OPTIMUM WATER REQUIREMENT FOR TOMATO PRODUCTION UNDER SMALL-SCALE BASIN IRRIGATION SYSTEM

BY

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JUNE, 2000

DECLARATION

I hereby declare that this thesis work has been composed and complied by me and it is a record of my own research work. The work has not been presented or accepted in any previous work for higher degree. All sources of information are acknowledged by means of references

Date: 22-6-2000

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CERTIFICATION

This thesis entitled "OPTIMUM WATER REQUIREMENT FOR TOMATO PRODUCTION UNDER SMALL-SCALE BASIN IRRIGATION SYSTEM" by TYA, T.S.K., meets the regulations governing the award of the degree of Master of Science (Agricultural Engineering) of Ahmadu Bello University, Zaria, and is approved for its contribution to knowledge and literary presentation.

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DEDICATION

TO MY BELOVED PATIENT AND HUMBLE WIFE

MRS MURNA STEPHEN TYA

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ABSTRACT

Six different amounts of water : 97, 125, 150, 175, 200 and 220mm designated as treatments A, B, C, D, E and F were applied to six basins of the same size (2m x 2m), respectively. Tomato (Pevabo) variety was used as a trial crop. Irrigation interval of 7 days was used throughout the season. Three plot units were established according to slope variation of the land with each unit having a different land slope.

Double ring infiltrometer was used to determine the infiltration rates of the plots and the values obtained indicated the soil to be suitable for irrigation due to its moderate intake rate and the soil textural classification. The net seasonal water requirement for the crop under study was in the range of 517.29 - 665.32mm for all the treatments. Optimum net water requirement of 543.00mm and peak evapotranspiration of 13.5mm/day were obtained from treatment B indicating a fairly good result.

Tomato yields obtained for the treatments were generally satisfactory.Treatment B gave the maximum yield of 14.225 t/ha, while the lowest yield of 9.272 t/ha was obtained for treatment F. A total yield of 11.691 t/ha was obtained for all the treatments. Treatment B was found to perform better than all the other treatments in terms of crop yield revenue generated, production cost, profit realized and cost-recovery. Irrigation water cost of N6316.80 per hectare per season, that

is, N451.20 per hectare per irrigation was obtained for treatment B which was moderate and much more economical since maximum yield, highest income and profit were attained. Treatment F had the lowest performance. Thus, treatment B (125mm) amount of water applied performed above average and is the most suitable and appropriate amount of water to be applied for maximum crop yield for self sustenance and profit making in a small scale irrigation system using 2m x 2m basin sizes with streamsize provided by GX140 Honda irrigation pump.

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CHAPTER ONE

INTRODUCTION

1.1. Background

Optimum water requirement is defined as the amount of water required during the growing season to produce maximum yields of different crops, where the amounts include soil moisture supplied by precipitation as well as water delivered by irrigation (FAO,1973). According to Adam and Farbrother (1978), optimum water requirement could be estimated from measurement of evapotranspiration and the actual water use when the evidence from soil moisture depletion confirms that available moisture in the rootzone has not been limiting.

In Nigeria, irrigation farming particularly in the low-lying land near rivers, streams and ponds usually called "Fadama" has been in existence for centuries, but the proper utilization of the available water to boost crop yield has not been attained. An estimated area of 2 million hectares of fadama soil along the country's water network has been identified as suitable for small-scale irrigation in Nigeria, half of which can easily be exploited (Erinle, 1991). The minimum and maximum cultivated plots of 0.2 ha and a little above 16 ha with a model size of 1-2 hectares were used by majority of the small-scale farmers in Nigeria. A wide variety of crops are grown in the irrigated fadamas. These include : pepper, tomato, onion, carrot, pumpkin and okra, cereals such as maize and wheat are also grown (Falola and Sangari, 1994).

Thus, for this study, tomato was used as a trial crop.

In order to sustain the productivity from the fadama soils, proper matching of the source and amount of water available per unit area and ensuring efficient delivery is important for plant health and optimum crop performance. This is lacking in the present day small-scale holder farmers. According to Tyson (1971), in many of the small scale irrigation farms, water is wasted through inefficient use, because of improper application, inadequate drainage, archaic technology, and restrictive cultural practices.

However, one of the key constraints to agricultural production in Nigeria has been the non-availability and inefficient distribution of water (Phillip, 1990). Perrier and Salkini (1991) showed that only 16% of the world's cultivated land is irrigated which supplies more than 40% of the world's crop production, clearly indicating that water is limited especially in the semi arid and arid regions. According to Qamar and Tyem (1994), water as an agricultural source was found to be limiting. Surface water sources were observed to have been over stretched and alternative sources have to be sought to expand crop production and sustain small scale farming. Thus, water supply is limited due to increase in demand for agriculture, urban and industrial uses. Also, water supply is limited due to decrease in river flows. Water is priced well below its marginal value which results in inefficient use of the water, since water charge does not

affect farmers' net returns. In addition, there is inconsistency in rationing water thereby making some farms to be over-irrigated, while others are deficient in water supply.

Thus, this study examined the above mentioned problems in order to improve on the management of the limited water supply with a view to creating an economic water supply of an optimal quantity with a capacity for delivery on demand and also to determine an appropriate water charge to be used by the small scale holder farmers whose aim is to maximize their crop yield for self sustenance and profit making.

Qamar and Tysen (1994) observed that there is a rapidly growing demand from small holder farmers for small scale irrigation infrastructure and facilities because of the observed high financial returns from the business. Traditional water lifting devices called the "Shadouf" have long been used to raise water from the streams, ponds, rivers or lakes to irrigate the field, but modern low horse power petrol engine-driven pumps recently introduced have proved effective and affordable and are therefore widely accepted for use in the small scale irrigation systems. In order to allocate the water supplied by these devices quantitatively, the farmer must possess a production function of the crop, thus, enabling him to evaluate the potential yield and gross or net water application (Shalhevet et al., 1979). The production of crops depend on the employment of the various inputs which include:

water, land, labour, fertilizer and pesticides, amongst which water has no definite value or price, that is, it is the variable input that does not have any expected value.

Increased value of water induces changes which lead to substantial increase in the value of agricultural output per unit of land and water. Fredrick (1975) stated that a major problem in determining farmers' per unit cost of water was that the cost is independent of quantity of the water supplied which varied tremendously from year to year, river to river and from canal to canal. Maila and Krishan (1995) suggested that in the short run, irrigation water demand was likely to be responsive to price changes especially after the crop has been planted. But for medium and long terms, it is expected that irrigation water demand would be more reponsive to price as the farmer can change crop and introduce better management and water-saving technologies.

1.2. Objectives

Having stated the problems encountered in the cycle of irrigation for small scale farming, with respect to the limited water supply, inappropriate water charge, and inefficient use of the irrigation water, the objectives of the study include :

1. To determine the optimum water requirement and maximum yield of tomato crop for a small scale irrigation system.
2. To determine an economic water charge for small scale

tomato production.

3. To determine the performance of tomato yield, net returns and water charge for the amount of water applied.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

In order to determine the optimum water requirement of crops, certain factors are taken into consideration; these include: the method of irrigation to be used, soil physical characteristics, infiltration rates, water supply, evapotranspiration, soil moisture and land utilization. Another important factor is the type of crop to be grown, which in this case is tomato. Tomato has certain factors to be considered, which include: the most suitable tomato variety recommended to be grown under fadama conditions for maximum yield production, the recommended cultural practices and irrigation schedule.

2.2 Basin Irrigation

The basin irrigation method is the simplest in principle for water supply to crops. For this reason, it is the most widely used for irrigating crops (Booher, 1976; Stern, 1989). However, according to Food and Agriculture Organisation (FAO) (1973), it is adapted for soils having moderate to slow intake rates, moderate to high available water holding capacities and have smooth gentle uniform slopes which result in the best field layout.

The basin irrigation method is seldom used for crops which are sensitive to wet soil conditions around the stems,

or for annual crops on soil which crust badly when flooded (Booher, 1976). Also, Booher (1976) stated that infiltration rate and the size of the stream available determine the area to be enclosed in each basin. The basin is formed with a minimum amount of land grading on slopes of less than 2%, by placing the levees the correct distance apart so that the difference in elevation within each basin is not excessive.

2.3 Land Slope Determination

Before grading a land, it is desirable to survey the soil profile. This will indicate the extent to which the top soil can be removed without reducing crop production. Land grading should be based on accurate topographic survey in order to select the most suitable slopes to which the land surface can be economically graded (Booher, 1976). Michael et al (1972) gave an expression for determining the percentage slope where the field is to be sloping as:

$$S_p = \frac{D_{ep}}{D_{sp}} * 100 \quad \text{.....(2.1)}$$

where;

S_p = Percentage slope (%)

D_{ep} = difference in elevation between the first point and last point (m)

D_{sp} = Horizontal distance between the first and last point (m)

Abubakar (1992) Suggested the safe limits of land slope for efficient check basin, border and furrow irrigation as ranging from 0.05% to 0.25% for heavy soils; 0.20% to 0.40% for medium soils and 0.25% to 0.65% for light soils which is consistent with the recommendations of Michael et al (1965).

2.4 Soil Textural Classification

The texture of soil is determined by the size and distribution of its soil particles, that is the percentage of coarse, medium and fine particles which are termed sand, silt and clay, respectively, and the various combinations of these fractions are used to classify the soil according to its texture. In addition, Doneen (1971) stated that the textural class of a soil can be accurately determined in the laboratory by mechanical analysis.

Mechanical analysis is a combination of sieve and sedimentation techniques. Soil samples are taken from desired depths and analysed using the procedure detailed by Loveday (1974). The results are then used to obtain the textural classification using the United States Department of Agriculture (USDA) soil texture classification triangle.

2.5 Irrigation Time

The total time of irrigation is made up of two parts for the basin irrigation method; the time of water spread and time of water ponding. When water is introduced into the basin, it

will take some time t_a to spread itself all over the entire basin area. After the water has spread itself all over the basin, it needs a period of time t_p to remain over the basin so that the whole area gets irrigated to the required depth. According to Sharma (1978), the time of spread is known as the intake opportunity time.

2.5.1 Time of water advance

An important characteristic of surface irrigation is the overland conveyance of irrigation water during the advance phase from the inlet to the end of the field (Or and Silva, 1996). Idealy, shorter advance times result in more uniform irrigation water application due to smaller spread in intake opportunity times across the field. However, in practice, Or and Silva(1996) observed that the advance phase may be long due to constraints of water supply system or soil properties such as high infiltration rate which result in differences in intake times and application depths at different points within the basin.

Walker and Skogerboe (1987) suggested that the soil's infiltration rate and inflow rate per unit width are the most important factors in determing the advance rates for surface-irrigated fields with mildslope and relatively smooth surface which is in line with the findings of Or and Silva (1996), that the advance rate during an irrigation event is influenced by: the flow rate, surface slope and roughness, hydraulic

cross-section, and soil infiltration properties. In addition, Sharma (1978) stated that the time of spread in levelled basins vegetated with close growing crops such as wheat and rice is dependent on the inflow streamsize, area of basin and infiltration rate of the soil.

2.5.2 Time of water ponding

The intake opportunity time is usually less at the downstream end than at the upstream end of a basin, and it is recommended that if the downstream end of the basin is to be fully irrigated, an additional time equal to the time of spread should be allowed at the upstream end (Sharma, 1978). However, Merrian and Keller (1978) recommended that if the entire basin area can be covered in about one-fourth of the time needed to irrigate it fully, the adverse effect of the unequal intake opportunity time on the water distribution uniformity will be minimum.

2.5.3 Available soil water storage

In a given period of time , the volume of water storage above the soil surface according to Michael (1978) is equal to the difference between the volume of water admitted into the basin during the period and the volume infiltrated into soil. He gave an expression for the surface storage volume as:

$$V_s = q_s t_s - A_c I_s t_s = A_c d_s \quad \ldots\ldots\ldots\ldots\ldots (2.2)$$

where;

V_s = volume of water stored in a given time t_s, cm^3

q_s = average size of entrance stream, cm^3/min

t_s = storage time, min

A_c = area of checkbasin, cm^2

I_s = average infiltration rate during the storage time, cm/min.

d_s = depth of storage during t_s, cm.

Having known the amount of water to be added to the soil, the duration of water application can be obtained from an expression given by Israelsen and Hansen (1962) as:

$$qt = ad \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2.3)$$

where: q = the stream size, m^3/s

t = time of irrigation, sec.

a = area of basin, m^2

d = depth of irrigation, m

Also, the depth of irrigation d, can be expressed as (Israelsen and Hansen, 1962):

$$d = \frac{P_y}{100} * A_s * D \quad \ldots\ldots\ldots\ldots\ldots 2.4$$

where: P_y = moisture percentage (dry weight basis), %

A_s = apparent specific gravity

D = depth of sampling or rootzone depth, mm.

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2.6 Irrigation Water Streamsize

The use of a cut-throat flume developed by Skogerboe et al. (1972) enables the measurement of irrigation water streamsize to be made with greater ease than other flumes such as Parshall flumes (Kraatz and Mahajan, 1975). The absence of longitudinal throat section facilitates the streamsize measurement and ensures a high degree of accuracy if it is operated under free flow conditions. Kraatz and Mahajan (1975) gave the expression used to determine the discharge through the cut-throat flume under free flow conditions as:

$$Q = C_f H_a^n \quad \ldots\ldots\ldots\

equation earlier given by Kraatz and Mahajan (1975) and gave an expression for a cutthroat flume operated under free flow condition as:

$$Q = 0.0525H_a^{2.105} \quad \text{.....(2.6)}$$

where all the terms are as previously defined. The discharge can be calculated for any given H_a, by using Eq (2.6) provided free flow condition prevails in the flume. Kraatz and Mahajan (1975) recommended the ratio of flow depth to flume length (H_a:L) to be less than or equal to 0.4 for accurate discharge measurements. They also found that higher values of this ratio result in greater inaccuracies in the measurements.

2.7 Determination of Infiltration Rates

The rate of entry of water into the soil is of fundamental importance in irrigation. The rate of water entry into the soil varies with many factors such as: depth of water on the soil surface, soil structure and texture, temperature of water, soil type and moisture content of the soil (Israelsen and Hansen, 1962). The failure to adequately consider the infiltration process may result in non-uniform distribution of water in the field as well as excessive water loss due to deep percolation and runoff in the basin; thus, an understanding of the infiltration process and factors affecting it are important in the design and operation of efficient irrigation systems.

For irrigation by flooding, the infiltration rates are

measured by ponding water on the surface of the soil and measuring the rate of water held or rate of inflow that must be supplied to maintain a uniform depth of water (Booher, 1976). Perrier and Salkini (1991) gave two major infiltration equations which approximate the infiltration rates of a soil under all conditions. These equations are the Kostiakov equations expressed as:

$$I = Kt^n \quad \text{..... (2.7)}$$

and

$$I = Kt^n + I_b t \quad \text{..... (2.7a)}$$

where:

I = infiltration rate, mm/min

K,n = empirically determined coefficients.

t = time of water intake, min

I_b = basic infiltration rate, mm/min.

