PERFORMANCE EVALUATION OF MINI SPRINKLER IRRIGATION SYSTEM: COMPARISON OF THE PLASTIC AND IRON MADE SPRINKLER SYSTEM

BY

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A PROJECT DISSERTATION SUBMITTED TO THE SCHOOL OF POSTGRADUATE STUDIES, AHMADU BELLO UNIVERSITY IN PARTIAL FULFILLMENT FOR THE AWARD OF MASTER OF SCIENCE DEGREE IN WATER RESOURCES AND ENVIRONMENTAL ENGINEERING

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DECLARATION

I declare that the work in this project Dissertation entitled: "**PERFORMANCE EVALUATION OF MINI SPRINKLER IRRIGATION SYSTEM: Comparison of the Plastic and Iron Made Sprinkler System",** has been carried out by me in the Department of water Resources and Environmental Engineering.

The information derived from the literature has been duly acknowledged in the text and a list of references provided. No part of this thesis was previously presented for another degree or diploma at this or any other institution.

_____	_____	_____
AbdulFatahAbdulRaheem	Signature	Date

CERTIFICATION

This project dissertation entitled **"PERFORMANCE EVALUATION OF MINI SPRINKLER IRRIGATION SYSTEM: Comparison of the Plastic and Iron Made Sprinkler System"** by **AbdulFatahAbdulRaheem,** meets the regulations governing the award of the degree of Master of Science of the Ahmadu Bello University, and is approved for its contribution to knowledge and literary presentation.

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DEDICATION

I dedicate this work to Almighty Allah, the source of my strength for giving me the grace to successfully complete this project.

I also dedicate this work to my incomparable, loving and caring mother (Mrs. AbdulRaheemNusirat)

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ABSTRACT

This dissertation is a study to evaluate and compare the hydraulic performance of plastic and iron mini sprinkler system using 8mm and 14mm diameter nozzle sizes.

The study was carried out at a farm land of the national water resources institute, Mando, Kaduna.

In this study, meteorological data such as rainfall, evaporation, relative humidity, wind speed/ direction, maximum and minimum temperature were first taken into consideration, soil, sample test were investigated for their physical and chemical properties.

Water is a key factor in increasing agricultural production. However, the global Climate Change and its attendant effects on scarce water resources have further reduced the amount of water available for agriculture. The need to encourage small scale farmers on the use of modern method such as sprinklers other than the traditional mass irrigation methods which waste water. At least, the stemming problems of neighbor irrigators sharing same water source will be arrested.

The work is based on the evaluation of the hydraulic performance of the plastic and iron sprinkler system towards the determination of the discharges of the sprinkles, Pressure radius of throw of the mini sprinklers, application rate, distribution pattern of the sprinklers on the soil, and the uniformity coefficient of the sprinkler system.

The experimental set up for determination of the hydraulic performance consist of a horse power (1hp) pump connected to a 200L reservoir tank filled to the brim with water. A pressured hose connected to the reservoir, takes water through the inlets to the pump. A pipe connected to the out let of the pump, take the water to the main line passing through a filter to entrap solid particles. The mainline, distribute the water to the sub main line, and the sub main line, takes water to the lateral line, hosting the sprinklers. The water gets to the riser pipe, and the sprinklers rotate and spread water.

All measurements for the parameters were set up for 9 different operating pressure with an increment of 0.5kg/cm^2, the results were collected and evaluated for their hydraulic efficiencies.

Maximum and minimum pressures were obtained as 8.9,11.1L/Min and 40.0 -52.6 L/Min for plastic and iron. The radius of throw were obtained as 2.0, 2.4cm and 8.2,14.5cm

respectively. For plastic and iron made sprinkler system. The sprinkler application rate (precipitation rate) were obtained at min and max to be213.5mm/hr,814.2mm/hr for 8mm iron and 692.3mm/hr,1172.3mm/hr for 8mm plastic. The distribution pattern of the system on the soil is uniform, with the system uniformity coefficient found to be 96.7%,97.2% 14mm plastic and iron. 96.99%,97.9%8mm plastic and iron respectively.

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ABBREVIATIONS

NWA: Net Wetted Area.

CCA: Cultivated Command Area.

TWA: Total Wetted Area.

MR: Management by Results.

ICID: International Commission on Irrigation and Drainage.

LQ: Low Quarter.

Vc: Volume of Water Diverted or Pumped from River.

V_4: Volume of Water Delivered to the Distribution System.

V3: Non Irrigation Deliveries from the Distribution System.

V2: Non Irrigation Deliveries from the Conveyance System.

Vi: Inflow from other Services.

VF: Volume of Water Delivered to the Fields.

VM: Volume of Water needed and made Available for Eva transpiration by the Crop to avoid Undesirable Water Stress in the Plant throughout the growing cycle.

Ec: Conveyance Efficiency.

Ed: Distribution Efficiency.

Ea: Application Efficiency.

Eu: Tertiary Unit Efficiency.

Es: Irrigation System Efficiency.

Ep: Overall Project Efficiency.

RWS: Relative Water Supply.

WUE: Water Use Efficiency.

WISE: Water for Irrigation Streams and the Economy.

RWST: Theoretical Relative Water Supply.

RWSA: Actual Relative Water Supply.

IR: Irrigation Water Supply.

RN: Rainfall.

ET: Evapotranspiration.

S&P: Seapage and Percolation.

AU: Area Utilization.

AH: Harvested Area.

TA: Theoretical Serviceable Area.

YR: Yield Rain- Fed Based.

YP: Yield Potential Base.

PY: Potential Yield.

IWO: Irrigation Water Output.

IY: Irrigation Average Yield for System.

PD: Production Distribution.

FD: Flow Distribution.

PFD: Production Flow Distribution.

CWR: Crop Water Requirement.

Farmer Satisfaction

RC: Response Capacity.

Vec: Volume of Catch Can.

PR: Precipitation Rate:

DEC: Depth of Catch Can.

TEB; Total exchangeable bases

CEC; Cation exchange capacity

ESP; Exchange sodium percentage

OC; Organic carbon

OM; Organic matter

TN; Total nitrogen

EC; Electrical conductivity

SAR; Sodium absorption ratio.

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

In many part of the world, rainfall is not uniformly distributed over time and space. In addition, the amount of rain is not adequate to meet the water requirement of crops and to supplement this deficiency, artificial application of water is required.

Irrigation is the application of water to soil to assist in the production of crops. It is practiced in many parts of the world with the aims of providing water for crop growth when natural precipitation is in short supply and /or distribution is erratic. Irrigation is usually supplied to supplement the water available from rainfall, soil moisture, and capillary rise of groundwater.

