SCHOOL OF ENGINEERING AND ENGINEERING TECHNOLOGY

FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA.

EVALUATION OF FURROW IRRIGATION SYSTEM AT NIGERIAN SUGAR COMPANY (NISUCO) BACITA, KWARA STATE, NIGERIA.

BY

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Sign.............. Date..........

DEPARTMENT OF AGRICULTURAL ENGINEERING

FEDERAL UNIVERSITY OF TECHNOLOGY, (F.U.T) MINNA.

A PROJECT REPORT

ON

EVALUATION OF FURROW IRRIGATION SYSTEM AT NIGERIAN SUGAR COMPANY (NISUCO) BACITA, KWARA STATE, NIGERIA.

BY

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Submitted in partial fulfilment of requirements for the award of Bachelor of Engineering. (Agricultural Engineering).

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DEDICATION

This project report is dedicated to my late grand father, Alhaji Salami Oladodo, who died on 4 th of june,1989. May his soul rest in perfect peace Amen.

ACKNOWLEDGEMENT

In an endeavour of this kind, a number of people too numerous to mention in this brief acknowledgement have offered valuable supports and assistant. My profound gratitude and appreciation go to Engineer F.J Makanjuola, the field manager for Nigerian Sugar Company, Bacita and the project site supervisor for his co-operation, special interest and sound judgements on many points of field experimentation, all of which have made this project successful. My thanks also go to Mallam S.N Mustapha who helped by conveying me to the project site everyday .

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Finally, I would like to express my appreciation to all those who have contributed in one way or the other to the good success of this project but whose names are not mentioned.

I wish you all God's help and guidance in all your endeavour.

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ABSTRACT

This project report present an evaluation of furrow irrigation system at Nigerian Sugar Company Bacita, Kwara State, Nigeria. The evaluation was based on the data collected during the field experimentation.

Inflow-outflow method (using a V-notch weir) was used to determine the intake rate characteristics of the soils. From the analysis of data obtained, the roughness coefficient of the furrow, n = -0.53, the infiltration rate capacity, I = 10.1mm/hr while the irrigation time was computed to be 11.6hrs. The investigation further showed that the water application efficiency was 71% and the potential application efficiency (system efficiency) was 78%. These values indicate fairly good management of the project under study. There is however much room for improvement.

CHAPTER 1

INTRODUCTION

1.1 Introductory Note

This study was aimed at evaluating the furrow irrigation system at Nigerian Sugar Company (NISUCO), Bacita, in Kwara state, Nigeria. Sound evaluation or appraisal implies that the technical, commercial, management, financial and economic aspects of the project can satisfy various tests of consistency and efficiency and can, therefore justify its worth to society.

This investigation however addressed the technical evaluation. It involved performance of tests and analysis of results of field central number 6c of the project area of NISUCO. The following parameters were determined:

(i) depth of water to be applied

(ii) furrow water advance rate

(iii) furrow infiltration rate

(iv) net depth of application

(v) roughness coefficient of the soil of the project area under investigation.

(vi) field application efficiency and

(vii) potential application efficiency.

Irrigation characteristics curves, such as furrow intake-time relationship, advance distance-time relationship were also presented graphically.

A 90° V-notch weirs were constructed and used to determine the inflow and outflow amount of water through the furrow, during the field test.

1.2 Location and Crop grown

1.2.1 Location

The sugar estate is located in Bacita (longitude 9°N and latitude 5°E) a small town about 120km North of Ilorin, the Kwara state capital, of Nigeria.

1.2.2 Crop grown

According to Doorentosetal (1979), sugarcane (saccharum officinarum) is a tropical crop which is grown predominantly between latitudes 30°N and 30°S. The suitable temperature range is between 18°C and 30°C. In most of the growing areas, crop production is often restricted by limited seasonal rainfall. Sugarcane requires between 1500mm to 2500mm of water per year depending on the climate (Doorentosetal 1979).

1.3 Objectives of this project

The objectives of this project were:

(i) To determine the efficiency of the system as it is being used. This involved determination of actual water application efficiency.

(ii) To determine how effectively the system can be operated and whether it can be improved upon. This involved determination of potential application efficiency.

(iii) To obtain information that will assist engineers in designing similar system. Such information is the infiltration characteristic equation of the soil type present on the field.

1.4 Justification of this project

This study was conducted to check how the furrow irrigation system at Nigerian Sugar Company, Bacita was being operated so as to find out possible improvement on the irrigation efficiencies (water application efficiency and potential application efficiency) based on the investigation. In addition, knowledge of the soil properties at the project site such as the soil infiltration characteristics are necessary for overall soil and water management and improve on design of the project. Such information will also be useful in maximum benefit for the entire project site which will in turn increase the sugarcane production as well as justify its worth to society.

CHAPTER 2

REVIEW OF LITERATURE

2.1 Introduction

Evaluation of existing systems can be approached in a number of ways. A simple method of determining under irrigation is by use of the soil auger or tube sampler. Observation of the opportunity time for infiltration in various parts of the field may be helpful. More sophisticated methods involved application of such equipment as portable flumes, meters and water intake rings in carefully conducted diagnostic procedures, such as described by Merriam (1968).

In evaluating of present practices the independent variables, such as discharge Q, hydraulic slope S, Manning roughness n, infiltration constants and time of cutoff are the basic parameters needed. The irrigation conditions of the particular field should be described and with the parameter obtained, a model will predict the dependent parameters such as advance, recession, infiltration, runoff, deep percolation, efficiency and uniformity. Models are mechanism that can tell us quickly, reliably and economically where irrigation water will go under given conditions and the mechanism is achieved through a description of surface irrigation hydraulics.

Fangmeier and Strelkoff (1978) showed the effects of Manning roughness (n) on advance recession, efficiency and uniformity. They noticed that the advance and recession curves are quite different for each Manning (n) values, but the effect on efficiency and uniformity is surprisigly small. They also demonstrated the usefulness of models by analyzing the effect of infiltration on efficiency and uniformity. The defect is that, it would be impractical and impossible to achieve this with field experiment.

New concepts are continually being suggested to improve irrigation system performance. The potential of these concepts as well as others in use can in some instances be evaluated with models less expensively than with any other procedure. For example, the result of using variable land slope within a single field can be determined and information gained on how the slope should vary for maximum benefit. This is less expensive than if field tests were made to get the same information. Models could also be used to study the effect of using various analytical expressions for infiltration and for surface resistance to flow.

2.2 Basic Theory

In furrow irrigation, water is passed along the furrows and infiltrates into the soil. The water infiltrates rapidly at first and then more slowly, often inversly proportional to the square root of the elapsed time, as indicated in Fig. 2.2.1. For any desired application depth, there is a required intake opportunity time as shown, when water must be present in the furrow.

When the irrigation starts, the stream front advances down the furrow as shown in Fig. 2.2.2. Larger streams would advance faster, but too large a stream will cause erosion or overtop. Too small a stream may never reach the other end of the furrow.