According to Israelsen and Hansen (1962), when light, frequent irrigations are applied, the irrigation may be completed before the final intake rate is reached, and since the initial rates are considerably in excess of the final rates, the amount of water entering the soil can best be represented by the accumulated depth of water Z, that has entered the soil, which is obtained as the integral of Eq.(2.7) as:

$$z = \frac{K}{n+1} t^{n+1} \quad \text{.....(2.8)}$$

The values of a, I_b and K are obtained by a procedure

detailed by Michael (1985). However, Michael (1985) found that if the functional relationship between I and t can be expressed by Eq. (2.7) then it is not necessary to determine the rectifying factor I_b, and that Eq. (2.7) is sufficiently accurate for characterizing the infiltration rate process.

In order to know the rate at which water enters the soil for the purpose of scheduling irrigation, it is necessary to estimate or measure the infiltration rate of the soil. There are many field methods that could be used for determining soil infiltration rates. These methods include:
(i).the double ring infiltrometer; (ii). the method of ponding; (iii) the single ring infiltrometer; and (iv) the use of rainfall simulators. The infiltration rates determined by some of these methods do not simulate the field conditions because of high degree of variability of values obtained due to uncontrolled lateral movement of water and therefore do not have general applicability to operations of basin irrigation systems. The double-ring infiltrometer method is an exception, because the lateral movement of water from the cylinders is minimized by ponding water in a guard cylinder of buffer area around the cylinders. However, it has the disadvantage of confining water in a stationary position which is in contrast to field conditions where water flows over the surface. However, infiltration rates are usually measured by the double ring infiltrometer in which the water levels in the inner and outer cylinders are kept approximately the same (Michael,

1978). After the initial reading, point gauge measurements were made at frequent intervals to determine the amount of water that has infiltrated during the time interval. Ahmed (1988) suggested that infiltration readings could be taken at 5-minute intervals for the first 20 minutes, 20-minute intervals for the next 100 minutes, and 30 - minute intervals for the next 90 minutes. The measurements are continued beyond the estimated time the water would stand in borders or basins during an irrigation.

2.8 Soil Moisture Content Determination

There are many ways of measuring the soil-water content and literature on the subject is very extensive. Actually, only a few methods are practical and widely used, and all have their limitations. Because of high variability of soil properties as well as water content encountered in the field, it is generally very difficult to find representative number for a given field (Blanke, 1965).

Available methods for measuring the soil moisture content include: electrical resistance method, the neutron method; the gamma attenuation method, the tensiometer method and gravimetric method. For the purpose of this study, the gravimetric method was used.

The gravimetric method is the basic and standard procedure for the determination of soil moisture content to which other methods are refered (Gairon and Hadas, 1973). The

gravimetric method is simple and cheap equipment are used. Also, the accuracy that can be obtained by the method together with the possibility it presents of assessing the measurement and sampling errors involved makes it the standard to which all other methods are compared. Also it does not require any special skill.

In using the method, soil samples are taken from the field at desired depths and weighed and then dried in an oven at a temperature, kept at 105^0C for 24 hours. The weight of the oven dried sample is determined. The difference in weight before and after drying divided by the weight of the dry soil gives the water content by weight. The expression is given as:

$$M_c = \frac{M_w - M_d}{M_d} * 100 \quad \text{.....(2.9)}$$

where: M_c = moisture content, %

M_w = wet weight of soil, g

M_d = dry weight of soil, g

However, because of the very large variability of water content in vertical as well as horizontal directions the sampling procedures and especially the number of samples needed to assess the water in the field are difficult (Gairon and Hadas, 1973).

2.9 Deep Percolation Losses

Deep percolation losses are inevitable in any irrigation for an area enclosed by the basin, but can be reduced by

adopting smaller basin sizes or higher streamsizes, so that the time of initial spread of water is reduced (Gupta et al, 1983). By considering variable infiltration rates and advance functions, simplified equations for predicting percolation losses can be developed (Murty, 1970). The infiltration characteristics of soil is represented by Eq. (2.7). Murty (1970) showed that the depth of water absorbed in a given time can be obtained by using Eq. (2.8). In a check basin immediately the water is introduced, it will take a time t_a to spread itself over the area and the average time during which the whole area is in contact with water is $t_a/2$ as the whole plot gets irrigated. Since water spread over the entire field in the time interval O to t_a, the area with which the water is in contact is continuously varying, and at the same time the infiltration rate is also continuously changing. Thus, instead of averaging the area which is in contact with water, it is more appropriate to average the time during which the whole area is in contact with water. The total volume of water, D_a absorbed in the check basin is obtained by Murty (1970) as:

$$D_a = A\int_0^{t_a/2} Kt_p^n \, dt + A\int_{t_a/2}^{T} Kt_p^n \, dt \quad \text{or}$$

$$Da = A\frac{K}{n+1} T^{n+1} \qquad \text{.....(2.10)}$$

in which T is the total time of irrigation.

In order to ensure application of water to the required depth all over the basins, some amount of water is applied in excess of the requirement. This amount is the deep percolation loss, P which depends on t_a. The area from which deep percolation losses will occur is A, as water will be standing for a period of t_p in addition to t_a thus, contributing an additional volume d_a:

$$d_a = D_a - d_p$$

$$= \frac{AK}{n+1} T^{n+1} - \frac{AK}{n+1} t_p^{n+1}$$

or

$$d_a = \frac{AK}{n+1} T^{n+1} - t_p^{n+1} \quad \ldots\ldots\ldots\ldots (2.11)$$

d_p is the volume of water contributed in time t_p. The deep percolation losses will start after an elapsed time T, ($T = t_a + t_p$). Thus, the percentage deep percolation losses can be obtained as (Murty, 1970)

$$P_p = \frac{d_a}{D_a} * 100 \quad \ldots\ldots\ldots\ldots\ldots\ldots (2.12)$$

Substituting Eqs (2.10) and (2.11) into Eq (2.12), the percentage deep percolation losses (P_p) is obtained in terms of both advance and ponding times :

$$P_p = \frac{T^{n+1} - t_p^{n+1}}{T^{n+1}} * 100 \quad \ldots\ldots\ldots\ldots\ldots (2.12a)$$

Equation (2.12a) indicates that if $t_d = 0$, then the deep percolation losses are nil. Thus, if irrigation water spreads instanteneously all over the basin area, the deep percolation losses will be eliminated.This is not practicable, and as such, the less the time of spread t_d, the less the percolation losses will be.

2.10. Water Requirements

Water is essential for plant growth and it is needed in much larger quantities than the plant nutrients. A large proportion of nutrients absorbed by the plant is retained, but the outstanding characteristics of water is its one way flow from the soil through the roots up the stems into the leaf surfaces where it is evaporated mainly inside the stomata through which it diffuses into the air (Russell, 1973).

Thus, the water requirement of a crop is defined as the amount of water used in producing a crop including the water evaporated through the wet soil surfaces. However, several methods are available for estimating the water requirement based on meteorological variables of : net radiation, temperature, relative humidity, windspeed, soil and plant variables (moisture stress, leaf water status, stomatal aperture) (Shalhevet et al, 1979).

The crop water reqirement may be determined from data collected on yields versus applied water for field on small experimental plots for a specific crop in a specific locality

having characteristic values of consumptive use and effective precipitation (James and Lee,1971). Perrier and Salkini (1991) also showed that water balance method could be used to estimate the crop water requirement, while FAO (1973) suggested soil moisture studies method to determine the crop water requirement.

However, in this study, the soil moisture studies method was used to determine the crop water requirement. The method is simple, simulates the water holding capacity of the area and results in more accurate values. FAO(1973) gave an expression for crop water requirement as :

$$U = \sum_{i=1}^{n} \frac{M_{1i} - M_{2i}}{100} * S_{bi} * D_i \quad \text{.....(2.13)}$$

where:

U = water used from the rootzone for a sampling period within one irrigation cycle, mm.

n = number of soil layers sampled in rootzone

m_{1i}= moisture percentage on oven dry basis at first sampling in the ith layer

m_{2i}= moisture percentage on oven dry basis at second sampling in the ith layer.

S_{bi}= apparent specific gravity at the ith layer

D_i = depth of soil in the ith layer, mm.

Summing the entire individual consumptve use values over the growing season of the crop results in the total crop water use for the season.

2.11. Efficiency Evaluation.

Irrigation efficiency is the measure of how effectively the water supplied is used. Merriam (1980), stated that the purpose of evaluating irrigation systems are : (i) to determine the efficiency of the system as it is being used; and (ii) to determine how effective the system can be operated and whether it can be improved upon. However, the evaluation of the irrigation method used in this study was based on the (USDA) United States Department of Soil Conservation method as given by Merriam and Keller (1978) that the use of potential application efficiency, water application efficiency and water distribution efficiency are enough to evaluate the efficiency of an irrigation system. The parameters are based on the average depth of water infiltrated in the field.

2.11.1. Water application efficiency.

The concept of water application efficiency was developed to measure and focus attention upon the efficiency with which water delivered to the field is being stored within the rootzone of the crop, where it can be used by plants. Israelsen and Hansen (1962) gave an expression for the water application efficiency, E_a, as :

$$E_a = \frac{W_s}{W_f} * 100 \quad \text{.....(2.14)}$$

where :

W_s = water stored in the rootzone of plant during irrigation, mm.

W_f = water delivered to the field, mm.

Michael (1978) found that for basin irrigation method, water application efficiencies range from 60 to 90%.

2.11.2. Water distribution efficiency.

This shows the extent to which water is distributed uniformly to enhance crop response. Abubakar (1992) stated that water distribution efficiencies range from 80 to 95% for the basin irrigation method conducted under fadama conditions in Samaru. Israelsen and Hansen (1962) gave an expression for determining water distribution efficiency as

$$E_d = 100\ [1 - (y/d)] \quad \text{.....(2.15)}$$

where :

E_d = water distribution efficiency, %

y = average numerical deviation in depth of water stored during irrigation,mm.

d = average depth of water stored during irrigation,mm.

2.12. Estimation of Land Utilization.

A procedure for quantifying and costing the land lost out

of production under basin irrigation method was recommended by Slabbers (1971). He considered the land loss due to that occupied by levees and channels as an additional loss in income that could be generated if crops were grown on such land. He based the product produced on a comparison of land lost under the largest basin size with that under the other basin sizes. The largest basin is assigned zero landloss while the other basins take different values, all relative to the largest. The total area occupied by all basins under one treatment is usually measured while that of the levees and channels associated with each treatment is estimated. The later is then subtracted from the total area. The balance from this is taken as the land lost. Slabbers (1971) further stated that the value of this land is then calculated from the expected crop yield that could be obtained from it. This is done for each treatment seperately and the amount calculated is assigned as additional loss in income due to land loss per hectare for each treatment. In addition, Abubakar (1992) stated that the land loss through levees and field channel constructions has to be estimated for each treatment which is then converted to loss in gross income and an additional production cost.

2.13. Irrigation of Tomatoes.

Tomato is a vegetative crop grown as annual or short lived perennial which is photo-periodical as regards to

flowering, but temperature has a marked effect on the growth, flowering and fruit set. According to Quinn (1974), tomato is one of the major irrigated crops in the semi-arid zone of West Africa. However, tomato production is limited by the existence of hard pan layers below the soil surface especially in some of the larger schemes in Nigeria where perched ground water tables are often as shallow as 250mm (Abdulmumin and Muazu, 1982).

The crop is widely adopted and can be grown at certain periods of the year which is mainly in the dry season. It is difficult to grow tomatoes during the wet season due to disease problems and flowers being disturbed by rain and the reduction of light which tends to decrease yields while increased in light gives better growth and yield (Mortensen and Bullard, 1966). Insufficient water supply causes blossom drop and tomato yield is reduced (Anonymous, 1976). High rates of irrigation delay maturity and reduction in both yield and the solid content of the fruits (Martains et al.,1966). In addition, Shimishi (1973) observed that too frequent irrigation causes slow maturation resulting in uneven maturity during harvest.

The tomato crop may be seeded between November and April and harvested 90 days later (Shalhevet et al, 1979; Hassan, 1981). Tomatoes thrive under wide range of environmental conditions, but for optimum production, they require plenty of sunshine, warm days and well drained soils to maintain soil

oxygen (Roe, 1950; Villareal,1980).

Martensen and Bullard (1966) also observed that tomato yields are best at 21 to 27^{0}C day-time temperatures. The critical night temperatures for setting fruits according to them is 17.8^{0}C. On the other hand, they found that high temperatures at low elevations may reduce yield. Hassan (1981) also stated that the growth of tomato is possible over a range of temperatures between approximately 15 - 30^{0}C and both when the day temperature is about 26^{0}C and night temperature is between 15^{0}C to 21.1^{0}C though the temperature vary for different varieties.

For optimum production, Martains et al. (1966)observed that high level of soil moisture throughout the vegetative and early flowering stage, a reduction in moisture level during the fruit development and a low level during the ripening stage of the fruit is required. Dunkel (1966) gave the level of soil moisture at about 70% of the field capacity to be most appropriate. However, Cosevki (1965) after six years of experiments concluded that the best irrigation schedule for tomatoes was 4 to 5 days for Macedonia in United States of America. In Nigeria, the recommended schedules of irrigation of tomatoes is two irrigations per week in case of sandy soil, while 7 days is suitable for other soils with water being added sufficiently at each application to saturate the soil well to a depth of 300 mm (Anonymous, 1982). Hassan (1981) also observed that for a 7-day irrigation interval, the depth

of water applied was 585 mm in 14 irrigations.

2.13.1. Rootzone depth.

Tomatoes are deep rooting crops and are grown in almost any type of soil with resulting good yields if supplied with plenty of sunlight and moderate amount of water (Roe,1950). Also, Shalhevet et al. (1979) stated that tomato plants are deep rooted and not sensitive to moderate moisture stress in the main rootzone. They also observed that tomato roots penetrate to a depth of over 1500 mm and that 83% of the water is taken from 0 - 900 mm depth in the semi-arid region. According to Kogbe (1981), the effective rootzone depth of tomato at the flowering stage was 68mm and at maturity 82mm during the dry season on an alluvial terrace consisting of matako series (Eutric Gleysols) at the Moor Plantation Research Station, Ibadan. Kwayas (1990) observed that for Devabo variety of tomato grown on Samaru soil, the effective rootzone depth was found to be 500 mm and 80% of the water required is taken from the 0 - 450 mm depth. Hussain and Munir (1986) reported that tomato is classified as one of the shallow-rooted crops especially when seed bed preparation is perfomred manually. However, Stern (1989) observed that the rooting pattern of a crop depends on local soil conditions and water availability. For tomatoes, he found that the depth of the full grown tomato ranges from 700 - 1500 mm and most of the water is taken from the upper half of the rootzone.

2.14. Irrigation Water Costs.

The cost of water may be defined as the amount of money paid to make the water available at a given flow rate, at a given time and a given place (Kulper, 1971). Prickett (1969) defined it as any charges made for supplying water to the farm boundary.

Water prices are extremely influential in determining the cropping pattern, optimum water use and efficiency in water use. When the cost is high, efficiency in its use is also high, when low water cost is fixed for some reasons, special regulatory measures will be imposed to ensure efficient water use; otherwise, the inefficient use will create drainage problems and consequently, reduction in crop yield (FAO, 1973).