Irrigation water is brought to dry land through artificial means, such as pipes, hoses, or ditches. The land that is being irrigated usually contains crops,grass, or vegetation that would not usually receive enough water from rainfall or other natural sources. Sometime,the reason to irrigate a portion of land is that it happens to be a dry season, with less than average amounts of rainfall. Or, it might be necessary to do so because theland never would receive enough water on its own to be fertile. The water that is used for irrigation might be taken from nearby lakes, reservoirs, rivers or wells. The source of irrigation water can be surface water, ground water or non-conventional water (such as desalinated water and treated wastewater)Sawa and Frenken, 2002.

The amount of water that is to be used for irrigation depends on the type of crop that is being farmed as well as the amount of rainfall in the region. The US for instance uses about

one third of the water utilized every year (US Geological Survey, 2014).Moreso, the correct amount of water to apply at each irrigation depends on the water holding capacity of the soil and root depth, infiltration rate, and the rate at which water goes into the soil which varies from one irrigation to the next and from season to season.

Water must be available in sufficient quantity from a locally accessible source. A clean supply of water free of sediment is required to avoid blockage in sprinkler nozzles and crop spoilage (FAO, 1988).

There are many methods that can be used for irrigating farmland, and each one needs an experienced farmer to know exactly how much water to use and when to use it. Some of the methods includes furrow, Basin, Border, Drip and Sprinkler. However, sprinkler irrigation is a method of applying irrigation water which is distributed through a system of pipes usually by pumping. It is then sprayed into air through sprinklers so that it breaks up into small water drops which falls to the ground. The pump supply system, sprinklers and operating conditions must be designed to enable uniform application of water.

Sprinkler Irrigation is suited for most row, field and tree crops and water can be sprayed over or under the crop canopy. However, large sprinklers are not recommended for irrigation of delicate crops such as lettuce because the large water drops produced by the sprinkler may damage the crop.

Sprinkler Irrigation is adapted to any farmable slope, whether uniform or undulating. The lateral pipes supplying water to the sprinkler should always be laid out along the land contour whenever possible. This will minimize the pressure changes at the sprinklers and provide a uniform irrigation.

Sprinklers are suited with high infiltration rates. Although they are adaptable to most soil types. The average application rate of the sprinkler (mm/hour) is set to lower than basic infiltration rate of the soil so that surface pounding and run off can be avoided. Sprinklers are not suitable for soil that easily form a crust or in case of risk of salinization. Moreover, they can easily clog with the presence of sediments or debris. If sprinkler irrigation is the only method available, then light fine sprays should be used. Sprinkler producing large water droplets should be avoided (FAO, 1991).

A good clean supply of water, free of suspended sediments is required to avoid problems of sprinkler nozzle blockage and spoiling the crop by coating it with sediments. A sprinkler requires water flow and water pressure to operate. When a sprinkler design fails, it is almost always due to a lack of water pressure at the sprinkler.

The water pressure of a sprinkler irrigation system is the energy that makes the water to flow. And as the water flow from the water source through an assembled system of pipes, only a small amount of water pressure is used up. So after the water gets through all the pipes and valves and reaches the sprinkler, there still must be enough pressure left to make the sprinkler head rotates correctly. So by using the correct sizes of pipes / hoses, etc. one can control how much pressure is lost in the irrigation system.

1.2 Statement of the Research Problem

Water is a key factor in increasing agricultural production. However, the global Climate Change and its attendant effects on scarce water resources have further reduced the amount of water available for agriculture.

More so, irrigation of plant is usually time consuming activity most especially for furrow, basin and border to be done in a reasonable amount of time, it requires a large amount of human resources and efforts.

All the steps were executed by humans with close monitoring by farmers to control water from overflowing its banks. Traditionally, mass irrigation remains one method used by small scale farmers to water their plants. This method only represents massive losses since the amount of water given is always in excess of the plants need. The excess water is evacuated by the holes of the pots in green house or it percolate through the soil in field. Perhaps, the contemporary perception of a small scale farmer towards irrigation water is free, renewable sources that can be used in abundance. However, this is not realistic as statistics have shown that the volume of accessible water surface is on the decrease. According to the UN Water's 2011 policy brief, it was forecast that by 2025, 1.8 billion people will experience absolute water scarcity, and two third of the world will be living under water-stressed conditions. (UN Water's 2011 brief)

It is therefore reasonable to assume that it will become very expensive resources everywhere. It has become imperative to begin plan to economies water use for optimum productivity. This is possible only through improved water management and adopting advanced techniques of irrigation. One such method of modern irrigation is sprinkler irrigation system which can become more popular among farmer in the country if encouraged.

1.3 Justification of the Study

Under water stressconditions or circumstances, the use of pressured irrigation system such as sprinkler system is an option to enhance the efficiencies of water consumption of plant towards maximum productivity. Sprinkler irrigation uses less water and provides better control.However,It should be encouraged by the government,to be used by small scale farmers on there farms as applicable to local circumstances.

1.4 Study Area

The site for this study is located at Faringida (A farmland of the National Water Resources Institute Mando, Kaduna). It is situated between latitude 10^{o} $31^{'}$ 35" North of the equator and longitude 07^{0} 26' 19" East of the Greenwich Meridian. Its elevation above sea level is between 626m(2053Ft). (Inform/city coordinates. Php retrieved on 4thJune, 2017).

It covers a total gross command area of 15.64ha and has a cultivable command area of 09.52 ha with a net command area of 7.8ha.

The topography of the site is fairly representative of surrounding plains which can be described as undulating plain with very broad and gentle slopes lying at an altitude of 626m above sea level.

Land Use, Farming System, Farming Season, and Cropping Pattern.

About 80% of the dry season farmers in the study area do not own their farmland, they solely depend on permission to use the farmland. Most farmers use the farmlands for free. Generally, the holding per farmer varies from 0.025ha to 0.55ha. Other even had as little as 100m^{2}

The farming system was basically traditional except for a wheat farmer who employed mechanization in the land preparation. However, crop rotation was well understood and extensively practiced. The irrigation of tomato and other vegetable was followed by the cultivation of maize/millet during the long dry season harmattan (November – April). Crop which include, tomatoes, wheat, green pepper, peas, leafy vegetables e.t.c acclimatized to cold season "harmattan" (Nov-Feb) and produces high yield, while crops such as yellow maize, okra, garden eggse.t.c. produces high yield during heat season.

The Irrigation system was furrow for other crops but basin for the wheat. Petrol engine pump (generally of 2.625kw capacity and either Honda or Yamaha make) were used to lift water from a close range. The water was conveyed through PVC pipes or hose or channels (where the topography permitted) to the fields and distributed by the farmers through the use of bunds. The yield is good.Though, dry season yield of between 25 and 37 tonnes per ha had been recorded or reported in Northern Nigeria, (Komolafe*et al.*, 1985).