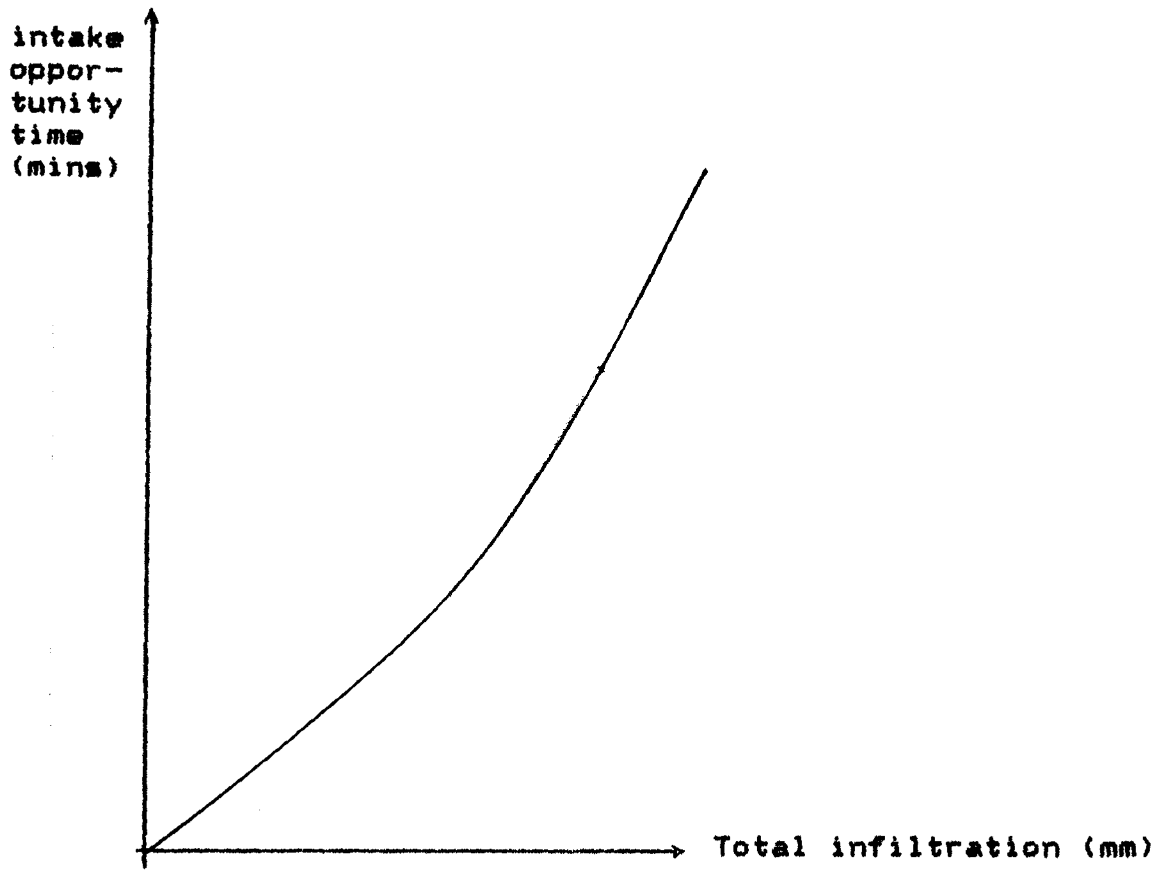


Fig. 2.2.1 Intake opportunity time versus Total infiltration

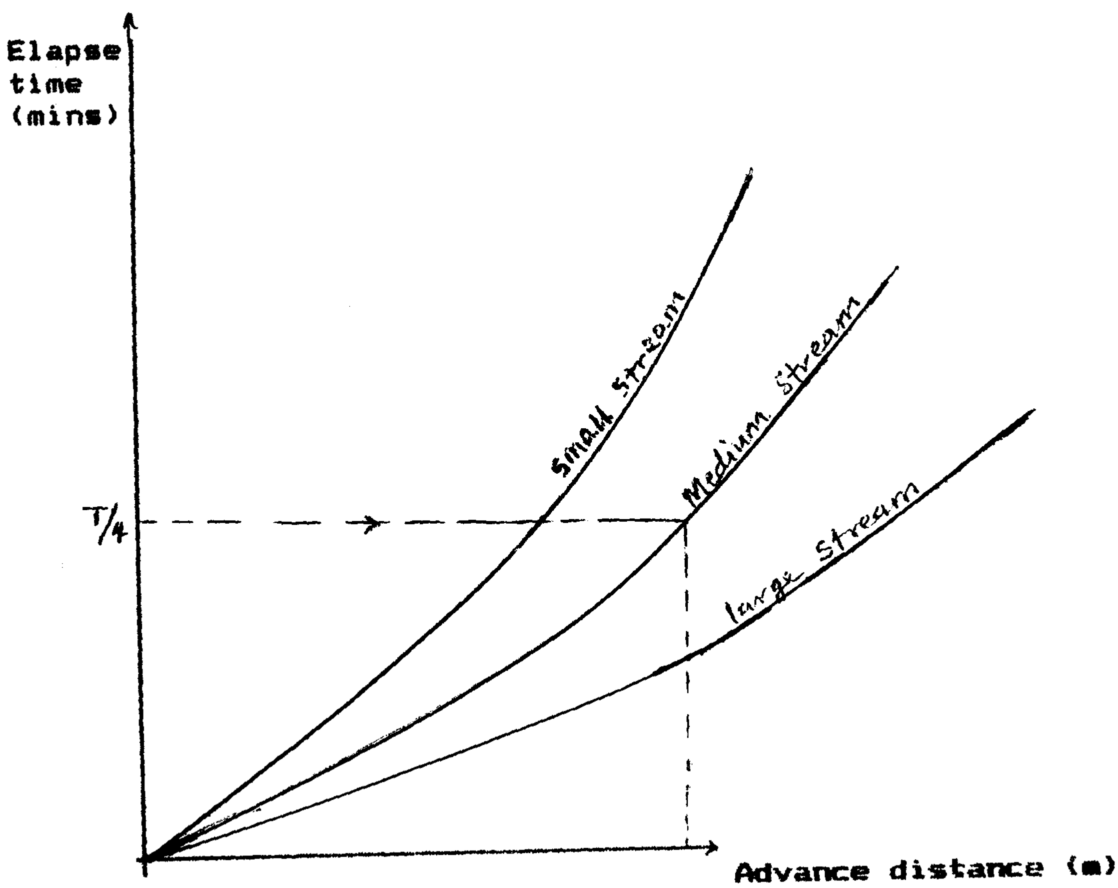


Fig.2.2.2 Elapse time versus Advance distance

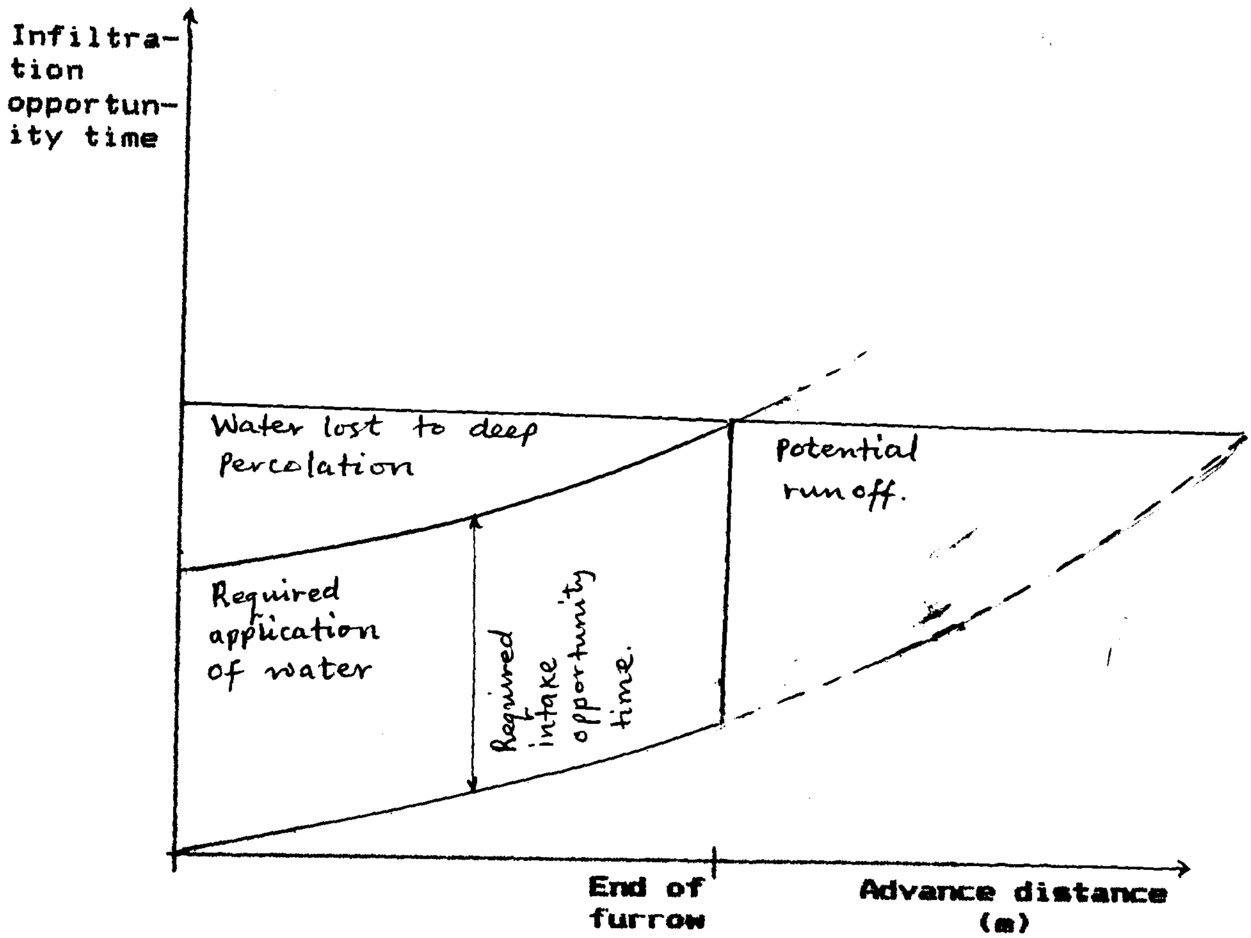


Fig. 2.2.3 Infiltration opportunity time Versus Advance distance

When the irrigation stops, the recession wave passes more quickly, and for practical purpose it is assumed all flow stops simultaneously. Thus, the intake opportunity time is greater at the head of the furrow than the tail, as shown in Fig. 2.2.3. The extra infiltration at the head is lost to deep percolation.

To minimize this loss, the advance time should be shortened. The largest practical non-erosive stream should be used. The furrow length could also be shortened, but this will increase labour requirements for irrigation and impede mechanization. A useful compromise is to set the furrow length to give an advance time of T/4, where (T) is the required intake opportunity time. This then gives a 25% difference in intake opportunity times, and if the square root relationship is valid, the average deep percolation loss is only about 5% USDA (1956).

Water is also lost as end runoff once the stream reaches the tail of the furrow. This may be re-used further down the system or pumped back to the head channel, or the runoff may be reduced by cutting back the stream size once the tail is reached. If the water is completely lost however, this must be taken into account and a longer furrow may prove more efficient. Where water use is not critical, longer furrows with advance times of T/3 or T/2 may be more practical. The simple field test described in chapter 3 is used to obtain the infltration data and the advance data for the system in use and from which efficiencies of the system were calculated and irrigation characteristic curves plotted.

2.3 Design parameters of furrow irrigation system

For effective design the variables involved in the hydraulics of surface irrigation should be recorgnised and understood. According to Hansen (1960) they are:-

(i) size of the stream

(ii) rate of advance

(iii) length of run and time involved

(iv) depth of flow

(v) intake rate

(vi) slope of land surface

(vii) surface roughness

(viii) erosion harzard

(ix) shape of flow channel

(x) depth of water to be applied

(xi) fluid characteristics.

Since the hydraulics of surface irrigation is complex and since some of the variables involved have not been evaluated and their relationships have not been determined, empirical procedures are often employed in design of surface irrigation system. Schwab et al (1981).

2.3.1 The existing data obtained from Nigerian Sugar Company, Bacita includes:

(i) type of soil	= clay loam
(ii) furrow spacing	= 75cm
(iii) consumptive use	= 8mm/day
(iv) irrigation cycle	= 14days
(v) area of the field	= 2.94ha
(vi) land slope	= 0.2 to 0.5%