Fredrick (1975) suggested that changes in costs and continuity of water concepts have reflected in the overall rate of agricultural growth and in the overall crop compositions. He stated that increased value of water induced changes which led to substantial increase in the value of agricultural output per unit of land and water. In addition, Heady and Jensen (1965) found that profit will be increased through irrigation only as long as marginal returns are greater than marginal costs. They stated that if water must be purchased at so much per hectare-millimeter, the cost and labour for applying it must be computed to get the added costs for comparison with the added return;, under these conditions

and with rapidly diminishing returns, it seldom pays to apply enough irrigation water to get maximum yield per hectare.

The cost of irrigation water is usually considered as an expenditure of agriculture calculated by considering the volume of the water consumed by the various crops according to the unit price that corresponds to the irrigation rate or to the market price at the time considered (Murcia and Maqueda, 1969). However, Kleinman (1972) suggested that since water is not freely marketed, its price can be estimated by the value of the increase in output resulting from addtional unit of water used in producing the output.

2.15. Production Function Concepts.

The Production Concept is used in many economic analysis. It represents a schedule or mathematical formulation expressing the relationships between inputs and outputs. It also indicates the maximum amount of product obtainable from a specified quantity of inputs given the existing technology governing the input - output relationships (Hexem and Heady, 1978). It provides information concerning the quantity of output that may be expected when particular inputs are combined in a specified manner. However, Rae (1977) stated that the production of crops depend on the employment of various resources sometimes called inputs or factors of production. These factors could be soil nutrients, soil moisture, plant spacing, herbicides and the amount of water

applied. Any of these factors exert an influence on the crop production and the physical quantity and quality of output will depend on the quantities employed by the various input factors. The production function is expressed in terms of yield (y) as a function of water applied (x) given by Rae (1977) as :

$y = f(x)$.....(2.16).

However, Hexem and Heady (1978) observed that a single variable production function is of little significance because few, if any actual production relationships involve a single input and so for a more meaningful relationship, they expressed the production function as :

$y = f(X_1/X_2, X_3, X_4)$.....(2.17)

where

Y = crop yield

X_1 = water applied

X_2 = fertilizer applied

X_3 = plant population

X_4 = other inputs available at fixed quantity.

The vertical bar denotes X_1, as the only variable input applied to a specified fixed levels of X_2, X_3 and X_4.

Kleinman (1972) suggested that production function analysis allows the incorporation of basic economic principles into the decision making framework. It permits assumption of the limits of resources used and the substitution of resources

for one another, and it provides a non linear response which is compatible with agronomic and economic theories. In addition, Rae (1977) found that productions are usually determined under the assumption that the most efficient technology for the crop is employed, and is a boundary that seperates impossible input-output combination from the possible but technically inefficient combination.

In order to facilitate the production function for maximum output and be able to obtain an optimum output on point of economic maximum, Olayide and Heady (1982) stated that an explicit production function of the form given in Eq. (2.18) may be assumed for a single variable input X as :

$$y = a + bx + cx^2 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2.18)$$

where:

y = output

x = input

a,b,c = parameters to be determined

For maximum output,

$$\frac{dy}{dx} = b + 2cx = 0 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2.18a)$$

In which, $$x = \frac{-b}{2c} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (2.18b)$$

If x is substituted in Eq. (2.18), one obtains,

$$Y = a - \frac{b^2}{2c} + \frac{cb^2}{4c^2} \quad \text{.....(2.18c)}$$

In order to obtain the optimum output at a point of economic maximum or level of maximum profit (Olayide and Heady, 1982)

$$\frac{dy}{dx} = b + 2cx = \frac{r}{p} \quad \text{.....(2.18d)}$$

where: r = price per unit of input

P = price per unit of output

$$x = \frac{r - Pb}{2cp} \quad \text{.....(2.18e)}$$

Substituting x in Equation 2.18, one obtains

$$Y = a + \frac{br - b^2P}{2cp} + \frac{b^2cP^2 - 2bcpr + Cr^2}{4c^2p^2} \quad \text{.....(2.19)}$$

2.16 Production Costs Determination

Production costs are costs of all inputs that are used in order to produce a product. They include the variable costs and fixed costs of production (Rae, 1977).

2.16.1 Variable Costs

These are costs that vary as level of output varies or they are the expenditure which can be immediately adjusted according to the level of resources and hence according to the level of output generated (Harder et al., 1970). However, Rae (1977) gave an expression for calculating variable costs as:

$$TVC = P(x_1)x_1 + P(x_2)x_2 + \ldots\ldots\ldots\ldots P(x_k)x_k \quad \ldots\ldots 2.20$$

Where: TVC = total variable cost of Production

$P(x_i)$, i = 1,2.....K = price per unit of input factor x_1

X_1 to X_k = variable inputs.

2.16.2 Fixed Costs

These are costs that remain unaffected by change in output. Rae (1977) gave an expression for determining fixed costs as:

$$TFC = P(x_{k+1})x_{k+1} + P(x_{K+2})x_{K+2} + \ldots\ldots P(x_n)x_n \ldots\ldots (2.21)$$

Where: TFC = total fixed costs of Production

x_{K+1}, to x_n = fixed inputs.

The total cost of production is expressed as:

$$TC = TVC + TFC \ldots\ldots\ldots\ldots\ldots\ldots (2.22)$$

2.17 Depreciation Determination

James (1988) defined depreciation as the decrease in system value due to age and obsolescence. However, Morston et al. (1976) suggested some methods that could be used to determine depreciation; these include: direct appraisal method; sum of the digits method; declining balance and the straight line depreciation methods. Riggs (1977) however, stated that the straight line method of determining depreciation is the most widely used of the depreciation methods and it is simple to apply. Morston et al., (1976) gave

an expression for the straight line depreciation determination as:

$$D = \frac{B - S}{n} \quad \text{.....(2.23)}$$

where: D = annual depreciation allocation

B = Original cost of property

S = Salvage value at the end of service life

n = useful life of property

CHAPTER THREE

MATERIALS AND METHODS

3.1 Introduction

The experiment was conducted at Ahmadu Bello University farm located near Nasarawa Buhari village along Samaru-Shika Road which is on latitude 11^0 11'N, longitude 07^0 38'E. The study was conducted during the 1997/98 cool, dry season period using the check basin irrigation method. The site is located in the Sudan Savannah ecological zone and the boundries are defined by an earth-dam in the West and North; and in the South, by the former Plant Science Departmental Experimental farm. The site is bounded in the East by the farm lands of the village inhabitants. The climate of the area is divided into three main seasons, namely:

(i) the cool, dry season from October to February;

(ii) the hot, dry season from March to May, and

(iii) the warm wet season from June to September.

Tomato (Pevabo) variety was used as the trial crop. The experiment was a randomized complete block design replicated three times. The treatments were six different amounts of water for each irrigation, which were: 97, 125, 150, 175, 200 and 220 mm applied to six 2m X 2m basins. A total number of 12 basins per block and 2 basins per treatment in a block was used. An irrigation interval of 7 days was imposed on the crop after transplanting. The following measurements were taken during the study:

landslope, soil textural classification, soil moisture content, stream size, advance time, ponding time, amount of water applied and the infiltration rate of the soil.

3.2 Field Layout and Experimental Design

The experimental field plot of 0.0648ha size with dimension 27m x 24m was divided into three equal parts called plot units, and each plot unit being along the direction of predominant slope. Figure 3.1a shows the details of the plot layout. The percentage slope of the plots were determined using Eq.2.1, and it was found that unit 2 was at the highest part of the plots with a slope of 1.89% followed by plot unit 1 with a slope of 1.87%, while plot unit-3 being at the lowest part had a slope of 1.40%. The plots were laid across the contours of the farm in order to have as much homogeneous soil as possible within and between the units. Each plot unit had an area of 0.0216ha with dimension of 27m x 8m which was further divided into three equal parts called blocks, along the direction of the predominant slope. Figure 3.1b gives the details of the block layout. The blocks each with an area of 0.0072ha with dimensions 27m x 2.7m were divided into 12, 2mx2m basin sizes. Each block consisted of two treatments A, two treatments B; two treatments C; two treatments D; two treatments E and two treatments F. Altogether, each unit consisted of a total of six (6) treatments A; six (6)

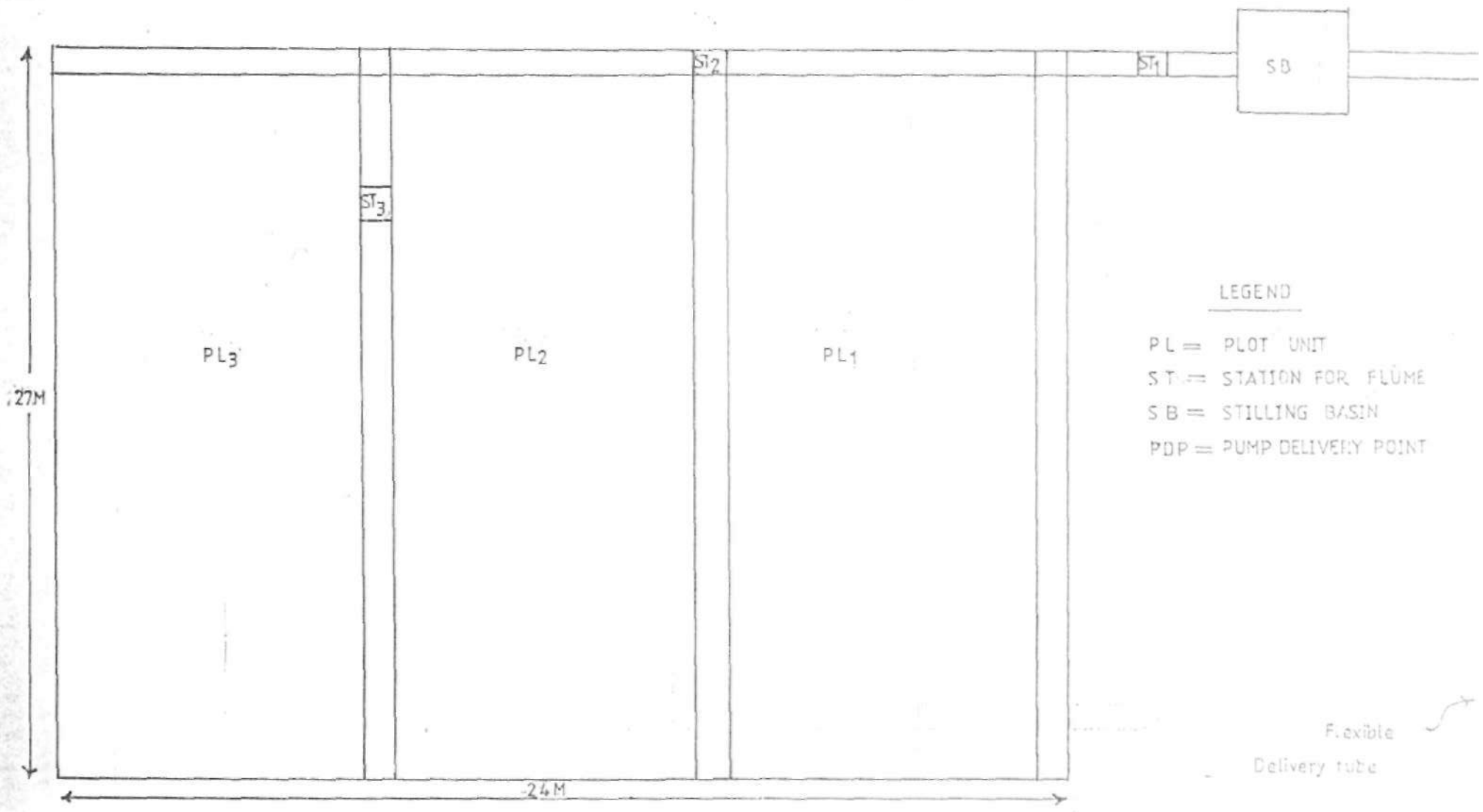


Fig. 3.1a DESIGN LAYOUT OF EXPERIMENTAL FARM

Fig.3.1b LAYOUT OF BLOCKS IN A PLOT UNIT, PL_2

treatments B; six (6) treatments C; six (6) treatments D; six (6) treatments E and six (6) treatments F. Figure 3.1c shows the details of the basins used for the various treatments. Randomized complete block design for a single factor experiment was used for the layout of the treatments within the three replications.

The total area of land used for channels and levees was 0.0216ha and the total land utilized in the study for crop production was 0.0432ha. The details are given in Appendix A. Table 3.1 gives the breakdown of the basins and the average amount of water applied to the basins.

Table 3.1 Treatment Layout Using 2m x 2m Basin Sizes

Treatment	Average water applied (mm)	Total number of basins
A	97	18
B	125	18
C	150	18
D	175	18
E	200	18
F	220	18
Total	967	108

3.3 Determination of Soil Textural Class

For the purpose of textural classification of the soil profile, mechanical sieve analysis was conducted on soil samples taken from various depths of interest at the site of

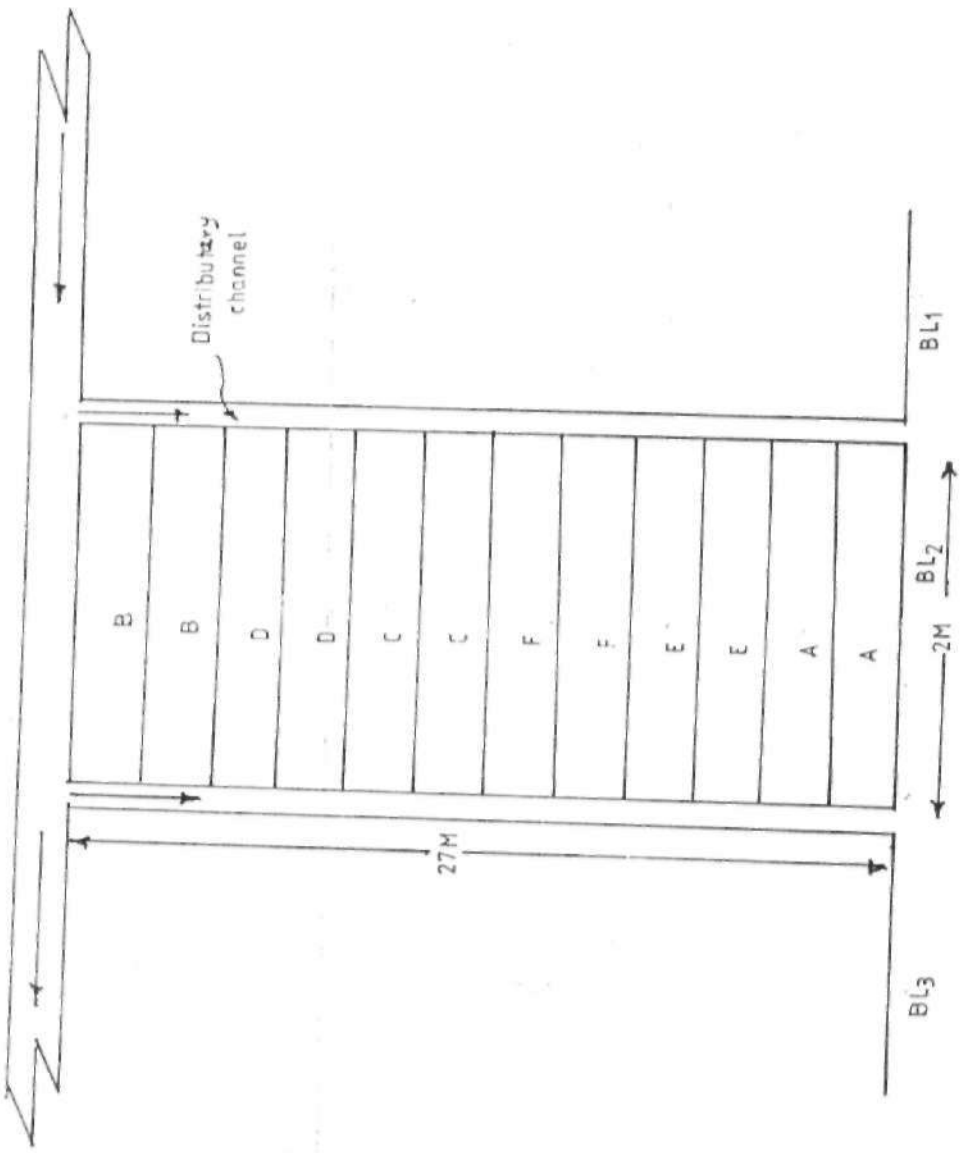


Fig-3-1c LAYOUT OF TREAMENTS IN A BLOCK, BL_2

the experimental farm. The soil samples were taken at incremental depths of 150mm down to a depth 600mm below the soil surface. A minimum of three replications were taken during each sampling which was randomized within the three plot units. The mechanical analysis was a combination of sieve and sedimentation techniques using the standard procedures reported by Loveday (1974). Table 3.2 shows the textural classification of the plots' soil where the experiment was conducted.