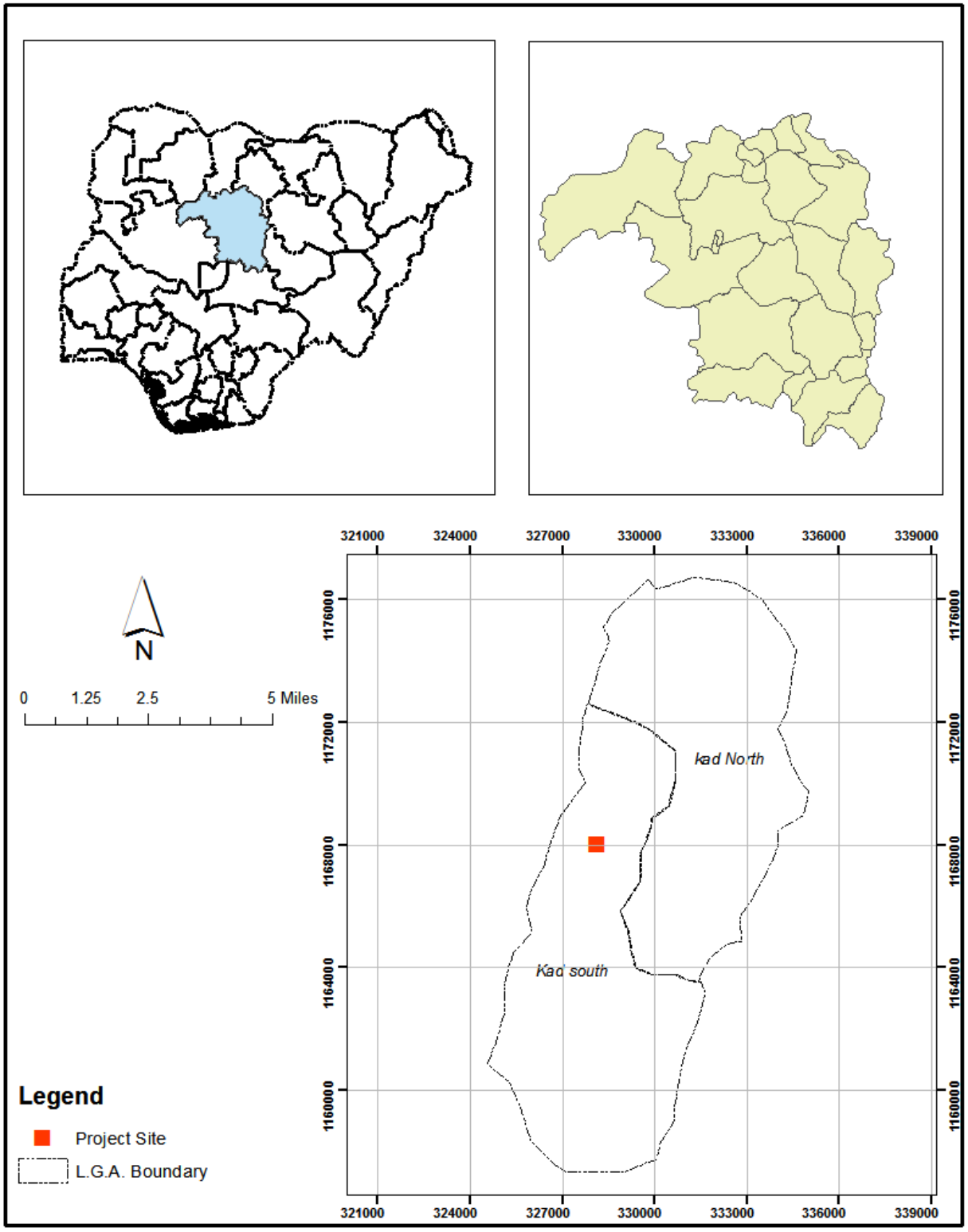


Figure 1.1: Map of Nigeria showing Kaduna state and the study area

1.5 Aim and Objectives

The aim of the study is to evaluate and compare the hydraulic performance of plastic and iron mini sprinkler system

The Specific Objectives of the study are;

i. To determine the discharges of the mini sprinkler.

ii. To determine the Pressure radius of throw of the mini sprinklers.

iii. To determine the relationship of sprinkler application rate and the operating pressure.

iv. To determine the distribution pattern of the soil.

v. To determine the uniformity coefficient of the system

1.6 Scope of the Study

The scope of the study lies between the investigation of the hydraulic performances of the plastic and the iron made sprinkler system.

1.7 Limitation of the Study

Financial constraint is a major limitation to this study as every single material has to be purchase to get to the root of this work. It's really money and time consuming.

System design limitation –pressure losses as water flows through the pipes and leakages from fittings

Evaporation loss when operating under high temperatures. The system was however operated under moderate temperature. Uneven water distribution due to wind effect the system was only operated under normal wind condition.

Blockages of sprinkler heads due to dissolved solids contained in the water source and also, coating of the plants due to colored water.

CHAPTER TWO

LITERATURE REVIEW

2.1 Preamble

Adequate water supply is important for growth when rainfall is not sufficient, the plants must receive additional water from irrigation. As available water resources become scarcer, more emphasis is given to efficient use of irrigation water for maximum economic return and water resources sustainabilityOdhambo (2000). Various methods can be used to supply irrigation water to the points of need. Each method has its advantages and disadvantages, which is often taken into account when choosing the methods which is best suited to the local circumstances (FAO 1984).

However, a simple irrigation method is to bring water from the source of supply, e.g. a well to each plant with a bucket or a watering can. The method can be time consuming and involves very heavy (tedious) work. However, it can be used to successfully irrigate very small plots of land such as vegetable gardens that are close to the water source.

More sophisticated methods of water application are used when larger areas require irrigation. There are three commonly used methods; surface irrigation, sprinkler irrigation and drip irrigation system.

However, historically, early irrigation works were typically implemented to ensure human, physical survival. In the absence of large population, industries and recreation, there was not much competition for water except among neighboring irrigators sharing same source of water. The problems stemming from control of a source were settled politically, militarily and diplomatically. The problems of bringing the water from source to plant were solved

technically with evermore and bigger hydraulic structures. With increasing competition not only among neighboring irrigators but also among agricultural and non- agricultural users of water, the notion of water conservation is born, the idea that crop could do well with limited quantity of water, even better than unlimited quantities of water because of water logging and salinization of crop lands, suggested a more sophisticated management than traditional practices. At the present time, with irrigation needs constituting the largest portion of a region consumption, and competing users often in a political majority rely on design and management of irrigation system towards efficient use of water to achieve a major goal as well as production of the crop.