(vii) length of the existing furrow	= 350m
(viii) application depth	= 76mm
(ix) management allowed deficiency, MAD	= 50%
(x) the design stream size	= 1.5l/s

2.4 Soil infiltration characteristics

The rate of infiltration influences the surface flow and the entire irrigation performance. The rate is bounded by two conceptual limits, zero for an impermeable bed and some high, nearly constant value for a highly porous bed. To make infiltration characteristic more understandable the Kotstiako (1932) equation is used to describe it:

$$I = KT^n \text{ ....(1)}$$

where

I is the infiltration rate (mm/hr)

T is the infiltration time (hr)

K and n are constants for a particular soil and condition, n has negative sign.

By integrating (1) with respect to time, the depth (D) of water that would have infiltrated into the soil up to that time is obtained.

$$D = \int I dt$$

$$= \int KT^{n} dt$$

$$= \frac{K}{n+1} T^{(n+1)} \qquad \text{.............................(2)}$$

Values of the soil constant for either the rate or depth equation can be obtained from existing information sources, such as United States Department of Agriculture (USDA) soil conservation service or can be measured in the field. These constants should be carefully selected since infiltration rate have marked effect on irrigation system performance. In this investigation, equations (1) and (2) were used and the values of K and n determined for the site under study.

CHAPTER 3

METHODOLOGY AND MATERIAL

The use of 90° V-notch weir was adopted to determine the inflow and outflow amount of water through the furrow during the field test. The reason for using 90° V-notch weir is due to the fact they are easier to handle, give accurate results because the flow is small and it is economically viable. The 90° V-notch weir used in performing the field test were designed and constructed locally by the author at Nigerian Sugar Company Bacita. The dimension of the 90° V-notch weir is given in Fig. 3.1 and the discharge through it was computed using the formula given below (Micheal, 1985) :

$$Q = 0.0138H^{5/2} \qquad \text{.........................(3)}$$

where

Q = discharge through the V-notch weir. (l/s)

H = depth of water flowing above the V-notch (cm)

In the determination of moisture content level of the soil, gravimetric method was used as explained in section 3.1.2 .

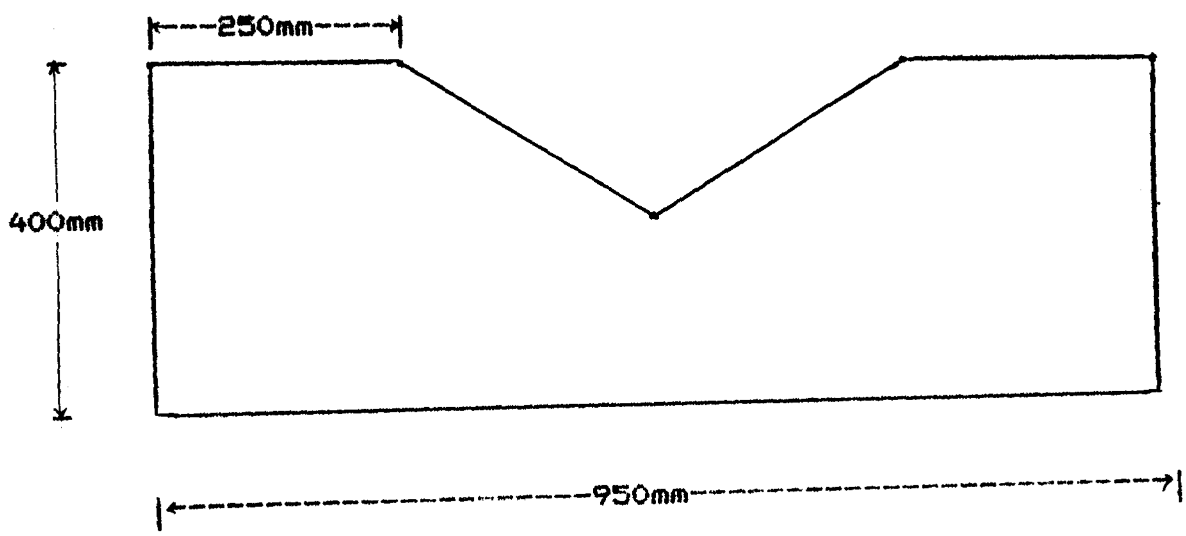


Fig. 3.1 A 90° V-notch weir

3.1 Field Experimentation

3.1.1 Determination of rootzone depth of the sugarcane

The determination of rootzone depth of the sugarcane was performed by digging round a stand of sugarcane and carefully pulled out to prevent breakage of the root. Metre rule was then used to measure the root length. This procedure was repeated for ten stands of sugarcane at different locations, the longest root was found to be 70cm. (see plate 1)

Plate 1. Measurement of root length.

