intake rates showed a slight decline after the first 30 min. However, the fraction retained directly beneath the ring decreased as the trials progressed and hence the infiltration rates plotted in Figure 1 show quite a marked decline. A similar but sharper decrease will be noted on Algoma Loamy Sand.

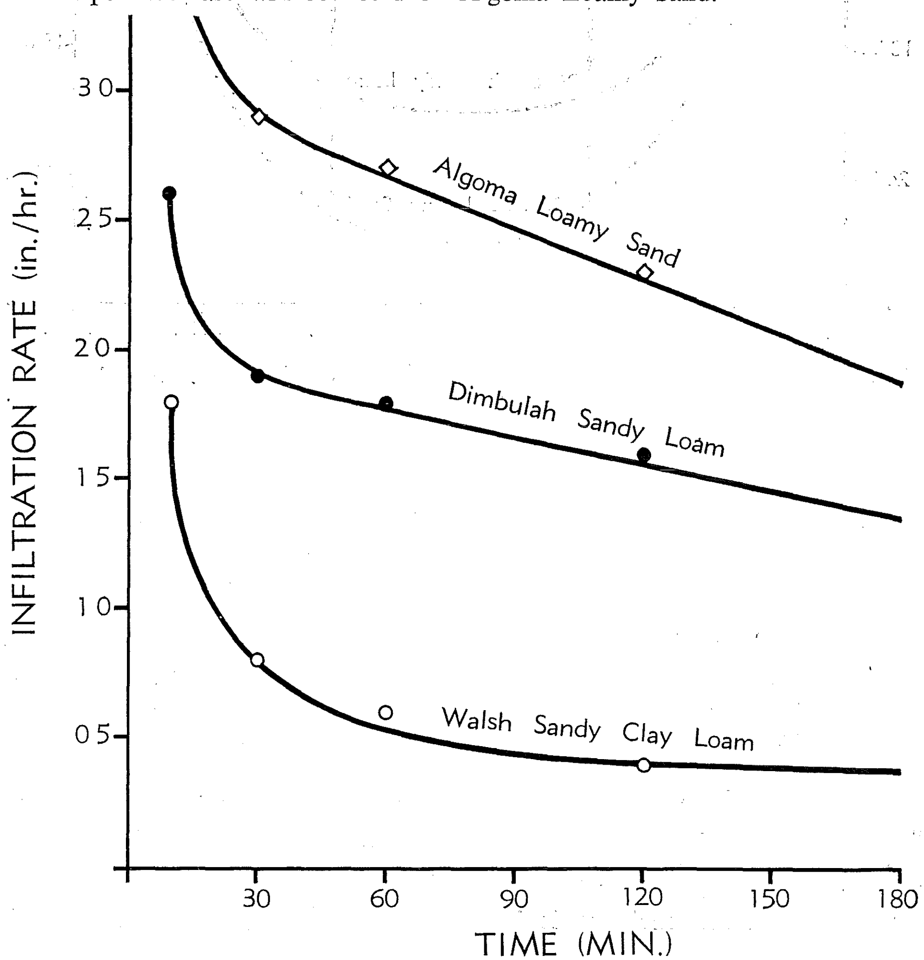

Fig. 1.—Change in infiltration rate with time.

On a number of occasions, pits were dug to expose the wetted profiles. As a result of these observations, Figure 2 has been drawn to represent the average penetration profiles immediately after 7 in. had been applied to each soil type. On the Walsh soil the B horizon considerably restricts downward movement.

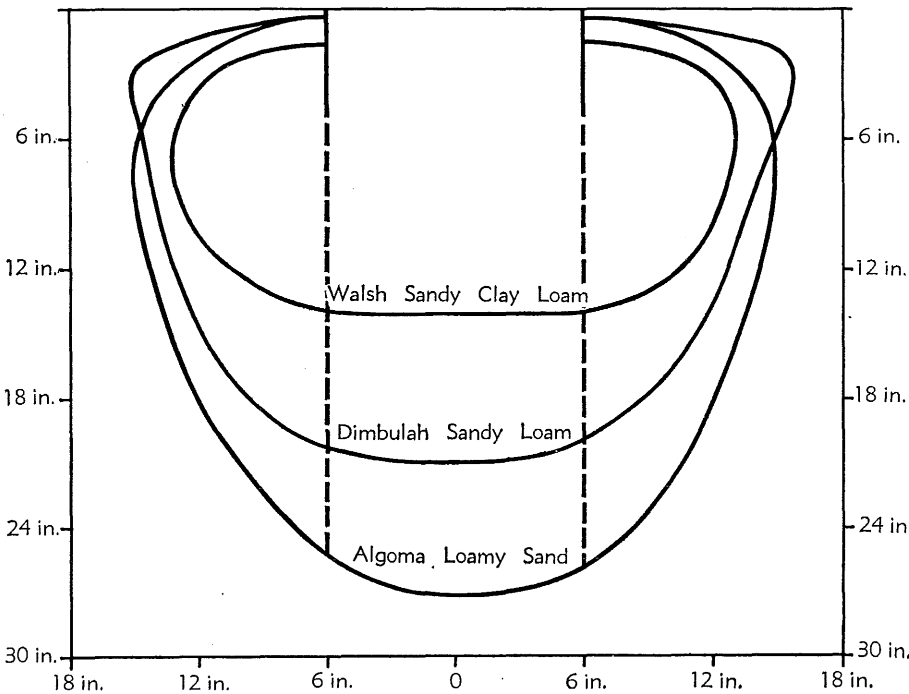

Fig. 2.—Ideal penetration profiles immediately after 7 in. had been applied to each soil.