2.1.1 Surface Irrigation

This is the application of water by gravity flow to the surface of the field. Either the entire field is flooded (basin irrigation) or the water is fed into small channels (furrows), or strips of land (borders).

2.1.2 Basin irrigation

Basins are flat areas of land, surrounded by low bunds. The bunds prevent the water from flowing to the adjacent fields. This irrigation system is commonly used for rice grown on flat lands or in terraces on hillsides. Trees also can be grown in basin, and generally, it is suitable for crops that are unaffected by standing for long periods.

2.1.3 Furrow irrigation

In this system, irrigation water flows from the field channels into the furrows by opening up the bank of the channel, or by means of siphons or spiles.

2.1.4 Border irrigation

Borders are long, sloping strips of land separated by bunds. They are sometimes called border strips. Irrigation water is fed into the border in several ways such as opening up the channel bank, using small outlet or gates, or by means of siphons or spiles. A sheet of water flows down the slope of the border, guided by bunds on either side.

2.2 Sprinkler Irrigation

Sprinkler irrigation system is an imitation of rainfall (similar to natural rainfall). Water is pumped through a pipe system (or pressurized hose) and then sprayed onto the crops through rotating sprinkler heads. The spray is developed by the flow of water under pressure through small orifices or nozzles. The pressure is usually obtained by pumping. The sprinkler irrigation system is made up of the following components which are;

a. The pump:-Is the component that sucked water from the source (such as borehole, canal, stream and reservoir).and deliver it to the irrigation system at required pressure. The pump may be powered by an internal combustion engine or electric motor or wind energy or solar energy.
b. The main line:- Is the pipe that delivers water from the pump to the laterals. The mainline can be permanently laid below the ground or portable mainline laid on the surface can be moved from field to field.
c. The lateral pipe:- Is the pipe that delivers water from the mainline or sub mainline line to the sprinklers.

d. Sprinkler heads/nozzles:- Is the component that sprinkles water on the field through the sprinkler head nozzles. It is the most important component of the system because its performance determines the effectiveness and efficiency of the system.



Plate 2.1 Sprinkler Irrigation System.

2.3 Drip irrigation

Drip irrigation system is the type of irrigation method where water conveyed under pressure through a pipe system to the fields. Where it drips slowly onto the soil through emitters or drippers which are located close to the plants. Only the immediate root zone of each plant is wetted. Therefore, this can be a very efficient system of irrigation too. This type of irrigation system is called trickler irrigationMegh (2012). Whatever irrigation method is being chosen, its purpose is always to attain a better crop and a high yield. Therefore, proper design, construction and irrigation practice are of utmost important, and, also, the after care of the system to keep it functioning as well as possible should not be neglected so as not to reduce the benefit from the irrigation system.

An irrigation system is defined as a set of physical and social elements used for the acquisition, control, delivery and dispersion of water to the crop root zonesMaozhi (1989). Its output water is one of a number of inputs to the irrigated agriculture system. The outputs of this system which are crops in turn are input to the agricultural economic system and so on. Small and Svendsen concentrate their analysis on the performance of the irrigation system, with emphasis on water delivery system.Clemens (1990) describes a method of evaluating and understanding water delivery performance. Maozhi (1989) further accessed the causes of poor performance of a typical irrigation system scheme in south China. Clemens (1990) approach is useful in determining the extent to which the causes of poor performance relate to the inadequate estimation of water requirement and improper preparation of water delivery schedule.

The framework of Small and Svendsen(1992) facilitates systematic comparative analysis of irrigation performance by specifying key terms and concepts very precisely.Akey feature of the framework is its conceptualization which includes discussion of a few key indicators of performance relevant to the system particularly the irrigated agriculture system.

Performance Assessment has been an integral part of Irrigation since man first started harnessing water to improve crop production (Bos et al 1993). Performance indicators may be used for several purposes. Indicators can be used by system managers to compare actual results to planned targets. Or they may be used by researchers, investors, higher-level managers or policymakers to compare the performance of a number of systems with one another. In the latter case, the type of indicator used may be called a comparator.

Abernethy (1989) presented a review of the indicators of the performance of irrigation water distribution systems at a Symposium on Performance Evaluation of Irrigation Systems held at the International Irrigation Management Institute, Cotombo, Sri Lanka in November 1989. Abernethy's review paper and an early version of the paper on a framework for assessing irrigation performance were also discussed at a workshop on Irrigation Performance held in Pang Bourne. England.Malhotra *et al* (1984) illustrated a methodology for monitoring the performance of large scale irrigation systems using a case study of a warabandi system of northwest India. An important contribution of their study is the use for a farmer's field in a water deficiency system. They define the net wetted area (NWA) as the area of farmer's land that is wetted at least once in an irrigation multiplied by the number of irrigations that the area receives. The area of every individual farmer that can be irrigated is measured and recorded. This area is called the cultivated command area (CCA). In the case study the warabandi system, the predicted outputs are; a) NWA is equal to one-third of (CCA): and b) TWA is equal to 133 percent of CCA. By measuring the actual outputs of NWA and TWA. It is possible to determine if the results of the warabandi system are within an acceptable range of error. Malhotra *et al* define allocation efficiency as the coefficient of determination between wetted area after a watering on each farm and the farm area (CCA). This will be 1.0 when there is perfect equity, in the sense that every farmer receives a share proportional to the size of this holding.

Seckler*et al* (1988), develop a performance index for managerial effectiveness. They conclude the coefficient of determination and suggest using a new index defined in terms of the concept of management by results (MR). In MR, the results are defined as the

relationship between the predicted outputs of the system as specified by its objectives and the actual results obtained from operation of the system.

In recent years, the review of performance of irrigation systems has become a growing concern of the researchers, irrigation policy makers and donor agencies Habib and Kuper (2001). However, Sampath (1988) review equity measures for irrigation performance evaluation and deals with the analytical issues involved in developing and using practical measures of equity for evaluating irrigation project performance, deriving from the economic literature on equity in income distribution, the paper discusses the usefulness of seven axioms (principles).The measures of equity such as range, the relative mean deviation, the variance, the coefficient of variation, the standard deviation of logarithms, the Gini coefficient and theils information measure. Based on the fulfillment and non-fulfillment of these different axioms, the paper discusses the relative merits and demerits of the seven different measure of equity on the basis of this critical evaluation, it includes that theil's information measure is more useful than the others since it fulfils many of the important axioms in addition to being amendable to decomposition analysis.