3.1.2 Gravimetric method of soil moisture measurement

The soil samples were collected with auger hoe (see plate 2) and poured inside the sampling cylinder until it filled up and kept inside a polythene bag. The sample was obtained at depth between 45 and 70cm. The soil sample together with the sampling cylinder were weighed when moist and then put inside oven at 105°C. The sample was left inside the oven for 24hours and then weighed, the weighing was repeated until there was no change. The constant weight was recorded as the weight of the dried soil. The readings obtained are as given in appendix C1. The weight and dimensions of the sampling cylinder were also measured and recorded.

Plate 2. soil sample collection using auger hoe.

3.1.3 Determination of accumulated depth and furrow water advance rate

To measure the incoming flow rate the 90° V-notch weir was installed at furrow inlet (see plate 3). The furrow was then divided into number of section of length twenty metres (20m) interval. The furrow cross-sectional profile at representative locations in the test furrow were determined. The furrow spacing was determined by measuring the distance between the centre of the adjacent furrow.

Water was then allowed to pass through the 90° V-notch weir, the head (H) of water above the V-notch was measured and kept constant at 6.5cm which corresponds to the design stream size. The following parameters were determined, the time spent by the flowing water to pass each marked position, the depth of flow and the width of flow. The readings are given in appendix C2 and C3. With the data obtained, the following parameters were obtained:-

Furrow cross-sectional area corresponding to the depth of flow (cm^2), accumulated infiltration volume (litres) and accumulated infiltration depth (cm). Graphs were also plotted to show the irrigation characteristic curves (Fig. 4.3 and 4.4) in chapter 4.

This method of determination of accumulated depth is known as balance method, and is considered to be satisfactory because it gives the average infiltration value by compensating various errors, inherent in the furrow arising out of soil heterogeneity, furrow cross-sectional difference, cracks, and puddling effects.

Plate 3. Installation of 90° V-notch weir

3.1.4 Inflow-outflow method of determining infiltration rate

This method involved the use of two 90° V-notch weirs, the first one was installed at a station A, one metre from the furrow inlet, and the second 90° V-notch was installed at station B, thirty metres (30m) from station A. Water was then allowed to flow into the selected furrow through the 90° V-notch at station A. The time spent by the flowing water to advance to station B, was noted. The measurement of the head (H) of water above the notch at stations A and B were made at intervals of time. with the head recorded, the corresponding discharge at each weir were calculated using equation (1).

The loss of water by infiltration was obtained as the difference between discharge at stations A and B. The infiltration rate was then obtained by using equation (4) below. The data obtained are presented in appendix C4. Stop watch was used to note the time interval, metre rule was used to measure head above the V-notch weir, the two 90° V-notch weirs were used to determine the quantity of water at the inflow and outflow points of the furrow. A measuring tape was used to obtain the distance between the two 90° V-notch weirs and the furrow spacing. The equation used to obtain infiltration rate is given below: (A.M Micheal 1985)

$$I = \frac{q * 3600}{W * L} \quad (mm/hr) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(4)$$

Where

q = loss of water by infiltration (l/s)

W = furrow spacing (m)

L = length of testing portion of a furrow (m)

CHAPTER 4

RESULT AND DISCUSSION

4.1 Results of analysis

Analysis of the field data obtained from all the tests are presented below.

4.1.1 Soil intake characteristic

The intake characteristic equation of the soil are represented by (See Fig. 4.1):

$$I = 126T^{-0.53}$$

Where I = infiltration rate (mm/hr)

T = irrigation time (min)

4.1.2 Infiltration rate capacity

From Fig. 4.2, the infiltration rate capacity was found to be 10.05mm/hr.

4.1.3 furrow length

From Fig. 4.3, the distance advanced by the water was 168m at the time 175min, which is the quarter of the irrigation time.

4.1.4 Infiltration depth

Figure 4.4 shows that the accumulated infiltration depth increases as the opportunity time increases. At the quarter of irrigation time, the accumulated infiltration depth was obtained to be 84mm.

4.1.5 Irrigation time

The irrigation time was found to be 11.6hrs. (see appendix B3)

4.1.6 Field efficiencies

The water application efficiency was calculated to be 71% and the potential (operating) efficiency for which the system was designed was evaluated to be 78%. (see appendix B4)

4.1.7 Soil moisture measurement

The following parameters were obtained from soil test using oven dry method (appendix B1):

(i) moisture content m.c = 19.5%

(ii) moisture holding capacity ch = 277mm/m depth of soil

(iii) available moisture Θ = 194mm

(iv) depth of water applied =97mm

4.1.8 Other parameters obtained

(i) accumulated depth of application dg = 96mm

(ii) gross depth of application dg = 135mm

(iii) volume of water to irrigate the field = 3980.76m^3

(iv) lateral canal design capacity = 95.331/s

(v) rootzone depth of crop drz = 70cm

4.2 Discussion of results

In discussing the result, the following limitation are firstly enumerated.

(i) The furrow infiltration test was carried out by using locally constructed 90° V-notches on the field and assuming several ideal conditions.

(ii) The V-notch weir was placed across the furrow and roughly level by pressing firmly into the furrow profile and assumed horizontal.

(iii) Slope of the furrow base varies down the furrow length ranging from 0.2% to 0.5%, but assumed to be fairly uniform for practical reasons.

(iv) Fluctuation heads down the furrow length was observed on applying the water stream at the furrow head and it was as a result of non-uniformity of furrow roughness.

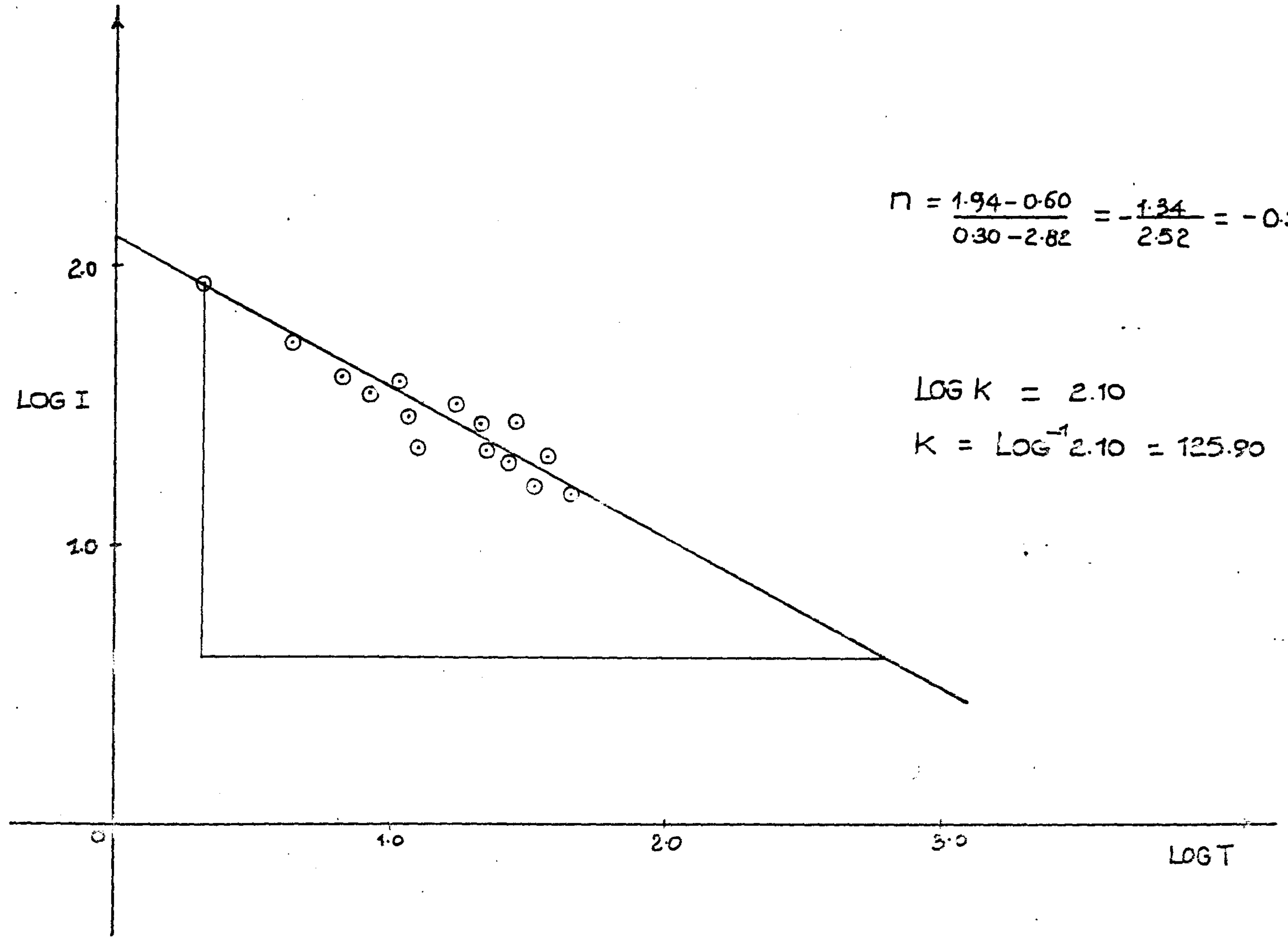
(v) On shutting off the supply stream at the furrow head recession waves were seen to be diminishing down the furrow, but assumed to be instantaneously cut-off as the supply stops.