3.4 Soil Moisture Measurement

The soil moisture content was determined using gravimetric method. Soil samples were taken at incremental depths of 150 mm down to a depth of 600mm using a soil sampling auger at six locations randomized within the plot units and ensuring that each treatment is represented within each unit. The samples were collected just before and 2 - days after irrigation due to the light nature of the soil. Air - tight aluminium cans were used for the soil sampling collections. These cans were weighed and then placed in an oven at 105^0C for about 24 hours, until all the moisture is dried up and weighed again. The moisture content on weight basis was determined using Eq.(2.9). The volumetric moisture content was obtained by multiplying the gravimetric values by the bulk density. Thus, the depth of water applied was calculated. Table 3.3 gives the summary of the soil moisture holding characteristics of the plot soils.

Table 3.2 Soil textural classification and Bulk Density of the Field.

Depth of soil (m)	Soil proportions Sand %	Silt %	Clay %	Mean bulk Density g/cm^3	Textural Class*
0 - 0.15	48	38	14	1.55	L
0.15 - 0.30	34	28	38	1.59	CL
0.30 - 0.45	34	30	36	1.60	CL
0.45 - 0.60	36	32	32	1.61	CL

* Based on USDA Textural Classification.
L = Loam; CL = Clayloam.

Table 3.3 Soil Moisture Holding Characteristics of the Field.

Depth of Soil (m)	Field Capacity (% by weight)	Wilting Point (% by weight)	Mean Bulk density g/cm^3	Available Moisture (mm)
0 - 0.15	23.08	12.85	1.55	23.78
0.15 - 0.30	22.27	12.47	1.59	23.37
0.30 - 0.45	24.78	15.54	1.60	22.18
0.45 - 0.60	25.38	15.08	1.61	24.87
Total				94.20

3.5 Streamsize, Advance and Ponding Time Measurement

A Honda GX140 petrol engine pump was used to lift water from the dam reservoir to a delivery point located at a distance 60 m from the pump. An earth stilling basin was constructed to store the water and maintained a constant flow rate in a 100-mm cut-throat metal flume as much as possible. Three 100-mm cut-throat metal flumes were installed at the three locations, namely: (a) 2m away from the stilling basin along the main channel; (b) at the inlet of the plot along the distributary channel and (c) at the inlet of the basin in the blocks. Figures 3.1a,b,c, show these arrangements. Water depths (H_a) were measured at the three locations. Streamsizes were determined using Eq.2.6 for the three locations. These measurements were carried out on each irrigation day. The advance time for the water applied into the basins was measured using a stop watch and noting the time taken for the water to spread from the inlet to the end of the basin. This was done randomly, but with good representation for each treatment. These measurements were taken on all irrigation days. When water was supplied to the basin, a stop watch was used to measure the time taken for the water to infiltrate into the soil from the soil surface, thus obtaining the ponding time. These measurements were done on each irrigation day throughout the season. Since the advance time, the ponding time and flow rates into the basins are known, the amount of water applied was obtained using Eq.2.3. An average

of 0.65l/hr was obtained as fuel consumption rate for the pump.

3.6 Infiltration Rate Measurement

The double ring infiltrometer method was used in this study. This method was used because of the small sizes of the check basins and the approximate ponding nature of the irrigation method used. The outer and inner rings of the infiltrometer used were 600 mm and 400 mm diameter, respectively. The rings were driven into the ground by using a falling weight type hammer on a wooden plank placed diametrically on top of the cylinders. Water level in the inner ring was read with a point gauge. After the initial reading, point gauge measurements were made at frequent intervals using a stop watch and obtaining the amount of water that has infiltrated during the time interval. The analysis of the infiltration rates was carried out as explained in section 2.7.

3.7 Field Operation

Tomato seedling (Pevabo) seed variety obtained from the Department of Plant Science, Ahmadu Bello University, Zaria was raised on a plot of land adjacent to the experimental plot. In accordance with the recommendations of Anonymous (1976), the seedlings were raised for a period of thirty days before being transplanted. Fertilizer (N.P.K.) was applied as

a basal application at the rate of 250 Kg/ha to the field before levelling of the basins commenced. A day before transplanting, the area was pre-irrigated to wet the soil down to a considerable depth and enhance rapid development of the tomato-root system. Transplanting was done manually on the 19th January, 1998. Irrigation interval of 7 days was used throughout the period of study. The first weeding and top dressing with fertilizer at the rate of 60 Kg/ha was done mannualy on the 29th January, 1998, thereafter the second weeding and top dressing with fertilizer at the rate of 60 Kg/ha was done on the 19th February, 1998. The third and fourth weeding with top dressing was done on the 12th March and 2nd April, 1998, respectively. Harvesting of the crop started on the 16th April, 1998 manually by picking at a predetermined interval of 7 days and ended on the 7th May, 1998.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1. Introduction

The performance of the various amountS of water applied were based on quantitative analyses. The parameters considered include : the water applied, crop water use, tomato yield, production cost and net returns. Average tomato yield for the various amounts of water applied in terms of how much water was utilized and revenue generated were determined and compared. All parameters mentioned above were ranked among the six treatments and the optimum water requirement to produce the maximum crop yield was obtained. The most economic water charge for the various amounts of water applied and the respective profits made were determined.

4.2. Water Application

Table 4.1 shows the water flow rates measured at three locations in 100 mm cut-throat flumes. The table shows that average flow rate decrease along the channel. At station 1, that is, 2 m away from the earth constructed stilling basin (flow rate for plot 1), the average water flow rate was 6.07l/s, at station 2, that is at unit inlet along the distributary channel (flow rate for plot 2), the average flow rate was 4.94 l/s and decreased as it moved along the channel to 4.52 l/s at station 3 being the basin inlet within the

blocks (flow rate for plot unit 3). This is due to seepage of the water as it moves along the channel. Table 4.2 shows the average advance times for the treatments in the plot units. It was observed that the advance times for all the treatments were similar for all the plot units and the treatments, since the length of the check basins were short and the same basin sizes were used. The results on the analysis of the infiltration rate characteristics of the soil (Appendix B) shows that the soil had a moderate intake rate, thus, streamsizes available were adequate. The little variation in the advance times could be due to slight differences in the slopes of the plot units.

Table 4.3 shows the ponding times for the treatments. The table indicates that ponding times were similar within all the plot units for the same treatment, but increases with increase in amounts of water applied for all the treatments in the plot units. The sum of advance time and the ponding time gave the total irrigation time.

Table 4.1. Flow Rates Measured at Three Stations.

	Measured flow rates (l/s)		
Irrigation Number	Station 1	Station 2	Station 3
1	4.93	3.15	2.28
2	5.47	4.03	3.57
3	8.01	6.10	5.36
4	7.14	5.86	5.36
5	7.97	6.55	6.18
6	4.45	3.54	3.41
7	5.19	4.76	4.18
8	5.57	4.80	4.43
9	6.57	5.69	5.36
10	6.69	5.00	4.18
11	5.51	4.53	4.43
12	6.67	5.69	5.36
13	5.41	4.60	4.43
14	5.40	4.86	4.75
Average	6.07	4.94	4.52

Table 4.2 Advance Time(t_a) for Treatments(sec)

Treatment	Plot Units 1	2	3	No. of irrigation	Average	Total
A	98	88	101	14	16	287
B	87	95	95	14	15	277
C	86	91	93	14	15	270
D	86	90	88	14	14	264
E	85	86	85	14	14	256
F	76	79	96	14	14	251

Table 4.3 Ponding Time(t_p) for Treatment(sec)

Treatment	Plot units 1	2	3	No. of irrigation	Average	Total
A	356	362	357	14	60	1075
B	487	485	470	14	80	1442
C	595	580	612	14	99	1787
D	710	725	736	14	120	2171
E	864	822	876	14	142	2562
F	934	981	969	14	160	2884

Table 4.4 shows the seasonal amount of water applied and the total times of irrigation for all the treatments. It was observed that the time of irrigation varied with the amount of water applied for the stream sizes used and basin sizes because of the increase in amounts of water applied leading to increase in ponding times. Thus, the amount of water tends to increase the times of irrigation as more water is applied, and more fuel was consumed.

Table 4.4 Seasonal Amount of Water Applied for Treatment

	Total Time of Irrigation		Amount of Water applied	
Treatment	Average per irrigation (hr)	14-irrigation (hr)	Average per irrigation (mm)	14-irrigation (mm)
A	0.38	5.28	97	1360
B	0.48	6.78	125	1755
C	0.57	8.03	150	2105
D	0.68	9.55	175	2450
E	0.77	10.84	200	2805
F	0.87	12.02	220	3080
Total	3.75	52.50	967	13555

4.2.1 Crop water use

Table 4.5 shows the values of the crop water use per treatment for the tomato crop under study. Table 4.5 indicates that crop water use varied for all the treatments due to differences in the amount of water applied and the soil texture. The amounts of water applied were found to be higher

than the water holding capacity of the soils (Table 3.3 and Table 4.4). However, the moisture content of the soil taken 2-days after irrigation (appendix G) showed that the moisture content was close to the value at the field capacity. Thus, even when high amounts of water were applied, soil moisture within the rootzone was maintained close to the field capacity values. That is, the excess water was completely disposed off by deep percolation. Consequently, treatment F (665.32mm) had the highest crop water used, followed by treatment E (635.60mm), D(596.81mm), C(552.95mm), B(543.0mm) and A(517.29mm) in that order, which were in line with the amounts of water applied, respectively.

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Table 4.5 Crop water use (mm)

	Irrigation Number														
Treatment	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Total
A	26.42	34.32	33.49	36.87	36.52	37.62	41.34	44.47	57.57	55.52	36.52	32.36	29.19	18.08	517.29
B	14.22	26.85	18.70	18.75	30.03	38.98	39.72	49.35	94.76	71.45	50.10	49.29	25.40	15.40	543.00
C	20.48	36.30	41.80	40.08	42.95	35.94	50.28	50.72	62.34	58.35	41.85	26.14	25.12	20.60	552.95
D	17.07	18.85	22.06	23.64	43.57	34.28	49.82	85.68	79.81	64.90	47.02	41.75	39.94	28.42	596.81
E	24.84	31.91	42.72	36.51	62.90	59.37	80.49	91.99	64.63	47.54	37.19	23.12	18.26	14.13	635.60
F	15.91	18.31	25.82	30.74	34.60	38.11	74.63	54.58	86.11	80.76	59.48	58.87	48.49	40.91	665.32

Growing Season = 98 days

Table 4.6 provides the evapotranspiration or rate of water use of the crop for the entire growing period of the crop under study. The table shows that evapotranspiration values were low at the initial stage of the crop, that is just after transplanting. The values increased to a peak value of 13.5 mm/day and then at maturity to a value of 2.0 mm/day. This is mainly due to the fact that at the initial stage, the crops' roots were not fully developed and so small amount of water was used, but as the crop developed, the rate of water usage increased up to the peak and thereafter decreased at maturity, as the crop did not require much water at that stage. The highest evapotranspiration value of 13.5 mm/day was recorded from treatment B which was in the range of 12-14 mm/day reported in earlier studies by FAO (1977). The evapotranspiration value of 13.5 mm/day had a net water use of 543.00 mm (Table 4.5) which was close to 585 mm and 580mm obtained by Hassan (1981) and Anonymous (1993), respectively for Kadawa soils in Kano State, Nigeria.

Table 4.6 Crop Evapotranspiration (mm/day)

	Irrigation Number													
Treatment	1	2	3	4	5	6	7	8	9	10	11	12	13	14
A	3.7	4.9	4.7	5.2	5.2	5.4	5.9	6.4	8.2	7.9	5.2	4.6	3.7	2.6
B	2.0	3.8	2.6	2.7	4.2	5.5	5.7	7.0	13.5	10.2	7.1	7.0	3.6	2.2
C	2.9	5.1	5.9	5.7	6.1	5.1	7.2	7.3	8.9	8.3	5.9	3.7	3.5	2.9
D	2.4	2.6	3.1	3.4	6.2	4.8	7.1	12.2	11.4	9.3	6.7	5.9	5.7	4.0
E	2.2	2.6	3.6	4.4	4.9	5.1	10.6	7.7	12.3	11.5	8.5	8.4	6.9	5.8
F	3.5	4.5	6.1	5.2	8.9	8.5	11.5	13.1	9.2	6.8	5.3	3.3	2.6	2.0

4.3 Land Utilization

Table 4.7 gives the amount of land area used for each treatment with the percentage of relative land loss. Land loss through making levees and field channel construction was estimated as a loss in income and as additional production cost. This was done by quantifying and costing the expected tomato yield from the land lost as stated above. Table 4.7 shows that percentage of land cultivated, wasted land and relative land loss of the area are the same for all the treatments since the same basin sizes were used for all the experiments. Table 4.8 also shows the estimated loss in income due to land loss. It was observed that since the same basin sizes were used for the experiments, the same loss in income was estimated for each treatment. The details of the quantification and costing of the land lost out of production are presented in Appendix C.

Table 4.7 Percentage of Land Utilization for Treatment.