Bos (1990) described a method of evaluating and understanding water delivery performance at an off-take; first, how accurate is the preparation of the water delivery schedule (delivery schedule performance)? And second, how did the system deliver water with reference to the schedule (operational performance)? When measurements of volumes (or discharge) are taken at any point in the system, there are three values that should be considered. The operating pressure, the time and the

Demens (1988) approach is useful in determining the extent to which the cause of poor performance relate to the inadequate estimation of water requirements and improper preparation of water delivery schedules or to the inability of the physical or management system to operate according to the schedule to deliver the intended supply. However, it will not determine whether the main cause of poor performance is physical system, limitation, operational problems, or management.

The convergence of opinion of researchers at these meetings suggested that indicators of performance should include not only the output indicators of the irrigation water delivery system but also some of the important indicators of the impacts of those outputs and rough indicators of overall system health. The present review reflects this emerging consensus.

The indicators reviewed in this work deal primarily with the quality of irrigation service provided by the managers of the water delivery system. The agricultural production which is the output of the irrigated agriculture system and to a limited extent the economic benefits derived from the agricultural production that forms the outputs of the agricultural economic system is nothing to write home about. The concepts and definitions of these systems and the conceptualization or irrigation in the context of nested systems are elaborated in the framework for assessing irrigation performance proposed by Small and Svendsen (1990, 1992).

Heermann*et al.*, (1990), Chambers (1978), Chambers (1988) and Smith (1990). All agreed that Irrigation systems often have a number of competing objectives and are assessed by interest groups with differing values and perspectives, a wide range of performance indicators is thus required. Any framework and any set of indicators of performance will

only capture a part of the complex reality. It is therefore also important to say what the review does not deal with the methodologies and measurements for determining the indicators or with the interpretation of the indicators in the context of diagnostic analysis of systems at various levels. Nor does it deal with the indicators for the performance of the managers and institutions responsible for the systems.

Thus, it becomes necessary to quantify the performance of irrigation systems, both on the drawing board as a design and management criterion and in the field as an operating criterion for over four decades. Performance indicators usually called efficiencies for intuitive appeal and meaning goodness have been defined differently to account for one factor or another, or in application to one or another irrigation method. Often given the same names say irrigation efficiency, they meant different things to different segments of the profession. Needness to say arguments based on different numerical values for terms having the same names lead to confusion. Another component of goodness or indication of performance was recognized namely; uniformity, reflecting the need for equal treatment of plants in various portions of a field in the confusion, the two terms were sometimes used interchangeably.

A major contribution to other in the profusion of terms and concepts (more concepts than terms) was provided by the on- farm irrigation committee of the irrigation and drainage division, American Society of Civil Engineers (ASCE, 1978). In their concise paper on uniformity and efficiency. Its very conciseness however contributed to the possibility for mis-interpretation, and confusion as persisted. Numerous paper addressing uniformity and efficiency have appeared since then, notably Merriam and Keller (1978), Bos (1985), Hermann *et al* (1990) and Wolters (1992).

Merriam*et al* (1983) describe the methods for evaluating irrigation system and practiceswhich include sprinkler system of various types, Furrow irrigation border strip irrigation and basin irrigation. Procedures are described to measure and determine the potential efficiency of the system as designed, and'actual' that is obtained with present management. A precise terminology is required to make and interpret the measurement. In order that all comparison have a common basis, the three performance parameters are i. potential application efficiency, ii actual application efficiency and iii distribution uniformity. Based on the average depth of water infiltrated or stored in the quarter of the area receiving the least amount of water. The low quarter (LQ) concepts was developed by the USDA soil conservation service and it is recommended as the standard for comparing alternative conditions. For some uniformity studies. Christianson's uniformity coefficient may be used.

Molden and Gates (1990) describe a number of performance measures for use in evaluations and design of new or rehabilitated irrigation water delivery system. Performance measures are introduced as functions of defined state variables and are used to indicate the state of system performance relative to objectives of adequacy, efficiency, dependability and equity of water delivery.

Bos*et al* (1991) also demonstrate the use of the average seasonal values of the ratio of intended and "actual" volumes of water delivered to the tertiary units in a performance evaluation of the Viejo Retamo Secondary Canal of the Rio. Tunuyan irrigation Scheme in Mandoza Province, Argentina.

Bos and Nugteren(1990) presented the most widely accepted concepts and definitions of irrigation efficiencies. Their paper is the result of a joint effort by the International Commission on Irrigation and Drainage (ICID) New Delhi, the University of Agriculture, Wageningenand the International Institute for Land Reclamation and Improvement(IILRI), Wageningen. These three organizations collaborated to collect information on irrigation practices in areas where small farms prevailed. A total of 29 National Committees of the ICU cooperated in this venture by submitting 91 sets of data covering as many irrigated areas. The results were first published in 1974.

Bosand Nugteren(1990 [1974]) divided the overall project efficiency into various components so that the efficiencies associated with different components of the water delivery system such asconveyance, distribution, and field application can be separately stated. The following terms are used in the definitions:

Vcis the volume of water diverted or pumped from river,

V_d is thevolume of water delivered to the distribution system.

$V_1$is the inflow from other sources.

$V_2$is the non-irrigation deliveries from the conveyance system.

$V_3$is the non-irrigation deliveries from the distributary system.

V_f is the volume of water delivered to the fields, and

Vm is the volume of water needed, and made available, for evapotranspiration by the crop to avoid undesirable water stress in the plants throughout the growing cycle.

2.3.1 Irrigation efficiencies

Various types of water losses occur in an irrigation system. Attempts are made to reduce these losses and to achieve an efficient use of water available. The ratio of the quantity of water actually used for a specific purpose to the quantity of water applied during a custom period expressed as a percentage is defined as Irrigation efficiencies. Depending upon the specific purpose served, we have the following irrigation efficiencies in practice.

2.3.2 Water application efficiency

Water application efficiency is a measurement of how effective the irrigation system is installing water in the crop root zone. It is expressed as the percentage of the total volume of water delivered to the field that is stored in the root zone to meet crop evapotranspiration (ET) needs.

2.3.3 Water conveyance efficiency

The term 'Water conveyance efficiency' as it applies to the area of reclamation can be defined as ' Ratio of the volume of irrigation water delivered by a distribution system to the water introduced into the system.

2.3.4 Water use efficiency

Water-use efficiency refers to the ratio of water used in plant metabolism to water lost by the plant through transpiration.

2.3.5 Water storage efficiency

Water application efficiency refers to the amount of water applied that is stored in the crop root zone. This value is determined by water distribution characteristics, system

management, soil conditions, the crop, and weather conditions.

2.3.6 Water distribution efficiency

Water distribution efficiency is defined as the percentage of difference from unity of the ratio between the average numerical deviations from the average depth stored during the irrigation. Water distribution efficiency indicates uniformity in distribution of water over the entire root zone.