(vi) The total losses between the two gauging stations A and B were assumed to be purely due to infiltration, neglecting seepage and evaporation.

All the aforementioned limitations will no doubt affect the results of the experiment. Nevertheless, the values of K and n from the infiltration curve (Fig. 4.1) were 126 and −0.53 respectively. The infiltration rate which was obtained as 10.05mm/hr (Fig. 4.2) found to be slightly higher than the value 7.5mm/hr obtained when same soil sample was analysed (Mazumder, 1983). The reason for this difference could be because of variation in soil constituent along the furrow length. The effective irrigation time (T) for the soil type on the experimental site was estimated to be 11.6hrs (appendix B3). Preliminary observation showed that water was often left inside the furrow for more than a day before it was allowed to flow out. This practice encourage too much water loss to deep percolation. To determine the water advance distance for efficient irrigation, the "quarter-time rule" which suggest a furrow length such that the advance water reaches the end of the furrow in one-quarter of the irrigation time (T) was used and from the advance / time curve (Fig. 4.3) with the T/4 (175mins.) the corresponding furrow length was obtained as 168m while the existing furrow length was 350m. The evaluated furrow length was too short when compared to the existing furrow length, this will increase labour requirements for irrigation and impede mechanization.

The accumulated infiltration depth increases as the opportunity time increases (Fig. 4.4). The net accumulated depth was obtained to be 96mm (appendix B5), during the experiment and the average depth of water was calculated to be 135mm (appendix B5). The application efficiency, which is a measure of how effectively the system is being operated was computed to be 71% (appendix B4). This value shows that the system is fairly operated. The potential efficiency, which is a measure of how effectively the system was designed to be operated was computed to be 78% (appendix B4). This value is not too low, but it would have being better if it is 100% . The reason for low value could be because of difference in the existing depth of water to be applied and the evaluated depth of water to be applied which were 76mm and 97mm respectively.

Finally, with these parameters, such as the net depth of application, gross depth of application and the application efficiency, the total volume of water to irrigate the field and the lateral canal design stream size were obtained as $3980.76m^3$ and 95.33l/s respectively. Thus, with these essential technical data the irrigator will know the amount of water and the duration to deliver it. This will no doubt ensure efficient water management and hence elimination of the harzard to productive farming resulting from high water table.