Treatment	Cultivated area (ha)	Wasted area (ha)	Percentage of relative land loss (%)
A	0.0072	0.0036	5.55
B	0.0072	0.0036	5.55
C	0.0072	0.0036	5.55
D	0.0072	0.0036	5.55
E	0.0072	0.0036	5.55
F	0.0072	0.0036	5.55
Total	0.0432	0.0216	33.30

Table 4.8 Estimated Loss in income due to Limited Land loss

Treatment	Relative land loss (ha)	Relative yield loss (Kg)	Loss in income (₦)
A	0.0036	21.04	210.40
B	0.0036	21.04	210.40
C	0.0036	21.04	210.40
D	0.0036	21.04	210.40
E	0.0036	21.04	210.40
F	0.0036	21.04	210.40
Total	0.0216	126.24	1262.40

4.4 Crop Yield

Crop harvested was classified into marketable and non-marketable yields and measurements were made with a weighing balance at the site. Marketable yields are those harvested crops that were obtained from the experimental farm and conveyed to the market with minimum damage and sold at the prevailing market price. Non-marketable yields, on the other hand, are those crops that were obtained from the experimental farm as damaged tomato fruits and /or those that could not be sold when taken to the market.

Table 4.9 shows the average marketable yield for all the harvests for the treatments and plot units. The highest average marketable yield of 12.235 t/ha or (0.529t/0.0432ha) was obtained for all the treatments. This quantity was sold at a market price of ten Naira (₦10) per kilogramme giving the highest average revenue of one hundred and twenty-two thousand, three hundred and fifty Naira (₦122,350) per hectare or five thousand two hundred and ninety Naira (₦5290) for 0.0432ha being the actual area used. Table 4.10 shows the highest average non-marketable yield of 1.99t/ha (or 0.086t/0.0432ha) which represented an average revenue loss of one thousand, nine hundred and ninety Naira (₦1990) per hectare or eight hundred and sixty Naira (₦860) for 0.0432ha.

Table 4.9:Marketable Tomato Yields for Treatment in Plot units (t/ha)

Treatment	Plot Units 1	2	3	Mean
A	14.896	9.117	4.896	9.636
B	16.108	13.929	6.667	12.235
C	14.879	12.808	6.000	11.229
D	13.042	9.938	8.725	10.568
E	9.721	8.967	6.542	8.410
F	8.745	8.800	6.333	7.959

Table 4.10: Non-marketable Tomato Yields for Treatment in Plot Unit (t/ha)

Treatment	Plot Units 1	2	3	Mean
A	2.917	1.875	0.729	1.840
B	2.667	2.700	0.604	1.990
C	2.521	2.521	0.542	1.861
D	2.229	1.925	0.729	1.628
E	2.146	1.625	0.667	1.479
F	1.667	1.583	0.688	1.313

4.4.1 Comparison of tomato yields

Table 4.11 gives the average tomato yield which is made up of marketable and non-marketable components. Total tomato yield of 11.691t/ha was obtained for the whole plots which is close to 12.3t/ha reported in earlier studies by Anonymous (1979). Average tomato yields of 11.476, 14.225, 13.090, 12.196, 9.889 and 9.272 t/ha were obtained for treatments A, B, C,D, E, and F, respectively. In a similar manner, average tomato yields of 15.256, 12.631 and 7.187 t/ha were also obtained for plot units 1,2, and 3, respectively. These averages of tomato yield obtained from 7.0-15.3 t/ha for all the treatments and plot units are in the range of 6.0-17.9t/ha obtained in earlier studies by Anonymous (1979).

However, when the data was subjected to statistical analysis, (Table 4.12) it was found that there was significant difference between the mean yields of the treatments at 95% level of confidence. Treatment B gave the highest mean yield of 14.225t/ha. This is followed by mean yields of treatments C (13.090t/ha), D(12.196t/ha), A(11.476t/ha) and E(9.889t/ha). Treatment F, had the lowest mean yield of 9.272t/ha. Generally, treatment B, had the highest yield, followed by treatments C,D,A,E and F in that order. When data obtained for the plot units were subjected to statistical analysis, it was observed that the mean yield for the plot units were highly significantly different from each other at 1% level of significance. Plot unit 1 had the highest mean yield of

15.256t/ha, followed by the mean yields for plot unit 2(12.631t/ha) and 3(7.187t/ha). These differences in yield among the plot units may be due to over irrigation of the land, slope variation, probable variation in soil texture and water holding capacities of the soils in the plot units.

When these mean yields were compared to the average amount of water applied, it shows that treatment B gave the optimum water use, followed by treatments C,D,A,E and F. Thus, treatment B had the best water utilization, while treatment F had the lowest water utilization considering the yield obtained for the treatments.

Table 4.11: Tomato Yield Distribution for Treatments and Plot Unit (t/ha)

	Yield per Plot Unit(t/ha)			
Treatment	1	2	3	Mean
A	17.813	10.992	5.625	11.476
B	18.775	16.629	7.271	14.225
C	17.400	15.329	6.542	13.090
D	15.271	11.863	9.454	12.196
E	11.867	10.592	7.209	9.889
F	10.412	10.383	7.021	9.272
Mean	15.256	12.631	7.187	11.691

Table 4.12: Analysis of Variance for Tomato Yield Distribution for Treatments and Plot Units.

Source of Variation	Degree of Freedom	Sum of squares	Mean Square	Computed F	Tabular F 5%	1%
Replication	2	203.292	101.6460	20.405**	4.12	7.56
Treatment	5	86.334	17.2668	3.530*	3.33	5.64
Error	10	48.914	4.8914			
Total	17	305.540				
LSD		4.023				

* = Significant

** = highly significant

4.4.2 Tomato yield-water use function

Table 4.13 shows the total amounts of water applied and the mean yields for the treatments. It indicates that crop yields increased with the amounts of water applied and thereafter, decline as more water was applied. Treatment B with 1755mm total amount of water applied gave the highest average yield of 14.225 t/ha. This was followed by treatments C, D, A and E. Treatment F with 3080 mm total amount of water applied gave the lowest average yield of 9.272t/ha.

Figure 4.1 gives the graph of the tomato yield versus the gross amount of water applied. Figure 4.1 indicates that tomato yield increased to maximum at an optimum amount of water applied and thereafter, decreases from the maximum yield with further increase in amount of water applied. This may be due to high deep percolation losses associated with high amount of water applied, thus leaching the required crop nutrients, resulting in yield reduction.

Table 4.13 Gross Water Application and Mean Tomato Crop Yield for Treatments.

Treatment	Water applied (mm)	Mean tomato yield (t/ha)
A	1360	11.476
B	1755	14.225
C	2105	13.090
D	2450	12.196
E	2805	9.889
F	3080	9.272

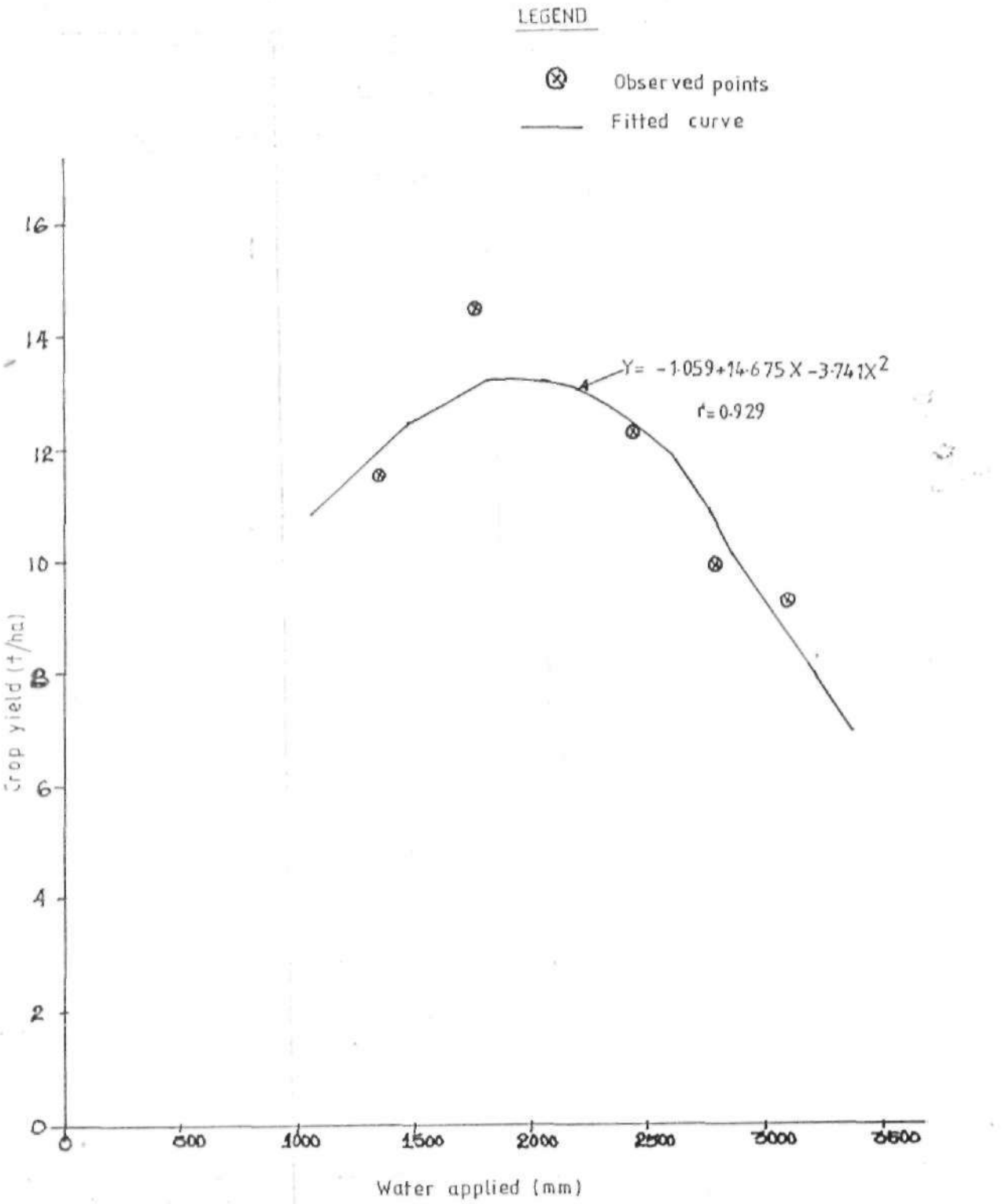


Fig:4-1 RELATION OF TOMATO CROP YIELD AND GROSS WATER APPLICATION

4.5 Production Costs

As earlier stated, production cost is the costs of all inputs that are used to produce a product. It is made up of the fixed cost and variable costs.

4.5.1 Fixed cost

Table 4.14 shows the fixed cost of production which consist of pump maintenance, depreciation values for the irrigation pump and other farm tools used annually. The details are provided in Appendix E. However, Table 4.14 indicates that the total fixed cost for all the treatments were four thousand, seven hundred and fifty-four Naira, eighty-eight Kobo (₦4754.88).

Table 4.14: Fixed Cost of Production for all Treatments

S.No	Item	₦
1.	Irrigation pump depreciation	3500.00
2.	Pump Maintenance	1175.00
3.	Other Farm tools	79.88
	Total	4754.88

4.5.2 Variable costs.

These consist of labour and material costs. Table 4.15 shows the labour and material costs for the treatments along with the unit prices and the time taken per activity on hectare basis. Variable costs of production of 44062.48, 45691.45, 47022.33, 48342.28, 49656.37 and 5071.56 Naira per

hectare were obtained for treatments A, B,C,D,E and F, respectively. Table 4.15 indicates that treatment F had the higest variable cost of production of N50711.56 per hectare, followed by treatment E(N49656.37 per ha). Treatment A had the lowest variable cost of production of N44062.48 per ha. Generally, treatment F had the highest variable cost of production, followed by treatments E, D, C, B and A in that order. This can be attributed mainly to the differences in irrigation labour among the treatments. Also, the cost of consumable items such as petrol, was highest for those treatments that were supplied with large amount of water. This was mainly caused by the length of time taken to supply large amounts of water to some treatments as compared to others.

Table 4.15 Variable Cost of Production for Treatment

Operation/item	Duration m.d	Unit price ₦/Units	Treatment(₦/ha) A	B	C	D	E	F
Land development	5	80/md	6172.84	6172.84	6172.84	6172.84	6172.84	6172.84
Basin Layout	2.5	80/md	3086.42	3086.42	3086.42	3086.42	3086.42	3086.42
Weeding	9	80/md	16666.67	16666.67	16666.67	16666.67	16666.67	16666.67
Transplanting	1.5	80/md	2777.78	2777.78	2777.78	2777.78	2777.78	2777.78
Fertilizer		20.98/kg	6939.91	6939.91	6939.91	6939.91	6939.91	6939.91
Tomato Marketing		0.03/kg	344.28	426.75	392.67	365.88	296.67	278.16
Tomato seeds		1.20/g	2777.78	2777.78	2777.78	2777.78	2777.78	2777.78
Irrigation Labour	2.125	0.03/m^3	408.00	526.50	631.50	735.00	841.50	924.00
Irrigation Water cost**		0.0061/m^2	4888.80	6316.8	7576.8	8820.00	10096.80	11088.00
Total			44062.48	45691.45	47022.37	48342.28	49656.37	50711.56

** = Details are given in appendix F
I.A.R One Man-day = 4 - working hours at ₦20/man-day.

4.5.3 Total cost of production

Table 4.16 gives the total cost of production of the crop under study. This was obtained by summing the fixed cost and variable costs for all the treatments. However, it was observed from Table 4.16 that the total cost of production for treatment F was the highest, while the lowest was recorded for treatment A. These differences in cost of production among the treatments were due to the varied amounts of water applied to the basins and irrigation labour.

Table 4.16 Total Cost of Production for Treatment(₦/ha)

	Treatments					
Cost Description	A	B	C	D	E	F
Fixed Cost	4754.88	4754.88	4754.88	4754.88	4754.88	4754.88
Variable Cost	44062.48	45691.45	47022.37	48342.28	49656.37	50711.56
Total	48817.36	50446.33	51777.25	53097.16	54411.25	55466.44

4.6 Irrigation Water Cost

This is the money paid to make the water available to the farmer on schedule. However, in order to estimate the cost of the water charge for this study the volume of water applied for the season, total time of irrigation, the petrol cost price of ₦20 per litre and an average fuel consumption rate of 0.65l/hr used during the study were used to obtain the cost of pumping the water for the season per hectare. The cost of

irrigation was estimated based on the amount of water applied to each basin, the details are provided in appendix F.

Table 4.15 shows among the variable costs, the irrigation water charge for all the treatments. It was observed that irrigation water charge increases with increase in the amount of water applied to an area. Table 4.17 shows the statistical analysis of the irrigation water cost for the treatments. It was found that water charges were highly significantly different for all the treatments at 1% level of significance. Treatment F had the highest water charge of ₦11088.00 per ha per season, followed by treatment E(₦10096.80) per ha per season. Treatments D and C had irrigation water charge of ₦8820 per ha and ₦7576.80 per ha per season, while treatments B and A had water charge of ₦6316.8 and ₦4888.8 per ha per season, respectively. Generally, treatment F gave the highest water charge, while the lowest was obtained for treatment A. This was mainly due to the differences in the amount of water applied.

Table 4.17: Analysis of Variance of Water Charge for Treatments.