2.4 Efficienciesof System Components as Explained byBos and Nugteren {1990} (1974)

2.4.1 Conveyance efficiency *(e_C)*

Conveyance is the movement of water from its source through the main and lateral or secondary canals or conduits to the tertiary off take. The conveyance efficiency $e_c$is the efficiency of canal and conduit networks from the reservoir, *river* diversion or pumping station to the off take of the distribution system. It can be expressed as follows;

$$e_c = \frac{V_d + V_2}{V_c + V_1} \qquad 2.1$$

Where

$e_c$is the conveyance efficiencies

v_d is the volume of water delivered to the distribution system

v_c is the volume of water diverted or pumped from river

v_1 is the inflow from other sources

$v_2$is thenon irrigation deliveries from the distribution system.

2.4.2 Distribution efficiency (ed)

Distribution is the movement of water through the tertiary (distributary) and quaternary (farm) canals or conduits to the tick inlet. Distribution efficiency (ed) is the efficiency of the water distribution canals and conduits supplying water from the conveyance network to individual fields.

It can be expressed as:

$$e_d = \frac{V_f + V_3}{V_d} \qquad 2.2$$

where;

$e_d$is the distribution Efficiency

$e_f$is the volume of water delivered to the distribution system.

$v_f$is the volume of water diverted to the field

v_3 is thenon irrigation deliveries from the distributary

$v_d$is the volume of water delivered to the distribution system.

2.4.3 Field application efficiency (e_a)

Field application is the movement of water from the field inlet to the crop. The field application efficiency is the relationship between the quantity of water delivered at the field inlet and the quantity of water needed to maintain soil moisture at the level required by the crop.This is an indirect way of establishing the field application efficiency, since the water used by evapotranspiration of a crop equals the amount of water needed to maintain the

required soil moisture for the crop. The field application efficiency can be expressed as follows;

$$e_a = \frac{V_m}{V_f} \qquad 2.3$$

Where

$e_a$is the application efficiency

v_m is the volume of water needed, and made available, for evapotranspiration by the crop to avoid undesirable water stress in the plants throughout the growing cycle.

$v_f$is the volume of water diverted to the field

2.4.4 Tertiary unit efficiency (E_U)

The tertiary unit efficiency (e_u); is the combined efficiency of the water distribution system and of the water application process. In other words, it is the efficiency with which water is distributed and consumptively used within the tertiary unit. The tertiary unit efficiency can be expressed as follows

$$e_u = \frac{V_m + V_3}{V_d} \qquad 2.4$$

where,

e_u is the unit efficiency

v_m is the volume of water needed, and made available, for evapotranspiration by the crop to avoid undesirable water stress in the plants throughout the growing cycle.

v_3 is the non irrigation deliveries from the distributary

v_d is the volume of water delivered to the distribution system.

If the no irrigation deliveries are insignificant compared with the volume of water delivered to maintain soil moisture at the required level for the crop, we may write as follows:

$$e_u = e_d.e_a \qquad 2.5$$

Where

e_u is the unit efficiency

e_d is the distribution efficiency

e_c is the conveyance efficiency

$e_d$is the distribution efficiency

The tertiary unit efficiency expresses the efficiency of water use downstream of the point where the control of water is turned over from the water supply organization lo the farmers

2.4.5 Irrigation system efficiency (Es)

The irrigation system efficiency (es); is the combined efficiency of the system of water conveyance and distribution:

If the non-irrigation deliveries are insignificant compared with the volume of water delivered to the fields, which is often true, we may write as follows:

$$e_s = e_c.e_d \qquad 2.6$$

where,

e_s is the system efficiency

$e_c$is the conveyance efficiency

$e_d$is the distribution efficiency

2.4.6 Overall project efficiency (E_P)

The separate assessments of conveyance, distribution, and field application efficiencies will indicate if and where remedial measures are required to improve the efficiency of water use in the project as a whole. The data used to assess the separate efficiencies can also be used

to assess a project's overall irrigation efficiency. The overall (or project) efficiency can be expressed as follows:

$$e_p = \frac{V_m+V_2+V_3}{V_c+V_1} \quad 2.7$$

Where

e_p is the project efficiency

v_c is the volume of water diverted or pumped from river

v_1 is the inflow from other sources

v_2 is the non irrigation deliveries from the distribution system.

v_m is the volume of water needed, and made available, for evapotranspiration by the crop to avoid undesirable water stress in the plants throughout the growing cycle.

v_c is the volume of water diverted or pumped from river

v_1 is the inflow from other sources

v_2 is the non irrigation deliveries from the distribution system.

v_3 is the non irrigation deliveries from the distributary.

This value represents the efficiency of the entire operation between river diversion or source of water and the root zone of crops. If the values of V1, V2, and V3 are negligible compared with V_c and V_L, which is often true the following relation holds as follows;

$$e_p = e_c \,.e_d \,.e_a \quad 2.8$$

Where,

e_p is the project efficiency

e_a is the application efficiency

$e_c$is the conveyance efficiency

$e_d$is the distribution efficiency

Levine (1982) presented a detailed exposition of the Relative Water Supply (RWS) concept and its use as an explanatory variable for irrigation systems. It was first presented in 1974 and has been extensively used in the project on "Determinants of Irrigation Problems in Developing Countries." The concept has also been widely tested in the field by many of Levine's graduate students. Two individual factors, the available water supply and the water "demand," are basic factors in irrigation planning, design, and operation. Individually, they are relatively difficult to use in attempting to understand system performance. Combined, they provide a variable with utility for both practical and theoretical applications. This variable, the Relative Water Supply (RWS), can be defined generally as the ratio of supply to demand.

Levine points out that the inverse of the relative water supply (RWS) variable is a "traditional engineering efficiency" term used in irrigation, Water Use Efficiency (WUE). The fundamental difference between the concept of relative water supply (RWS) and that of water for irrigation streams and the economy (WISE) is the difference in perspective that is engendered. The RWS variable presents a neutral view of the relationship between the amount of water available or delivered and the amount utilized for crop production. The WUE variable, by contrast, has value connotations inherent in the term "efficiency" the

higher the efficiency, the better it is. However, for a variety of reasons, a higher WUE is not necessarily better than a lower level, and in fact may be worse. In addition to its neutral character, the RWS variable lends itself to improved understanding and planning for the behavior of the major participants in the irrigation process. The irrigation managers or controllers and the farmers. Two forms of the RWS variable have been found to be useful; the Theoretical Relative Water Supply (RWST) and the Actual Relative Water Supply (RWSA).

2.5 Theoretical Relate Water Supply (RWST) is defined as the ratio of water supply at the location of interest to the water "demand" associated with maximum production of the optimal crop or cropping pattern grown with appropriate cultural practices on the total irrigable area designed or intended to be served from that location.