$$n = \frac{1.94 - 0.60}{0.30 - 2.82} = -\frac{1.34}{2.52} = -0.53$$

$$\text{LOG } K = 2.10$$

$$K = \text{LOG}^{-1}\, 2.10 = 125.90$$

FIGURE 4.1 INFILTRATION CHARACTERISTIC CURVE

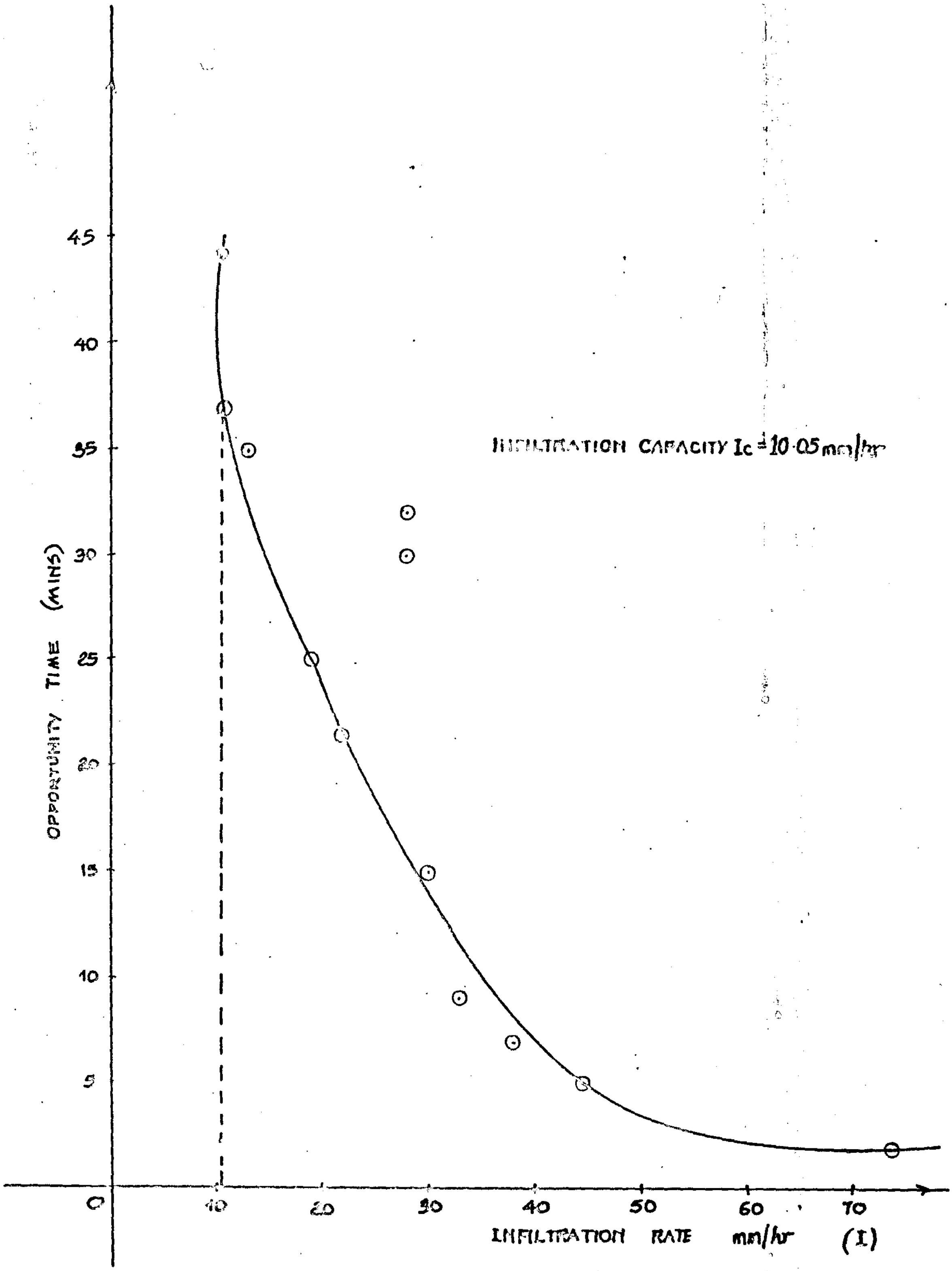


FIGURE 4.2: INTAKE RATE CURVE

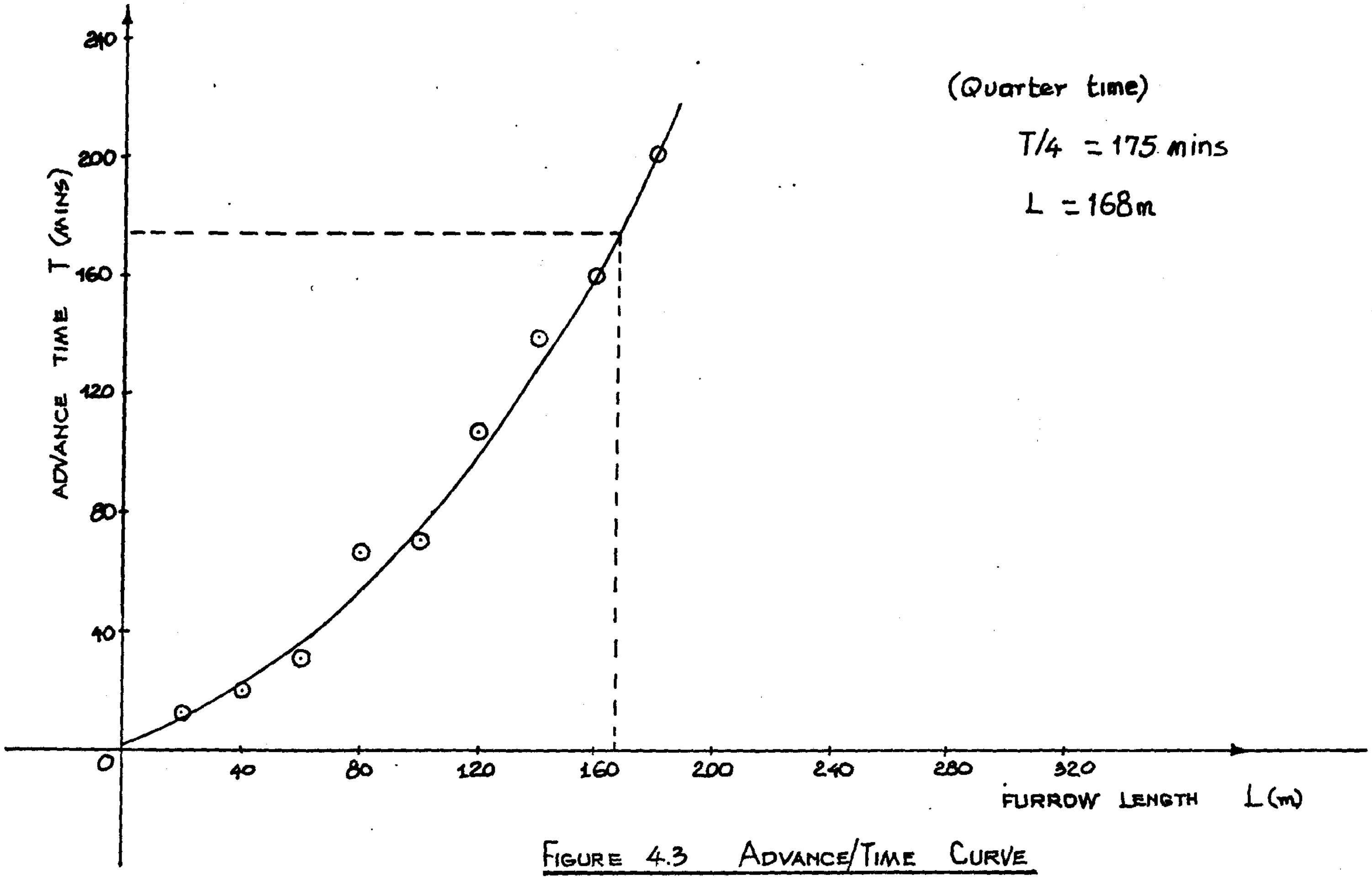


FIGURE 4.3 ADVANCE/TIME CURVE

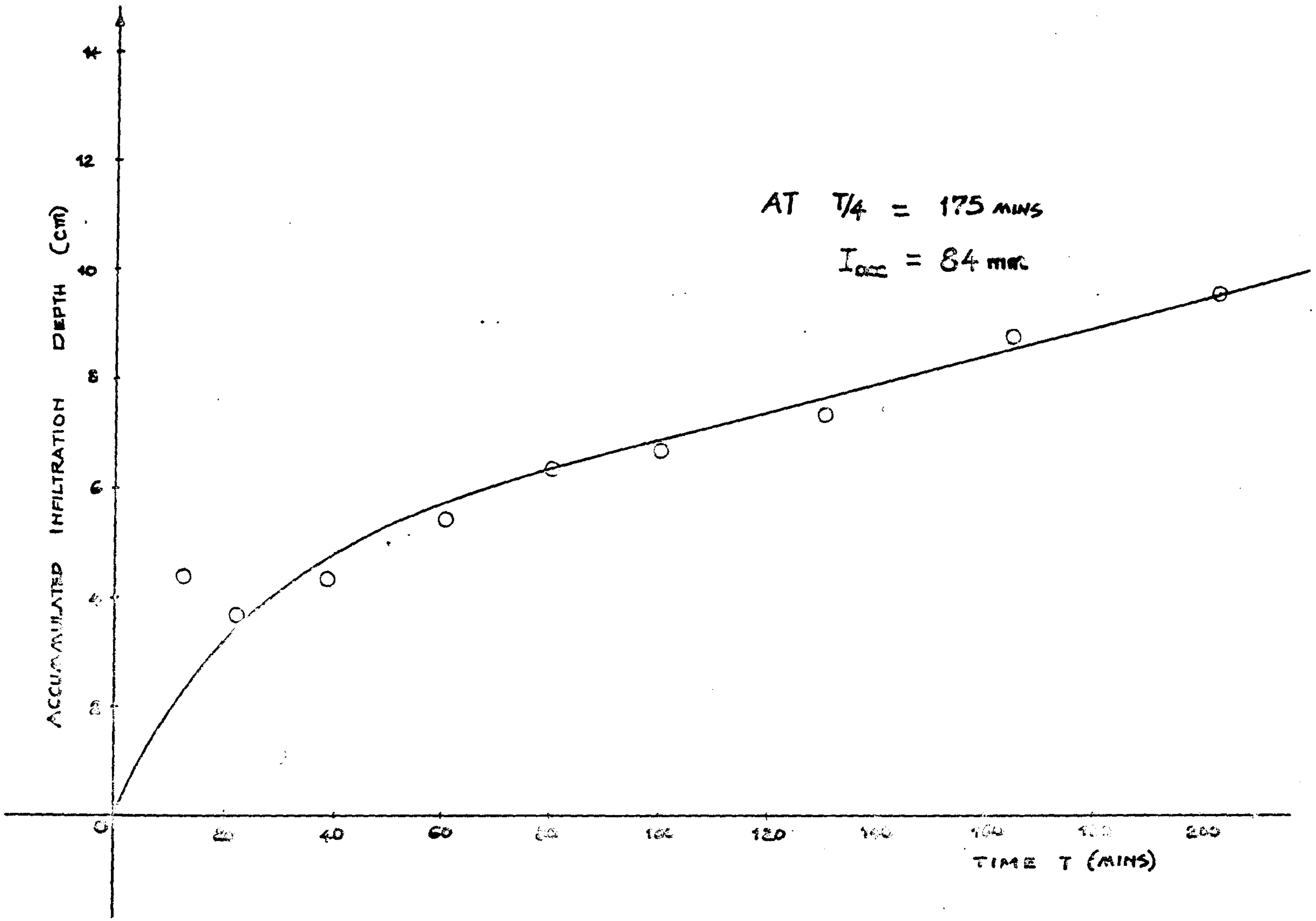


FIGURE 4.4 INFILTRATED DEPTH/TIME CURVE

CHAPTER 5

RECOMMENDATION AND CONCLUSION

5.1 Recommendation

(a) Irrigation time (I)

The irrigation time obtained was 11.6hr for the field under investigation. This do not mean that the irrigation stream should be left running throughout this time, but the lower end of the furrow could be blocked to allow water to accumulate and remain in the furrow till the end of the irrigation time before the excess is drained off. The present practice allows water to remain in furrow for not less than 24hr.

(b) Furrow spacing

Furrow should be spaced close enough to ensure that water spreads to the sides of the ridge and into the rootzone of the crop to replenish the soil moisture uniformly. It should be determined based on soil texture. From the observation made on the field, there should be broader wetting pattern occuring in clays than in sandy soils. For example, the furrow should not be spaced more than 50cm to 60cm apart in sandy soil while it should be one metre or above in clay soil. In Bacita the furrow spacing was measured to be 75cm.