Source Variation	Degree of Freedom	Sum of squares	Mean Square	Computed F	Tabular F 5%	1%
Replication	2	172751.17	86375.585			
Treatment	5	912633.01	182526.602	163.258**	3.33	5.64
Error	10	11180.24	1118.024			
Total	17	1096564.42				

** = highly significant

4.7. Revenue Generated

The revenue generated from each treatment was determined by first obtaining the gross income from the tomato sales. The total cost of production and loss in income due to land loss as an additional income that the farmer would have obtained if the land had been fully utilized was subtracted from the gross income, thus, resulting in the profit made in each treatment. The cost - benefit ratios (C/B) for all the treatments were determined. The total cost incurred in each treatment in producing the tomato crop is taken as cost (C), while the income obtained in each treatment as revenue generated from the sales of tomato is the benefit (B) realized by the growers. The lower the (C/B) ratio for a treatment, the better the treatment performance in cost recovery.

Table 4.18 shows the gross income generated and profit made for each treatment. It was observed that treatment B gave the highest gross income of ₦142250 and profit of ₦91593.27 per hectare. This was followed by treatments C, D, A and E in that order. Treatment F had the lowest income of ₦92720 and recorded a profit of ₦37043.16 per hectare. Generally, the highest profit of ₦91593.27 per hectare was obtained for treatment B. Treatment C had a profit of ₦78902.35 per hectare higher than treatment D of ₦68652.44 per hectare. Treatment A (₦65732.24) per hectare had less profit than D, but higher than the profit made by treatment E (₦44268.35) per hectare.Treatment F has the lowest profit of

₦37043.16 per ha among all the treatments. These variation in income, cost of production and the profit made were mainly due to differences in the amount of water applied, yield obtained for each treatment, the time of irrigation and the prevailing soil condition of the field where the experiment was conducted.

The implication of this result is that farmers will be advised to accept and implement the treatment that had the highest income and profit made among all the treatments, which in this case is treatment B. It also implies that farmers will manage the available water supply in order to obtain such a high profit at minimum cost of production, thus, utilizing the water supply and all other inputs involved in the production more effectively.

Table 4.18. Cost and Returns for Treastment (₦\ha)

Treatment	Gross income	cost of Production	Loss in income due to land loss	profit
A	114760	48817.36	210.40	65732.24
B	142250	50446.33	210.40	91593.27
C	130890	51777.25	210.40	78902.35
D	121960	53097.16	210.40	68652.44
E	98890	54411.25	210.40	44268.35
F	92720	55466.44	210.40	37043.16
AVERAGE	116911.67	52335.97	210.40	64365.30
TOTAL	701470	314015.79	1262.40	386191.81

4.8. Assessment of the Treatments.

The assessment of the amounts of water applied considered based on the tomato yield, gross income from tomato sales, irrigation water charge, profit made and the cost benefit ratio for each treatment are provided in Table 4.19.

Average crop yield of 11.476, 14.225, 13.090, 12.196, 9.889 and 9.272 t/ha were obtained for treatments A, B, C, D, E and F, respectively. It was found that the differences between the treatment mean yields were significant at 95% level of probability. Treatment B had the highest mean yield of 14.225 t/ha, followed by the mean yields of treatments C(13.090 t/ha), D(12.196 t/ha), A(11.476 t/ha) and E(9.889 t/ha). The lowest mean yield of 9.272 t/ha was obtained for treatment F. This may be due to high percolation losses associated with large amount of water applied to the basins resulting in lower yield.

Irrigation water charges of ₦4888.8, ₦6316.8, ₦7576.8, ₦8820, ₦10096.8 and ₦11088 per hectare were obtained for treatments A,B,C,D,E, and F, respectively. Statistically, it was found that at 1% probability level irrigation water costs were highly significantly different. Treatment F gave the highest irrigation water charge of ₦11088 per hectare, followed by irrigation water charge for treatments E (₦10096.8), D(₦8820), C(₦7576.80) and B(₦6316.80) per hectare. Treatment A had the lowest irrigation water cost of ₦4888.80 per hectare.

The average profit made for treatments A,B,C,D,E and F were ₦65732.24, ₦91593.27, ₦78902.35, ₦68652.44, ₦44268.35 and ₦37043.16 per hectare, respectively. It was observed that treatment B gave the highest average profit of ₦91593.27 per hectare, while the lowest average profit of ₦37043.16 per hectare was obtained for treatment F.

Figure 4.2 shows the relations of the average crop yield, irrigation water charge, net returns and the amount of water applied. The figure shows that crop yield was maximum at an optimum amount of water applied and thereafter, tends to decrease with either increase or decrease in the amount of water applied. Profit realised seems to be highest at the optimum amount of water applied and thereafter tends to decline with either increase or decrease in the amount of water applied. This was consistent with tomato yield obtained for the various treatments. However, irrigation water charge increases with the amount of water applied to the basins. Figure 4.2 also shows that for optimum crop yield and optimum profit, water applied in the range of 1360 - 2650mm and water charge in the range of ₦4888.80 to ₦9000.00 per hectare is required. Beyond these ranges, farmers will not be willing to pay for the amount of water applied. The amount of water applied will be large such that it tends to reduce yield with high water charge resulting in low profit made. However, for maximum profit the figure indicates that an optimum yield of 14.2 t/ha with optimum water application of 1750mm with an

adequate water charge of ₦6316.80 per ha per season, that is an average of ₦451.20 per ha. per irrigation is required. This irrigation water charge per irrigation of ₦451.20 per hectare is close to the cost of hiring an irrigation water pump by farmers at the rate of ₦500 per hectare as reported by Mohammed (1998), a farmer from Shika village in Zaria.

The cost/benefit percentages obtained were 42.5, 35.5, 39.6, 43.5, 55.0 and 59.8% for treatments A,B,C,D,E and F, respectively. Treatment B had the lowest cost-benefit ratio of 35.5%, followed by treatments C(39.6%), A(42.5%), D(43.5%) and E(55.0%). Treatment F had the highest cost-benefit ratios of 59.8%. Table 4.19 indicates that cost benefit ratios for small amounts of water applied were low and that the ratios tend to rise with increase in the amount of water applied, which shows that smaller amounts of water applied had better cost recovery than large amounts of water applied. This confirms the relationship obtained on tomato yield for the treatments.

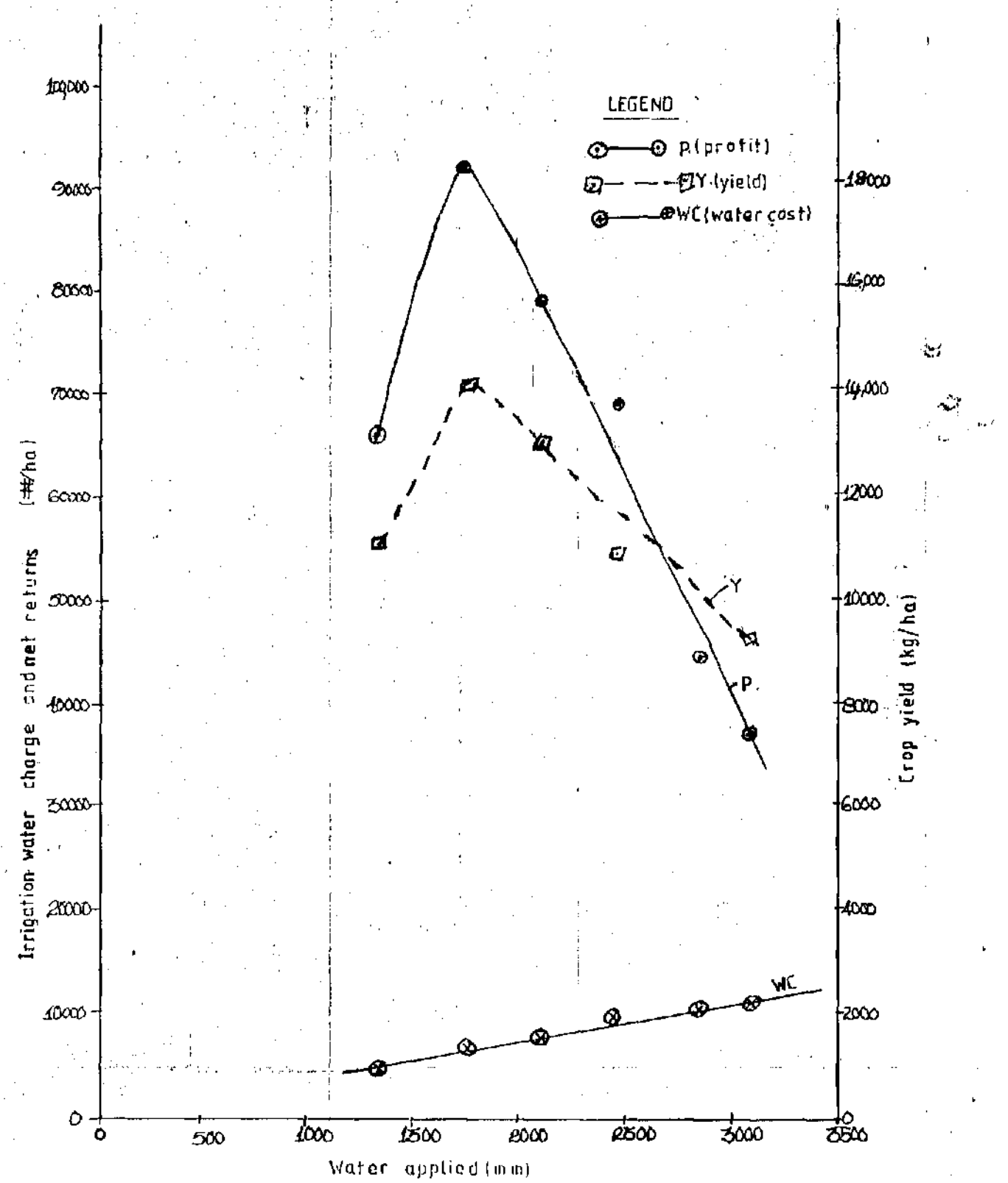


Fig. 4.2 RELATIONS OF THE WATER CHARGE, YIELD, NET RETURNS AND THE AMOUNT OF WATER APPLIED

Combining the performances of the treatments based on water requirement, crop yield, income, water charge and cost-benefit ratio, it was observed that treatment F which had the highest amount of water applied recorded the highest crop water use, cost - benefit ratio and lowest in yield, income and profit made, which was due to high labour requirement resulting in low revenue generated from the tomato sales. Treatment B had the best performance in terms of yield, revenue generated, labour utilization and cost recovery. This was followed by treatments C,D E and A, respectively. Treatment B performed above average in both the water requirement and economic evaluations. Thus, treatment B(125mm average amount of water applied per irrigation) and irrigation water charge of ₦451.20 per hectare per irrigation was selected as the most suitable and appropriate amount of water to be applied at the most economic water charge for tomato production in a small scale irrigation farming in Samaru.

Table 4.19 Overall Performance for Treatments.

	Average performance			
Treatment	Yield t/ha	Water charge ₦/ha	profit ₦/ha	C/B ratio %
A	11.476	4888.80	65732.24	42.5
B	14.225	6316.80	91593.27	35.5
C	13.090	7576.80	78902.35	39.6
D	12.196	8820.00	68652.44	43.5
E	9.889	10096.80	44268.35	55.0
F	9.272	11088.00	37043.16	58.9

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Summary

Six different amounts of water; 97, 125, 150, 175, 200 and 220 mm were applied to six basins of the same sizes 2mx2m and studied as treatments A, B, C, D, E and F. These amounts of water applied were in excess in order to give a meaningful range of irrigation water charge to enable the farmers pay for the water applied to enhance good utilization of the water for crop production. The experiments were conducted in three plot units with slopes of 1.87, 1.89 and 1.40%. Each plot contained six treatments. Irrigation interval of 7 days was imposed on all the treatments after transplanting the seedlings. The soil texture, infiltration characteristics of the soil, crop water requirement and daily evapotranspiration of the crop under study were determined for the various basins. The seasonal net water requirement ranged from 517.29 to 665.32mm among all the treatments. Peak consumptive use of 13.5mm/day was obtained from treatment B.It is found that an Optimum seasonal water requirement of 1755mm is required to produce a maximum yield of 14.225t/ha at an economic water charge of ₦6316.8 per hectare per season, that is, ₦451.20 per hectare per irrigation which is adequate for farmers to adopt for effective crop production and profit making under small scale irrigation farming.

Average crop yield obtained ranged from 9.272 t/ha to

14.225t/ha among all the treatments. Treatment B gave the higest crop yield, while the lowest yield was obtained for treatment F. Irrigation water charge varied from ₦4888.80 to ₦11088.00 per hectare among all the treatments depending on the amount of water applied. The profit made varied from ₦37043.16 to ₦91593.27 per hectare among all the treatments. Treatment B had the higest profit while the lowest profit was recorded by treatment F. Treatment B had the best cost-recovery among all the treatments.

5.2 Conclusions

For this study, the results presented herein show that the following conclusions can be drawn:

1. Treatment B (125mm amount of water applied per irrigation) gave an optimum yield of 14.225 t/ha for tomato production on the prevailing soil texture under small scale irrigation system using 2m x 2m basin size when stream size was provided by Gx140 Honda irrigation pump.

2. Treatment B with irrigation water charge of ₦6316.80 per hectare per season, i.e ₦451.20 per hectare per irrigation is considered the most economical among all the irrigation water charges for the treatments. The irrigation water charge provided the higest crop yield and adequate water application, thus enabling the farmers

to pay for the water and utilize the water properly for tomato crop production under small scale irrigation system using 2m x 2m basin size.

3. Tomato yield and net returns increased with the amount of water applied up to a maximum and thereafter decreased as more water was applied. Thus crop yield, net returns and water charge influence the amount of water the farmers are willing to pay for on tomato crop production under small scale irrigation system.

5.3 Recommendations

1. For efficient water utilization to enhance increase in tomato yield at low irrigation water charge, water application depth of 125mm per irrigation is recommended for tomato production on loan to clay-loam soils under small-scale irrigation system using 2m x 2m basinsize when streamsize is provided by Gx140 Honda irrigation pump.

2. It is recommended that the adoption of irrigation water charge by farmers be always related to the amount of water supplied for maximum utilization to enhance increase in yield and profit making under small scale irrigation farming.

3. Similar experiments are also recommended for other crops in the irrigation schemes for the provision of necessary data needed for implementing an efficient water use at an economic water charge to the small scale farmers to increase the production of the different irrigated crops the farmers produce for more efficient sustenance and profit making.

4. It is recommended that similar experiments be carried out using other irrigation water pumps, soil texture and basin sizes so as to provide more data for general implementation of range of streamsizes, amounts of water applied and the basin sizes regardless of the type of irrigation water pump, soil type and the basin size to the small scale farmers for maximum crop production at an appropriate water charge.

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APPENDIX A

Evaluation of Experimental Field Layout

Length of the field = 27m

Breadth of the field = 24m

Area of field = 27 x 24 = 648m^2

= 0.0648ha

$$1 \text{ plot unit} = \frac{0.0648\text{ha}}{3} = 0.0216\text{ha}$$

$$1 \text{ Block unit} = \frac{0.0216\text{ha}}{3} = 0.0072\text{ha}$$

$$1 \text{ treatment} = \frac{0.072\text{ ha}}{12} = 0.0006\text{ha}$$

Total area for Treatment = 4m^2 x 6 = 24 x 6 = 144m^2

= 0.0144ha

Total area for blocks = 0.072ha x 6 = 0.0432ha.