2.6 Actual Relative Water Supply (RWSA) is defined as the ratio of water supply to the water demand associated with the crops actually grown, with the cultural practices actually used, and for the actual irrigated area. RWSA is derived from field observations and measurements. The implications of the various terms in the definitions and the methods of commuting RWST and RWSA are elaborated in Levine (1982). The RWS methodology has been widely applied and tested in rice irrigation systems, though in principle it can be applied to all types of systems. RWSA is computed by the followingexpression as follows:

$$\text{RWSA} = \frac{\text{IR} + \text{RN}}{\text{ET} + \text{S\&}P} \qquad 2.9$$

Where,

IR = Irrigation water supply

RN = Rainfall,

ET = Evapotranspiration, and

S&P = Seepage and percolation.

RWSA can be calculated for a certain period, a week, a month, or a season. It is important to note that RN is the total rainfall for the period and that seapage and percolation (S&P)are treated as a component of the ‘demand.” RWSA can be calculated at any level in the system where the water supply can bemeasured.RWS has been used as an independent variable to study and explain the operations of the irrigation systems associated with different management behaviors.

On the basis of case studies and observations, Levine proposes the hypothesis that each management pattern has a minimum RWST value which would permit the “optimum’ production and which could result in an equal value for RWSA. This minimum value could be considered as critical level, for both RWST and RWSA. These could be used to evaluate system management. This ability of RWS to serve as a useful tool in evaluating management implications is the most significant contribution of the concept. In addition to its potential role in evaluating management and equity, the RWS variable has proven useful for inferring the decision that characterize system operation.

In order for an indicator like RWS to serve as a basis for comparative studies and analysis of irrigation systems in different regions or countries, it is necessary to use it in a standardized manner. As the effective rainfall computation is not as unambiguous as the total rainfall, this makes it difficult to interpret RWSA as a tool for comparative study of the associated management implications. Abernethy (1991) argues that the “demand” element in the denominator be defined as only the ET, the amount needed to satisfy crop evapotranspiration. He gives a good reason to support the argument, instancing percolation-reducing practices, such as pudding for rice, if not used, then the demand is higher and so

RWS is lower indicating better management, which is not the true case. It is not clear, though, whether the error in the estimation of S & P is not higher than what the differences in pudding can cause. Abernethy has also referred to the difficulty of estimating S&P values. Levine mentions that, while the measurement of seapage and percolation (S&P) is relatively simple in principle, the estimation of system values frequently presents difficulties. Sinceseapage and percolation(S&P) constitute a site-specific characteristic, area-wide values are obtained through interpretation.

Notwithstanding the significant problems in measurement and estimation of seapage and percolation (S&P), there is a good case for standardizing the methodology for the benefit of comparative studies Huang *et al* (2003).

Garces (1983) develops a methodology to evaluate the performance of irrigation systems and applies it to Philippine national systems. He makes extensive use of non-dimensional indices for evaluating each of the four broad interacting subsystems. Water, human, environmental, and economics of the total irrigation system. The desired qualities of the performance indicators identified are: that

i) They be quantifiable;

ii) The data be collected on a regular basis by the project management;

iii) They be sufficiently robust to give an indication of system performance whether in a wet or a dry

iv) They are applicable to all technical system type.

Water Subsystem for the water subsystem, three water-based performance indicators are selected that can help rate the success in achieving the crop production objective. They are productivity, equity, and efficiency. Each of these “indicators” is to be assessed by one or

more "descriptors.' Productivity performance of the system is assessed by the following descriptors:

i) Area Utilization (Au), defined by the ratio of the harvested area (AH) and theoretically serviceable area (TA).

$$A_u = \frac{AH}{TA}, 0 \leq A_u \leq 1 \qquad 2.10$$

ii. a) Yield: Rain-fed-Based (Yr), defined as the ratio between the system's average yield (IY) and nearby rain-fed areas' average yield (RY).

$$Y_r = \frac{IY}{RY}\ ;\ RY > 0 \qquad 2.11$$

b) Yield Potential-based(Yp), which utilizes a potential yield (PY) for the area for comparison with (IY). Potential yield is obtained from experiment stations or from demonstration plots in farmers' fields.

$$Y_p = \frac{IY}{PY}, 0 \leq Y_p \leq 1 \qquad 2.12$$

c) Yield: Top Yielders-Bosed (Yr); which utilizes the highest farmer yield within the system. If TY is the average yield of 10 or 20 percent of the top yielders,

$$Y_t = \frac{IY}{TY}, 0 \leq Y_t \leq 1 \qquad 2.13$$

iii) Irrigation-Water Output (IWO) is given by the expression

$$IWO = \frac{IY}{(W/A)} \qquad 2.14$$

Where, 1V is the Irrigated average yield for systems,

W is the total volume of irrigation water per season, and

A is the total area harvested.

IWO describes the productivity per unit of water supplied to the system in kg/mm per unit area.

Equity achievement is described by the following descriptors:

1) Production Distribution (PD) uses the proportionality between the percentage of the total area planted corresponding to a section and the percentage of the total production that particular section contributes. By looking at the production deviations from the respective areas, one can assess a systems' equity.

$$PD = 1 - \sum_{s=1}^{n} (\%A_s - \%P_s) \qquad 2.15$$

$= 1 - d_p;$

$$0 \leq PD \leq 1$$

$$0 \leq d_p \leq 1$$

Where, As is the % of total area harvested contributed by section,

Ps is the % of total production contributed by section,

n is the number of sections into which system is divided, and

dp is the absolute value of summation of deviations (shortages) of % total production from % total area harvested for each section into which the system is divided, in fractional form.

ii. Flow Distribution (FD) follows the same logic as the PD descriptor but utilizes information on flows going to each section.

$$FD = 1 - \sum_{s=1}^{n} (\%A_s - \%P_s) \qquad 2.16$$

$= 1 - d_f;$

$$0 \leq FD \leq 1$$

$$0 \leq d_f \leq 1$$

Where,

Fs is the % of total flow received by section.

iii) Production Flows Distribution (PFD) combines the information on production and flows from the above equations for FD arid PFD to define

$$PFD = 1 - \sum_{s=1}^{n}(\%P_s - \%F_s)$$

$$= 1 - dp_f; \qquad 2.17$$

$$0 \leq PFD \leq 1$$

$$0 \leq d_{pf} \leq 1$$

Efficiency of water use is considered for Iwo clearly distinguished periods of a cropping season: I) land soaking and land preparation (LS and LP), and ii) from planting to terminal drainage (crop water requirement period, CWR).

i) Land Preparation Span (LPS) descriptor is given by the expression

$$LPS = \frac{TLPS}{ALPS}, 0 \leq LPS \leq 1 \qquad 2.18$$

where,

TLPS is the targeted or programmed LPS, arid

LPS is the actual LPS in days.

ii. For the crop water requirement period Relative Water Supply Actual (EWSA) is used as a descriptor. It reflects the ability of the human subsystem to react to the dynamic process of decision making and subsequent implementation. Leading to the achievement of a set of predetermined irrigation-oriented goals. There are two descriptors:

i. Response Capacity (RC), which seeks to relate the preparedness and versatility of the project staff to plan, address, and resolve the day-to-day operation and maintenance matters of the system.

ii. Farmers' Satisfaction (FS); which is the degree of satisfaction perceived by the farmers with the irrigation system as a descriptor of system performance.