IV. DISCUSSION

It has long been known that initial moisture content exerts a considerable effect on infiltration. Tisdall (1951) carried out the first Australian enquiry into the relationship and his observations are in agreement with the theoretical conclusions of Philip (1957). Tisdall found that the lower the initial soil moisture the higher the infiltration rate but suggested that the longer the time of application the less effect the antecedent soil moisure would have. An endeavour was made to take cognizance of this factor by conducting the trials reported here after the northern "wet" season as the soil moisture declined.

Although there are only a limited number of observations from the field capacity end of the available moisture range, neither the intake rates nor the infiltration rates show a significant increase with decreasing soil moisture. In the case of Dimbulah Sandy Loam a positive correlation rather than a negative correlation with soil moisture is indicated, inasmuch as the mean infiltration rate for tests conducted below wilting point is 1·5 in. per hr, compared with an infiltration rate of 2·5 in. per hr for tests conducted above wilting point. However, the difference is still within the variability recorded on this soil type.

A number of investigators have found higher infiltration rates during the summer than during the cooler seasons of the year (e.g. Parr and Bertrand 1960). Factors other than soil moisture that could produce this result are soil and water temperatures and water viscosity. As the temperature increases to 30°C (85°F), a corresponding increase in infiltration rate has been reported. The temperature records in Table 4 show that there was a general decrease in temperature to June and then a slight increase in July and August. It is suggested that, although the soil moisture level was decreasing, the expected small increase in infiltration rate could have been compensated by the decrease in temperature. However, the results were obtained under conditions which would be representative of irrigation practice.

TABLE 4

MEAN MONTHLY TEMPERATURE (°F), FEBRUARY TO AUGUST, 1959

Month	Maximum	Minimum	Mean Hourly	Earth 4 in.	Earth 8 in.
February	87·0	67·5	76·5	81·0	83·5
March	90·5	68·5	77·0	78·0	79·0
April	81·5	59·5	70·5	71·5	73·3
May	75·0	58·0	65·3	67·6	69·3
June	74·5	35·5	54·7	61·5	64·5
July	78·4	43·6	61·4	63·4	66·0
August	75·7	50·1	63·7	56·3	68·4
Mean	80·4	54·7	67·0	68·5	72·0

Parr and Bertrand (1960) in their review of water infiltration into soil state that ". . . it is well to consider that there may be far greater variation between the infiltration rates obtained under different surface conditions on a single soil type than might be found for different soil types having the same surface conditions. This may make it necessary to think of infiltration rates characteristic of surface conditions rather than characteristic of a specific soil type". The formation of a compacted layer at the immediate surface appears to be the principal reason for the lower infiltration rates frequently reported on cultivated land.

An attempt was made to evaluate the changes likely to occur after cultivation of the soil types under consideration. Six infiltrometer tests were run in furrows previously compacted by furrow irrigation on both the Walsh and the Algoma soil types. On the Walsh an uncorrected intake rate of 0·5 in. per hr was recorded, compared with 1·5 in. per hr on virgin soil having a similar soil moisture level. On the Algoma an uncorrected rate of 6·0 in. per hr was measured, compared with 18·0 in. per hr on virgin soil with a similar soil moisture level. Both these cultivated areas had grown at least two tobacco crops. After a period under cultivation the intake rates could be expected to be reduced to approximately one-third of their original values.

The rates reported in this paper could be considered as maximum rates, being obtained at low antecedent soil moistures on freshly cultivated virgin soils.

The results indicate that the compact B horizon on Walsh Sandy Clay loam restricts the downward movement of water. The penetration profile in Figure 2 illustrates this point further. This would have been expected from the high bulk density figures quoted by Keefer and Ward (1961) and indicates that this soil has good external drainage but poor internal drainage. One advantage of the extensive lateral movement of water should be a more complete irrigation of the surface horizons in furrow irrigation.

The B horizon on Dimbulah Sandy Loam affects the infiltration process to a much smaller extent.

Finkel and Nir (1960) have reviewed the criteria for the choice of irrigation method, i.e. spray, furrow, multi-furrow or flood. The infiltration rate is a basic design factor for all methods of irrigation. Spray irrigation can be designed for soils with a wide range of infiltration capacities and is most useful for soils with a high infiltration rate. For furrow irrigation there is a limiting infiltration rate above which it is difficult to design a practicable layout.

The above authors state that as a general criterion soils with an infiltration rate below 0·5 in. per hr are suitable primarily for gravity methods, and those with infiltration rates above 3 in. per hr are suitable only for spray irrigation. Those in between these limits are suitable for either method and other criteria govern the method of application. Finkel and Nir do not discuss the method of measuring infiltration nor whether the limits apply to the maximum or minimum rates on any soil type.

The mean 30-min and 60-min corrected values in the tables indicate that all the soils could be included in the intermediate group, with the Walsh soil type at the bottom of the range and the Algoma soil type at the top of the range.

The application of the other criteria discussed by Finkel and Nir indicate that for tobacco growing Walsh Sandy Clay Loam could be efficiently irrigated by either furrow or spray irrigation. On Dimbulah Sandy Loam, slopes of 2·5 per cent. and greater would favour spray irrigation and this method of irrigation is also indicated on Algoma loamy sand. Practical tests and experience in the field favour these conclusions.

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