Total area used for channel and levees = 0.0648ha - 0.0432ha

= 0.0216ha

For each treatment, area used for channel and levees

$$= \frac{0.0216}{6} = 0.0036\text{ha}$$

APPENDIX B

Evaluation of Soil Intake Rate Characteristics

Table B_1: Soil intake rate Characteristics for the Experimental Farm.

n	Elapsed Time (min)	Initial gauge Reading (mm)	Final gauge Reading (mm)	Depth (mm)	Accumulated infiltration (mm)	Infiltration Rate mm/min
1	0	0.00	0.00	-	-	-
2	5	0.00	10.00	10.00	10.00	2.00
3	10	10.00	14.00	4.00	14.00	0.80
4	15	14.00	17.50	3.50	17.50	0.70
5	20	17.50	20.67	3.17	20.67	0.634
6	40	20.67	30.67	10.00	30.67	0.50
7	60	30.67	39.67	9.00	39.67	0.45
8	80	39.67	47.67	8.00	47.65	0.40
9	100	47.67	55.00	7.33	55.00	0.37
10	130	55.00	65.00	10.00	65.00	0.33
11	160	65.00	74.00	9.00	74.00	0.30
12	190	74.00	83.00	9.00	83.00	0.30

Infiltration Rate Expression, $I = 2.3871t^{-0.5880}$

Coefficient of Determination $r^2 = 0.712$

Accumulated intake Expression $Z = 3.6238t^{0.5903}$

Coefficient of determination $r^2 = 0.998$

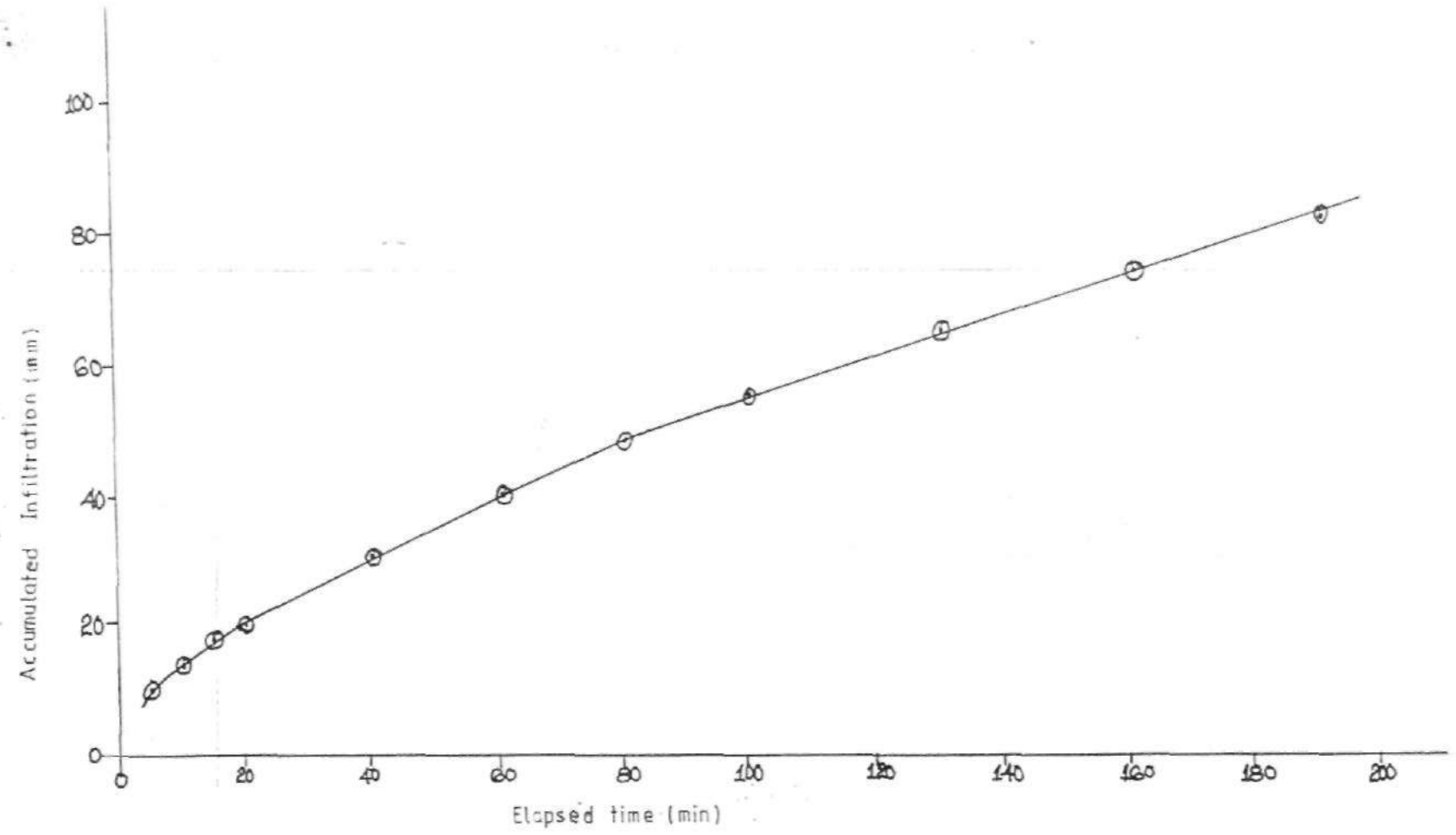


Fig: B_2 ACCUMULATED INFILTRATION CURVE.

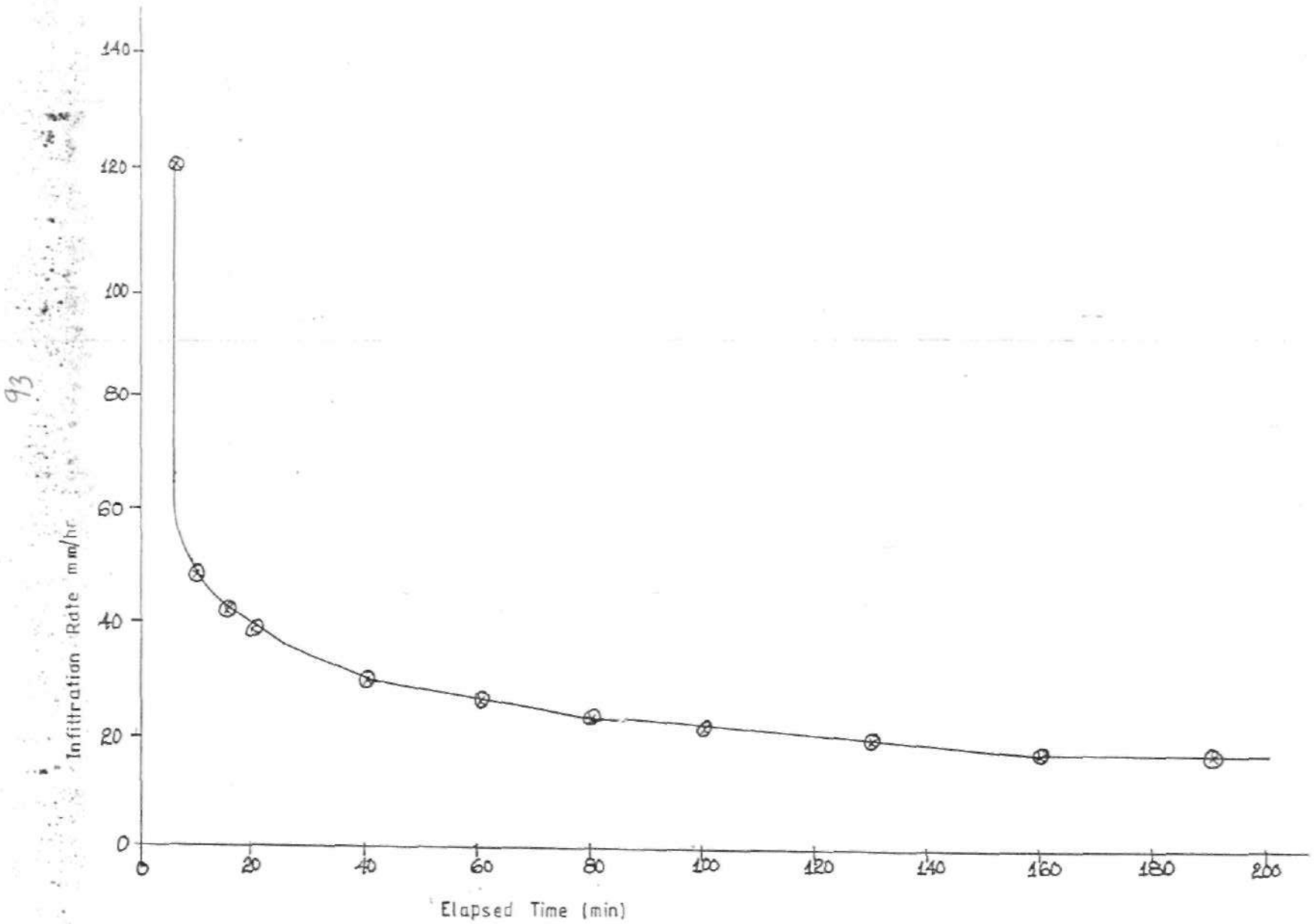


Fig:B_1 INFILTRATION RATE CURVE

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APPENDIX C

Evaluation of Land utilization

Yield loss Due to Land Loss For Treatments

The total area of the experimental farm was 0.0648ha. The total area covered by basins used to accommodate all the various amount of water applied were measured including the levees and channels associated with it. The length and width of both levees and channels were measured. These measurements were all added together to obtain the total area taken out of production. This was done for each basin, but because the same basin sizes were used, the same area of land was taken out of production for all the treatments. Table 4.10 provide the total cultivated area and wasted area as 0.0432ha and 0.0216ha, respectively and the percentage of relative land loss for each basin.

From Table 4.14 combined yield obtained from the farm (11.69t/ha) was used to estimate the expected yield from the wasted land in the whole land. Thus, expected yield from the wasted land in the whole land equals

$$\frac{0.0216\text{ha} \times 11.691\text{t/ha}}{0.04832\text{ha}} = 5845.5\text{kg/ha}$$

Yield loss per Treatment

Treatment A = 36×10^{-4}t/ha x 5845.5 kg/ha

= 21.04kg

Since all the basin have the same land loss of 36 x 10^{-4}ha, it implies that yield loss will be the same for all the treatments.

YL_B = 21.04kg

YL_C = 21.04kg

YL_D = 21.04kg

YL_E = 21.04kg

YL_F = 21.04kg

However, the loss in income incurred from the yield loss was obtained by using the prevailing market price of tomato (₦10/kg) to be multiplied by the total expected yield obtainable from the landloss. Results are provided in Table 4.8

APPENDIX D

Determination of Polynomial Relation of Tomato Yield and Amount of Water Applied.

$$Y = a_0 + a_1X + a_2X^2$$

where Y = yield

X = amount of water applied

a_0, a_1, a_2 = constants

$$\begin{vmatrix} n & \Sigma x & \Sigma x^2 \\ \Sigma x & \Sigma x^2 & \Sigma x^2 \\ \Sigma x^2 & \Sigma x^3 & \Sigma x^4 \end{vmatrix} \begin{vmatrix} a_0 \\ a_1 \\ a_2 \end{vmatrix} = \begin{vmatrix} \Sigma Y \\ \Sigma XY \\ \Sigma X^2Y \end{vmatrix}$$

where n = number of treatments

Table D_1 Determination of Yield - water Polynomial Relation

X	Y	X^2	X^3	X^4	XY	X^2Y
1.360	11.476	1.8496	2.515	3.421	15.607	21.226
1.755	14.225	3.080	5.405	9.487	24.965	43.813
2.105	13.090	4.431	9.327	19.634	27.554	58.002
2.450	12.196	6.0031	14.706	36.030	29.880	73.206
2.805	9.889	7.868	22.0705	61.906	27.739	77.807
3.080	9.272	9.486	29.218	89.992	28.558	87.958
13.555	70.148	32.717	83.242	220.469	154.303	362.013

$$\begin{vmatrix} 6 & 13.555 & 32.717 \\ 13.555 & 32.717 & 83.242 \\ 32.717 & 83.242 & 220.469 \end{vmatrix} \begin{vmatrix} a_0 \\ a_1 \\ a_2 \end{vmatrix} = \begin{vmatrix} 70.148 \\ 154.303 \\ 362.013 \end{vmatrix}$$

$$A = 6 \begin{vmatrix} 32.717 & 83.242 \\ 83.242 & 220.469 \end{vmatrix} - 13.555 \begin{vmatrix} 13.555 & 83.242 \\ 32.717 & 220.464 \end{vmatrix}$$

$$+ 32.717 \begin{vmatrix} 13.555 & 32.717 \\ 32.717 & 83.242 \end{vmatrix}$$

$$= 1703.122 - 3592.465 + 1895.728 = 6.385$$

$$a_0 = 70.148 \begin{vmatrix} 32.717 & 83.242 \\ 83.242 & 220.469 \end{vmatrix} - 13.555 \begin{vmatrix} 154.303 & 83.242 \\ 362.013 & 220.469 \end{vmatrix}$$

$$+ 32.717 \begin{vmatrix} 154.303 & 32.717 \\ 362.013 & 83.242 \end{vmatrix}$$

$$= 19911.770 - 52652.255 + 32733.718$$

$$= -6.767$$

$$= \frac{-6.767}{6.385} = -1.059$$

$$a_1 = 6\begin{vmatrix} 154.303 & 83.242 \\ 362.013 & 220.469 \end{vmatrix} - 70.148\begin{vmatrix} 13.555 & 83.242 \\ 32.717 & 220.469 \end{vmatrix}$$

$$+ 32.717\begin{vmatrix} 13.555 & 154.303 \\ 32.717 & 362.013 \end{vmatrix}$$

$$= 23306.052 - 18591.239 - 4621.114 = \frac{93.699}{6.385} = 14.67486$$

$$= 14.675$$

$$a_1 = 6\begin{vmatrix} 32.717 & 154.303 \\ 83.242 & 362.013 \end{vmatrix} - 13.555\begin{vmatrix} 13.555 & 154.303 \\ 32.717 & 362.013 \end{vmatrix}$$

$$+ 70.148\begin{vmatrix} 13.555 & 32.717 \\ 32.717 & 83.242 \end{vmatrix}$$

$$= -6003.066 + 1914.576 - 4064.601 = \frac{-23.889}{6.385} = -3.741$$

$$Y = -1.059 + 14.675X - 3.741X^2$$

Table D_2 : Correlation Analysis of Tomato Yield and Amount of water Applied

X	Y_p	Y_a	$(Yp - \bar{Y}_p)$	$(Y_p - \bar{Y}_p)^2$	$(Y_a - \bar{Y}_a)$	$(Y_a - \bar{Y}_a)^2$	$(Y_p - \bar{Y}_p)(Y_a - \bar{Y}_a)$
1.360	11.980	11.476	0.285	0.0812	-0.215	0.046	-0.061
1.755	13.173	14.225	1.478	2.1840	2.534	6.421	3.745
2.105	13.255	13.090	1.560	2.433	1.399	1.957	2.182
2.450	12.439	12.196	0.744	0.553	0.505	0.255	0.376
2.805	10.670	9.889	-1.025	1.051	-1.802	3.247	1.847
3.080	8.651	9.272	-3.044	9.266	-2.419	5.851	7.363
$\bar{Y}_p = 11.695$		$\bar{Y}_a = 11.691$		15.569		17.778	15.453

$$r = \frac{\Sigma(Y_p - \bar{Y}_p)(Y_a - \bar{Y}_a)}{(\Sigma(Y_a - \bar{Y}_a)^2 X (Y_p - \bar{Y}_p)^{\frac{1}{2}}} = \frac{15.453}{(17.778 \times 15.569)^{\frac{1}{2}}}$$

$= 0.9288$

$r = 0.929$

$r^2 = 0.863$

Hence, $Y = -1.059 + 14.675x - 3.741X^2$

APPENDIX E

Evaluation of Depreciation Rates for farm Tools. Depreciation of all the tools or items used during the study was determined. This was to enable estimation of the fixed costs incurred during the period of study. Straight line method of determining depreciation was adopted for use as explained in section 2.17.