(c) Furrow length

The optimum length of a furrow is the longest furrow that is safely and efficiently irrigated. From the observation on the field it could be recommended that furrow length should be left as it was (350m) so as to reduce labour requirements for irrigation and to favour mechanization.

(d) Furrow slope

Low and uniform slope along the furrow result to uniform and efficiently application of water along the furrow. The existing furrow slope at Nigerian Sugar Company is between 0.2% to 0.5% . This could still be used, but the only problem is that it is uneven along the furrow.

(e) Furrow stream

To obtain the most uniform irrigation, the largest stream of water that will not cause erosion and will be enough to irrigate effectively should be used in each furrow at the beginning of irrigation. For efficient application of water the stream size should be reduced or cut back after the water advance to the end of the furrow, so that it will just keep the furrow wet throughout its length with a minimum water wastage. The recommended stream size is 3.0l/s .

Also for a more efficient evaluation of the furow irrigation systems, it is strongly suggested that more detailed tests should be conducted on the site in order to confirm the actual values of these parameters obtained.

5.2 Conclusion

From the results obtained the following conclusions were drawn:-

(i) The water application efficiency of the system as it was being used was estimated to be 71% , but in order to prevent or limit deep percolation the water application efficiency should be greater or equal 80% . To attain this efficiency, the time require for the water to advance to the end of the furrow should not be greater than 25% of irrigation time. That is, quarter time rule should be obeyed.

(ii) The operating efficiency for which the system was designed was evaluated to be 78% . The cause of low value was because of difference in the existing depth of water to be applied and the depth of water obtained from analysis which were 76mm and 97mm respectively.

(iii) The infiltration characteristic equation was obtained as $I = 126T^{-0.53}$

Inspite of the discrepancy the Company should continue the use of the furrow irrigation system, but can only be advised to improve on the irrigation efficiencies by taking note of the results obtained from this preliminary evaluation.

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APPENDIX A

Formulae used in the computation of parameters.

(a) The Kotstiako (1932) equation

(i) Infiltration characteristic equation

$$I = KT^{n} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

(ii) Accumulated depth equation

$$D = \frac{K}{60(n+1)} T^{(n+1)} \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Where I = infiltration rate mm/hr

K and n are constants for particular soil, n has negative sign.

D = infiltrated depth (mm)

T = irrigation time (min)

(b) Formula for computing 90° V-notch discharge

$$Q = 0.0138H^{5/2} \quad \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Where Q = discharge (l/s)

H = head above notch (cm)

(c) Formula for computing infiltration rate I

$$I = \frac{q * 3600}{W * L} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

Where

q = loss of water by infiltration (l/s)

I = infiltration rate (mm/hr)

W = furrow spacing (m)

L = distance between the weirs (m)

(d) Formula for computing wetted perimeter

$$P = b + 2y(\sqrt{Z^2 + 1}) \ldots\ldots\ldots\ldots\ldots\ldots (5)$$

Where

P = wetted perimeter (cm)

b = width of flow (cm)

y = depth of flow (cm)

side slope 2 vertical to 1 horizontal (Z =1/2)

(e) Formula for computing average depth of water applied

$$d = \frac{Q * 360 * t}{W * L} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots(6)$$

Where

d = average depth of water applied (cm)

Q = stream size (l/s)

t = duration of irrigation (hr)

W = furrow spacing (m)

L = furrow length (m)

(f) Accumulated infiltration depth is determined from the following relationship.

(i) Accumulated wetted area = wetted perimeter * the length of the test section

(ii) Accumulated infiltration (volume) = accumulated inflow − accumulated storage

(iii) Accumulated infiltration (depth) = $\frac{(ii)}{(i)}$

(iv) Furrow cross-sectional area corresponding to depth of flow(cm^2) = width of flow (cm) * depth of flow (cm)

(v) Accumulated inflow = discharge * advance time

(vi) Accumulated storage = (iv) * distance (cm)

(g) Formula for computing field efficiencies

(i) Application efficiency = $\frac{\text{accumulated infiltration depth}}{\text{average depth of water applied}}$

(ii) Potential efficiency = $\frac{\text{design depth of water to be applied}}{\text{evaluated depth of water applied}}$

(h) Formula for the analysis of gravimetric data of the samples.

(i) s.m.c.p (by weigth) = $\frac{\text{w.m.s} - \text{w.d.s}}{\text{w.d.s}} * 100\ \%$

Where

s.m.c.p = soil moisture content percentage w.m.s = weigth of moist soil (g)

w.d.s = weigth of dried soil (g)

(ii) s.m.c.p (by volume) = s.m.c.p (by weight) * α

(iii) $\alpha = \frac{w.d.s}{V}$

Where

α = bulk density g/cm^3

V = volume of the core cylinder cm^3

(I) Other formula

(i) gross depth of application = $\frac{\text{net depth of application}}{\text{efficiency}}$

(ii) volume of water to be diverted (l) = (i) * area of field

(iii) lateral canal design capacity l/s = $\frac{\text{(ii)}}{\text{irrigation time}}$

(iv) available moisture θ = ch * drz (mm)

(v) depth of water to be applied D = θ * MAD (mm)

Where

ch = moisture holding capacity (mm/m)

drz = rootzone depth (cm)

MAD = management allowable deficiency %

APPENDIX B

Sample calculation of parameters

Appendix B1.

(i) moisture holding capacity ch mm/m depth of soil.

From equation (hi) of appendix A

$$\text{s.m.c.p (by weight)} = \frac{\text{w.m.s} - \text{w.d.s}}{\text{w.d.s}} * 100\%$$

$$= \frac{1022.8 - 855.9}{855.9} * 100\%$$ (see appendix C1).

$$= \frac{166.9}{855.9} * 100\%$$

$$= 19.5\%$$

From equation (hii) of appendix A

$$\text{s.m.c.p (by volume)} = \text{s.m.c.p (by weigth)} * \alpha$$

$$\text{ch} = 19.5 * 1.42$$

$$= 277\text{mm/m depth of soil}$$

From equation (hiii)

$$\alpha = \frac{\text{w.d.s}}{V} = \frac{855.9}{602} = 1.42\text{g/cm}^3$$

$$V = \frac{\pi d^2 h}{4} = \frac{\pi(7.4)^2 * 14}{4} = 602\text{cm}^3$$

(ii) rootzone depth drz of the crop was determined to be 70cm

(iii) available moisture θ = ch * drz

$$= 277\text{mm/m} * 0.70\text{m} = 194\text{mm}$$

(iv) management allowable deficiency MAD = 50%

(v) depth of water to be applied D = θ * MAD (mm)

$$= \frac{194 * 50}{100} = 97\text{mm}$$

Appendix B2

(i) Accumulated depth of infiltration

This parameter is to be determined for each advance distance of furrow, but an example of how they could be determined is shown below:

Equation (f) of appendix A is used:

stream size Q = 1.5l/s = 90l/min

For distance 40m corresponding to advance time of 22mins (see appendix C6).

Accumulated inflow = stream size l/min * advance time (min)

= 90 * 22 = 1980 litres

Accumulated storage = furrow cross-sectional area corresponding to the depth of flow cm^2 * advanced distance cm

= 203.0 * 4000

= $812000 cm^3$

= 812 litres

Accumulated wetted area (cm^2) = wetted perimeter (cm) * length of the section (cm)

= 78.8 * 4000 = 315700 cm^2

Accumulated infiltration (volume) = accumulated inflow − accumulated storage

= 1980 − 812 = 1168 litres

Accumulated infiltration (depth) = $\frac{\text{accumulated infiltration (volume)}}{\text{wetted area}}$

$$= \frac{11680000}{315200} = 3.71 \text{ cm}$$

The same process was repeated for other advance distance (see appendix C6).

(ii) Average depth of water applied

From equation (e) of appendix A

$$d = \frac{q * 360 * t}{W * L}$$

$$= \frac{1.5 * 360 * 203/60}{0.75 * 180} = 13.54cm = 135mm$$

Appendix B3.