Table E_1 gives a summary of depreciation rates for all farm tools used in this study. Recommended price for some farm tools were used in the calculations, where such prices were not available, farmers' claims and opinions were used especially the life span of the hand tools.

Table E_2 provides a summary of pump maintenance cost during the course of study, Standard charges were used where available.

Depreciation of farm tools and cost of irrigation pump maintenance are fixed cost since they affect all the treatments irrespective of the amount of water applied. Table 4.14 gives the final fixed cost of production of study as obtained herein.

Table E_1 Farm tools Depreciation Values

Tools/Items	initial Cost Price (₦)	Salvage value ₦	life span Yr	Depreciation rate ₦/Yr
1. Honda Gx 140 Irrigation pump	(Market Price) 38,000	10,000	8	3500.00
2. Cutlass 2-pieces	60.00	5.50	farmers' opinion 4	13.63
3. Hand Hoes 3-pieces	240.00	30.00	4	52.50
4. Hand Rakes 2-pieces	70.00	15.00	4	13.75
				3579.88

Table E_2: Irrigation Pump Maintenance Costs

Items	Quantity	Unit Price ₦/unit	Total ₦
i. Engine Oil (SAE 30)	4L	200/L	800.00
ii. Spark plug	1-piece	75/piece	75.00
iii. Pump servicing	2-service	(ADADP) 150/service	300.00
Total			1175.00

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APPENDIX F

Irrigation Water Cost Estimation

In determining the irrigation water cost used for this study, certain basic information are necessary; these include:

i. Average fuel consumption rate of 0.65l/ha

ii. Petrol cost price of ₦20/l

iii. Total irrigation time of 52.5 hours

iv. Total amount of water applied 13555mm

Calculations

I. Total amount of petrol consumed seasonally,

= petrol consumption rate x total time of irrigation

= 0.65l/hr x 52.5hr = 34.125l per season

II. Amount of petrol consumed to deliver $1m^3$ of water per

$$\text{season} = \frac{\text{Total petrol consumed}}{\text{Total amount of water applied}}$$

$$= \frac{34.125l}{13.555m * 4m^2 * 108}$$

$$= 0.00592\ l/m^3$$

$$= 0.006l/m^3$$

Cost of irrigation Water Per Treatment

Irrigation water cost for Treatments

$$= \frac{\text{Amount of water applied x Area of basin x No. of basins x fuel consumed to deliver } 1m^3}{\text{Area of basin x no. of basins}}$$

For Treatment A,

$$\frac{4.074m \times 4m^2 \times 18}{4m^2 \times 18} \times 0.0061/m^3 \times 10^4 ha$$

$= 244.441/ha \times ₦20/l$

$= ₦4888.80/ha$

Treatment B,

$$\frac{5.264m \times 4m^2 \times 18}{4m^2 \times 18} \times 0.0061/m^3 = 0.0315841/m^2$$

$= 0.0315841/m^2 \times 10^4 ha \times ₦20/l$

$= ₦6316.80/ha$

Treatment C,

$$\frac{6.314m \times 4m^2 \times 18}{4m^2 \times 18} \times 0.0061/m^3 \times 10^4 ha$$

$= 378.84\ l/ha \times ₦\ 20/l$

$= ₦7576.80/ha$

Treatment D,

$$\frac{7.35m \times 4m^2 \times 18}{4m^2 \times 18} \times 0.0061/m^3\ ₦ \times 10^4 ha$$

$= 4411/ha \times ₦20/la$

$= ₦8820/ha$

Treatment E,

$$\frac{8.414m \times 4m^2 \times 18}{4m^2 \times 18} \times 0.0061/m^3 \times 10^4 ha$$

$= 504.841/ha \times ₦20/l$

$= ₦10096.8/ha$

Treatment F,

$$\frac{9.24m \times 4m^2 \times 18}{4m^2 \times 18} \times 0.0061/m^3 \times 10^4 ha$$

$$= \quad 554.41/ha \times ₦20/l = ₦11088/ha$$

APPENDIX G

Table G: Weekly Moisture Content Measured at the Field (Percent Dry Weight Basis)

Irrigation 1

Treatment	Depth of Sampling (mm) 0-150 W	0-150 D	150-300 W	150-300 D	300-450 W	300-450 D	450-600 W	450-600 D
A	15.67	12.97	18.74	15.47	18.71	15.83	18.07	15.81
B	12.66	16.62	16.00	13.80	17.1	15.97	17.65	15.09
C	17.27	14.89	18.47	16.92	18.21	17.06	19.57	16.05
D	14.78	11.15	17.20	14.28	18.03	18.00	17.97	17.30
E	18.10	14.48	15.35	14.33	14.91	14.75	20.53	14.89
F	14.89	12.50	18.01	16.09	17.76	16.52	16.81	15.64

W = moisture content taken 2-days after irrigation

D = moisture content taken just before irrigation.

Irrigation 2

Treatment	Depth of Sampling (mm) 0-150 W	0-150 D	150-300 W	150-300 D	300-450 W	300-450 D	450-600 W	450-600 D
A	16.66	12.65	19.70	15.27	19.12	16.28	19.49	16.33
B	15.07	11.89	17.97	14.86	19.43	17.04	18.50	15.88
C	16.98	12.83	18.90	15.55	20.44	16.83	19.91	15.76
D	14.79	13.25	15.41	13.27	19.29	17.15	17.32	15.23
E	16.19	13.92	18.64	14.11	19.12	15.03	18.90	16.40
F	13.67	12.50	16.77	13.09	16.52	14.49	15.57	15.23

Irrigation 3

Depth of Sampling (mm)	0-150		150-300		300-450		450-600	
Treatment	W	D	W	D	W	D	W	D
A	15.12	10.50	17.82	13.00	19.25	17.43	19.75	16.89
B	14.01	13.56	15.86	12.38	17.64	16.54	16.79	14.00
C	15.31	10.84	19.05	15.16	19.68	15.89	21.03	15.63
D	14.13	10.02	10.95	9.56	16.30	15.23	17.81	15.06
E	17.73	12.28	16.84	14.02	18.10	13.74	17.48	12.15
F	18.28	11.49	17.59	14.88	17.76	17.40	16.83	15.70

Irrigation 4

Depth of Sampling (mm)	0-150		150-300		300-450		450-600	
Treatment	W	D	W	D	W	D	W	D
A	15.33	11.00	18.67	14.15	19.85	16.88	18.92	15.23
B	15.21	11.31	17.40	15.70	18.60	16.88	17.00	15.99
C	17.66	12.62	19.97	16.62	20.71	16.66	18.64	14.22
D	13.96	10.36	14.60	13.05	19.27	17.48	17.33	14.31
E	20.81	15.17	19.36	16.11	20.05	17.49	20.91	16.97
F	17.36	11.17	16.06	14.48	19.80	17.52	18.51	15.56

Irrigation 5

Depth of Sampling (mm)	0-150		150-300		300-450		450-600	
Treatment	W	D	W	D	W	D	W	D
A	14.79	13.59	17.54	12.92	17.39	14.65	16.77	10.07
B	15.24	11.72	18.38	15.34	18.90	16.92	18.26	14.18
C	23.05	19.95	21.23	18.17	21.55	15.41	21.54	15.90
D	16.86	12.25	19.08	15.40	23.76	17.17	20.85	17.43
E	19.35	8.17	17.90	13.11	18.59	14.49	19.45	12.97
F	14.50	9.78	17.89	14.60	19.71	17.16	19.60	15.60

Irrigation 6

Depth of Sampling (mm)	0-150		150-300		300-450		450-600	
Treatment	W	D	W	D	W	D	W	D
A	14.16	11.75	14.37	12.76	16.85	11.86	18.11	11.40
B	13.27	10.75	14.46	12.67	18.11	14.88	18.12	9.38
C	15.16	12.94	18.07	12.67	17.72	14.88	16.45	11.86
D	15.33	13.70	17.28	12.92	18.15	13.40	18.04	14.44
E	23.79	18.87	19.83	15.17	21.03	15.77	21.51	11.49
F	14.02	11.34	17.14	13.35	18.19	13.31	18.64	14.86

Irrigation 5

Depth of Sampling (mm)	0-150		150-300		300-450		450-600	
Treatment	W	D	W	D	W	D	W	D
A	14.79	13.59	17.54	12.92	17.39	14.65	16.77	10.07
B	15.24	11.72	18.38	15.34	18.90	16.92	18.26	14.18
C	23.05	19.95	21.23	18.17	21.55	15.41	21.54	15.90
D	16.86	12.25	19.08	15.40	23.76	17.17	20.85	17.43
E	19.35	8.17	17.90	13.11	18.59	14.49	19.45	12.97
F	14.50	9.78	17.89	14.60	19.71	17.16	19.60	15.60

Irrigation 6

Depth of Sampling (mm)	0-150		150-300		300-450		450-600	
Treatment	W	D	W	D	W	D	W	D
A	14.16	11.75	14.37	12.76	16.85	11.86	18.11	11.40
B	13.27	10.75	14.46	12.67	18.11	14.88	18.12	9.38
C	15.16	12.94	18.07	12.67	17.72	14.88	16.45	11.86
D	15.33	13.70	17.28	12.92	18.15	13.40	18.04	14.44
E	23.79	18.87	19.83	15.17	21.03	15.77	21.51	11.49
F	14.02	11.34	17.14	13.35	18.19	13.31	18.64	14.86

Irrigation 9

Depth of Sampling (mm)	0-150		150-300		300-450		450-600	
Treatment	W	D	W	D	W	D	W	D
A	15.40	10.32	19.05	12.39	20.25	14.18	20.29	13.95
B	21.26	9.88	22.68	13.32	22.67	12.99	23.11	13.69
C	20.60	9.82	18.51	12.99	18.10	12.79	19.81	15.10
D	16.78	8.59	22.37	13.28	19.94	11.52	20.11	12.29
E	19.75	9.66	19.35	12.11	19.54	14.58	20.14	15.67
F	21.12	10.31	22.63	14.63	17.52	9.54	18.50	9.08

Irrigation 10

Depth of Sampling (mm)	0-150		150-300		300-450		450-600	
Treatment	W	D	W	D	W	D	W	D
A	16.74	10.59	18.58	13.99	20.43	15.43	17.32	9.75
B	16.19	8.80	18.30	11.38	18.71	11.97	19.21	10.27
C	18.99	7.01	18.26	15.02	18.58	13.75	19.57	14.94
D	19.38	11.39	17.99	11.70	20.11	14.09	18.78	11.79
E	19.30	11.28	17.84	14.23	18.51	15.49	19.39	13.99
F	21.41	11.78	17.18	9.36	18.88	10.53	18.89	10.75

Irrigation 11

Depth of Sampling (mm)	0-150		150-300		300-450		450-600	
Treatment	W	D	W	D	W	D	W	D
A	15.35	12.11	18.68	13.89	19.79	15.88	18.92	15.53
B	17.31	11.35	19.42	15.72	20.69	16.89	19.33	15.89
C	18.19	13.72	19.61	14.15	20.01	16.23	17.98	14.10
D	17.20	11.28	17.75	13.20	19.56	14.93	17.81	13.13
E	16.88	13.77	18.73	14.62	19.53	15.90	19.70	14.96
F	17.76	8.93	19.52	14.48	19.23	13.50	17.96	12.50

Irrigation 12

Depth of Sampling (mm)	0-150		150-300		300-450		450-600	
Treatment	W	D	W	D	W	D	W	D
A	13.76	9.60	17.63	13.48	18.97	16.97	18.93	15.62
B	17.46	12.89	19.04	12.83	17.41	12.80	16.54	11.24
C	13.08	9.84	16.82	14.66	17.52	15.08	17.37	14.22
D	16.58	10.89	12.95	8.09	18.30	15.23	17.84	13.88
E	16.90	13.82	17.60	14.20	18.23	15.74	17.66	16.88
F	18.53	8.36	17.84	11.63	18.08	14.16	17.10	12.54

Irrigation 13

Depth of Sampling (mm)	0-150		50-300		300-450		450-600	
Treatment	W	D	W	D	W	D	W	D
A	16.44	13.56	18.75	15.27	18.08	15.82	18.72	16.33
B	14.90	11.98	17.98	14.86	18.11	16.09	18.51	15.89
C	15.12	12.18	17.31	14.99	18.85	16.11	18.35	15.79
D	18.14	14.52	17.76	13.25	18.83	14.34	20.22	16.08
E	14.53	13.29	16.71	14.55	17.50	15.18	17.33	15.40
F	17.85	11.38	19.89	15.01	18.19	14.09	18.93	13.97

Irrigation 14

Depth of Sampling (mm)	0-150		150-300		300-450		450-600	
Treatment	W	D	W	D	W	D	W	D
A	14.93	12.79	18.56	16.74	18.43	16.88	17.97	15.88
B	14.59	12.24	18.39	16.89	18.04	16.99	18.72	17.13
C	17.98	14.79	18.90	16.74	17.83	15.87	17.19	15.81
D	17.89	13.15	18.84	16.53	19.38	17.02	22.59	20.01
E	19.00	15.84	15.52	14.39	14.18	13.57	18.07	16.98
F	17.47	12.39	17.79	13.19	17.45	14.21	19.75	15.46

APPENDIX H

Actual Tomato Yield and Poduction Cost Data.

Table H_1: Tomato yield obtained for Treatments (Kg/0.0072ha)

Treatment	Marketable	Non-marketable
A	69.38	13.25
B	88.09	14.35
C	80.85	13.40
D	76.15	11.75
E	60.55	10.65
F	57.31	9.45
Total	432.33	72.85

Table H_2: Variable Production Cost for Treatment (₦/0.0072ha)

Treatment	Variable cost
A	317.25
B	328.98
C	338.56
D	348.06
E	356.87
F	365.12

Table H_3: Total production cost and returns for Treatment(₦/0.0072ha)

Treatment	Production cost	Returns
A	351.48	473.27
B	363.21	659.47
C	372.80	568.09
D	382.99	494.30
E	391.76	318.73
F	399.36	266.71
Total	2261.6	2780.57