Infiltration rate parameter

The Kotstiako (1932) equation

(i) infiltration characteristic equation

$$I = KT^n$$

Taking logarithm of both sides of equation we have

$$\log I = \log K + \log T^n$$

$$\log I = n \log T + \log K \ldots\ldots\ldots\ldots\ldots\ldots (*)$$

Equation (*) is like straight line equation with slope n and intercept along the y-axis is log K.

From Fig. 4.1 (infiltration characteristic curve), the value of n and K were deduced as follows:-

$$n = \frac{1.94 - 0.6}{0.3 - 2.83} = -0.53$$

$$\log K = 2.10$$

$$K = 126$$

(ii) Accumulated depth equation

D = depth of water to be applied (mm)

$$D = \frac{KT^{(n+1)}}{60\ (n+1)}$$

$$T = (D(n+1)60/K)^{\frac{1}{n+1}}$$

$$= (97(-0.53+1)60/126)^{\frac{1}{-0.53+1}}$$

$$= (97(0.47)60/126)^{\frac{1}{0.47}}$$

= 698min.

= 11.6hrs

Thus irrigation time is 11.6hrs

Appendix B4.

Field efficiencies

The field efficiencies are calculated as follows

(i) Application efficiency % = $\frac{\text{accumulated infiltration depth}}{\text{average depth of water applied}}$

$$= \frac{96}{135} * 100\% = 71\%$$

Potential efficiecy % = $\frac{\text{design depth of water to be applied}}{\text{evaluated depth of water applied}}$

$$= \frac{76}{97} * 100\% = 78\%$$

Appendix B5.

(i) Volume of water required to irrigate the field

Volume of water = depth of application * area of field

$$= \frac{135 * 29400}{1000} = 3980.76m^3$$

(ii) lateral canal design capacity (Q) for the experimental field.

$$Q = \frac{\text{volume of water required}}{\text{irrigation time}}$$

$$= \frac{3980.76}{11.6} = 343.20\ m^3\ /hr$$

$$= 95.33 l/s$$

APPENDIX C

Tabulation of data obtained

Four tests viz, rootdepth determination, moisture content determination, accumulated depth determination for the design discharge and furrow infiltration rate were carried out for the evaluation of furrow irrigation system at central number 6c. The data collected are shown in appendix C1 to appendix C7.

Appendix C1. Gravimetric method of determining moisture content.

(1) diameter of core sampler d (cm)	(2) depth of core sampler h (cm)	(3) weight of core sampler with moist soil (g)	(4) weight of core sampler with dried soil (g)	(5) weight of core sampler (g)	(6) (3)-(4) weight of moisture (g)	(7) (3)-(5) weight of moisture and soil (g)	(8) (4)-(5) weight of dried soil (g)
7.4	14.0	1110.1	943.2	87.3	166.9	1022.8	855.9

Appendix C2. Furrow water advance data

station distance (m)	0	20	40	60	80	100	120	140	160	180
Elapsed time (min)	0	12	22	38	60	80	100	130	165	203

Appendix C3. Determination of wetted perimeter and furrow cross-sectional area.

stream size (l/min)	distance (m)	advance time (min)	width of flow water b (cm)	depth of flow water y (cm)	wetted perimeter p (cm)	furrow cross-sectional area corresponding to depth of flow (b * y)
	0	0				
90	20	12	71.5	2.8	77.8	200.2
	40	22	72.5	2.8	78.8	203.0
	60	38	72.5	2.9	79.0	210.3
	80	60	73.0	2.9	79.5	211.7
	100	80	73.5	2.9	80.0	213.2
	120	100	73.0	3.0	79.7	219.0
	140	130	73.5	3.2	80.7	235.2
	160	165	74.0	3.0	80.7	222.0
	180	203	74.0	3.2	81.2	236.8

Note $p = b + 2y(\sqrt{z^2 + 1})$

Appendix C4.Furrow infiltration rate for stream size 901/min.

watch time (a.m)	elapse time (min)	station A		station B		losses	
		Head H (cm)	Flow Qa(1/s)	Head H (cm)	Flow Qb(1/s)	Diffe-rence Q (1/s)	infilt-ration rate I
10.01		3					
10.05		4.5					
10.07		4.5					
10.10		4.8					
10.15		5.8					
10.18	0	6.5					
10.20	2	6.5	1.486	5.6	1.023	0.463	74.08
10.23	5	6.8	1.664	6.3	1.378	0.285	45.71
10.25	7	6.6	1.544	6.2	1.301	0.243	60.32
10.27	9	6.4	1.430	6.0	1.223	0.207	49.92
10.28	10	6.2	1.321	5.1	0.811	0.510	81.60
10.32	12	6.0	1.217	4.9	0.733	0.484	77.44
10.34	14	5.9	1.167	4.9	0.733	0.484	77.44
10.36	16	5.7	1.071	4.8	0.697	0.374	59.84
10.38	18	5.4	0.935	4.6	0.627	0.308	49.28
10.40	20	5.0	0.772	4.5	0.593	0.179	28.64
10.42	22	4.8	0.697	4.4	0.561	0.136	21.76
10.45	25	4.6	0.627	4.2	0.508	0.119	19.04
10.47	27	5.0	0.772	4.3	0.529	0.243	38.88
10.50	30	5.0	0.772	4.5	0.593	0.179	28.64
10.52	32	5.0	0.772	4.5	0.593	0.179	28.64
10.55	35	4.7	0.661	4.4	0.561	0.100	16.00
10.57	37	4.5	0.593	4.3	0.524	0.069	11.04
11.00	40	4.4	0.560	4.2	0.494	0.066	10.50
11.04	44	4.4	0.560	4.2	0.494	0.066	10.50

Note :

$$I = \frac{3600 * Q}{W * L}$$

(Where W = 0.75m, L = 30m)

Appendix C5. Determination of bulk density (From appendix C1.)

weight of moisture (g) (1)	weight of dried soil (g) (2)	moisture content by weight % $\frac{(1)}{(2)}$ *100	volume of the sampler core (cm^3) $V = \frac{\pi d^2 h}{4}$ (3)	bulk density $\alpha (g/cm^3)$ $\frac{(2)}{(3)}$
166.9	855.9	19.5	602	1.42

Appendix C6. Determination of accumulated infiltration depth for 90l/min stream size.

Distance (m)	Accumulated storage (litre) (1)	Accumulated inflow (litre) (2)	wetted area (cm^2) (3)	Accumulated infiltration (volume) * 1000 (cm^3) (2-1)	Accumulated infiltration (depth) (cm) $\frac{(2-1)}{(3)}$
0					
20	400.4	1080.0	155600.0	679.6	4.37
40	812.0	1980.0	315200.0	1168.0	3.71
60	1261.8	3420.0	474000.0	2158.2	4.56
80	1693.6	5400.0	636000.0	3706.4	5.83
100	2132.0	7200.0	800000.0	5068.0	6.34
120	2628.0	9000.0	956400.0	6372.0	6.66
140	3292.8	11700.0	1129800.0	8407.2	7.44
160	3552.0	14850.0	1291200.0	11298.0	8.75
180	4262.4	18270.0	1461600.0	14007.6	9.59

Note:

Accumulated inflow = stream size * advance time

Accumulated storage = furrow cross-sectional area * distance advance

Accumulated wetted area = wetted perimeter (cm) * distance advance (cm)

Appendix C7. Infiltration characteristic data.

time T (mins.)	infiltration I (mm/hr)	Log T	Log I
0.0			
2.0	74.08	0.30	1.87
5.0	45.71	0.70	1.66
7.0	38.90	0.85	1.59
9.0	33.11	0.95	1.52
10.0	81.60	1.00	1.91
12.0	77.44	1.08	1.81
14.0	77.44	1.15	1.89
16.0	59.84	1.21	1.78
18.0	49.28	1.26	1.69
20.0	28.64	1.30	1.46
22.0	21.76	1.34	1.34
25.0	19.00	1.40	1.28
27.0	38.88	1.43	1.59
30.0	28.64	1.48	1.46
32.0	28.64	1.51	1.46
35.0	16.00	1.55	1.20
37.0	11.00	1.57	1.04
40.0	10.50	1.60	1.02
44.0	10.50	1.64	1.02