The descriptors are qualitative in nature and their assessment involves either survey methods using questionnaires or informal or open-ended interviews with farmers and key informants.

The environmental subsystem uses "impact on the environment" as the indicator. The three descriptors are:

i. Water Logging(W): percentage of area affected, frequency of occurrence(seasonal basis); and magnitude of production loss.
ii. Soil Toxicities (ST): percentage of area affected, severity of the condition; and magnitude of production loss.
iii. Irrigation Water Quality (WQ): water quality standards for irrigation are well-defined and readily available. The particular setting of each system should be analyzed to determine what importance the water quality issue might have in the performance of the system.

For the economic subsystem, the strategy followed in the identification of an economic indicator is to look for a suitable element which can convey a message of economic stability in the short- and long-run time frames and which can be monitored on a seasonal basis. The indicator "cost recovery" is used. The ability to generate resources to cover the costs of regular operation and maintenance is important for system sustainability. The descriptors are:

i. O&M Financing (OMF), which can be defined as that portion of the O and M expenses that is self-generated by the irrigation system.

2.19

$$\mathrm{OMF} = \frac{\mathrm{AC}}{\mathrm{OME}}$$

Where.

AC is the amount collected as service fee, and

OME is the O and M expenses during the period.

ii. Threshold Level (TL), Is the fraction of the maximum collectible that would equal the O and M expenses of the system.

$$\mathrm{TL} = \frac{\mathrm{OME}}{\mathrm{MC}} \qquad 2.20$$

Where,

MCis the Maximum collectible, a function of fee level and area benefited.

iii. Percentage Collected PC Is the percentage of the total amount due that is actually collected.

$$\mathrm{PC} = \frac{\mathrm{AC}}{\mathrm{MC}} \qquad 2.21$$

The three descriptors are Interrelated:

$$\mathrm{OMF} = \frac{\mathrm{PC}}{\mathrm{TL}} \qquad 2.22$$

The approach and methodology developed by Garces (1992) are important contributions to the search for performance indicators for evaluation of irrigation system using data regularly collected by the agencies in the Philippine rice systems.

Merriam *et al*., (1983) describe the methods for evaluating irrigation systems and practices which include sprinkler systems of various types, furrow irrigation, border-strip irrigation, and basin irrigation. Procedures arc described to measure and determine the potential efficiency of the systems as designed and the actual efficiency that is obtained with present management. A precise terminology is required to make and interpret the measurements. In order that all comparisons have a common basis, the three performance parameters are

potential application efficiency, actual application efficiency and distribution uniformity,are based on the average depth of water infiltrated or stored in the quarter of the area receiving the least amount of water. The low-quarter (IQ) concept was developed by the USDA Soil Conservation Service and is recommended as the standard for comparing alternative conditions. For some uniformity studies, Christiansen's uniformity coefficient may be used.

CHAPTER THREE

MATERIALS AND METHOD

3.1 Materials

The following materials were used in this study:

i. The Pump (1HP): was used to suck irrigation water from the source (200L) reservoir tank and delivered it to the irrigation system at a given pressure setting.

ii. The Mainline: was used to deliver water from the pump to the submain.

iii. Sub –mainline; receive water from mainline and delivers it to the lateral line.

iv. Laterals line: receive water from the submain lineand delivers it to the riser pipe.

v. The Risers line: The line delivers water to the sprinkler head.

vi. The Filter: The filter was used to entrap solid particles from blocking the sprinklers.

vii. The Sprinkler heads: The sprinkler head was connected to the riser pipe to rotate and throw water droplets.

viii. The Pressure Gauge(kg/cm^2): The gauge was used to keep gauge pressure of water going into the system for each setup.

ix. The Control valve: The Valves were used to lock / open up the flow of water in the system.

x. The Plastic bucket (20 litres capacity): The 20 litres capacity bucket was used to collect the flow of water for discharge measurement set up.

xi. The Graduated cylinder (ml): was used to measure the volume of water collected in catch cans.

xii. Measuring tape: was used to measure the radius of throw of the system.

xiii. Stop watch: was used to keep count of time (sec).

xiv. Software such as SPSS, ANOVA, GIS were used to analyze the values.

3.2 Meteorological Data

The basic meteorological data available for this study were obtained from the land and water department of the National Water Resources Institute (NWRI) Mando, Kaduna.

The data include daily rainfall,evaporation, relative humidity, wind speed/direction, maximum and minimum temperature. The duration of data collection was one month (May, 2016).SeeTable 3.1

Table 3.1: Meteorological data of the site for month of May 2016

S/N	DATE	RAINFALL (mm)	EVAPORATION (mm)	DRY BULB	WET BULB	WIND DIRECTION	TEMPERATURE	
							Max ^{o}c	Min^{o}c
1.	01/05							
2.	02/05	4	24.54		30	SW	32.5	22
3.	03/05	5.1	19.44		28	SW	25	21
4.	04/05	15	11.22		27.5	NW	28	20
5.	05/05	0			27	SW	26	23
6.	06/06							
7.	07/05							
8.	08/05	0.58			29	SW	29	24
9.	09/05	28.6			27	SW	26	19
10.	10/05	29.52			28	SW	28	20
11.	11/05	22.87			28	SW	27.5	21

12.	12/05	38.04		25	SW		22
13	13/05						
14	14/05						
15	15/05	14.64		26.5	SW	27	23.4
16	16/05	43		25.5	SW	26	22
17	17/05	39.5		27.5	SW	28	22.5
18	18/05	32.56		27.5	SW	28	23
19	19/05	28.46		28	SW	28	23

S/N	**DATE**	**RAINFALL (mm)**	**EVAPORATION (mm)**	**DRY BULB**	**WET BULB**	**WIND DIRECTION**	**TEMPERATURE**	
							Max ^{o}c	**Min^{o}c**
20	20/05							
21	21/05							
22	22/05	44.27			28	SW	29	21
23	23/05	38.05			27.8	SW	28	23
24	24/05	34.62			28	SW	29	21
25	25/05	38.83			25	SE	26	20
26	26/05							
27	27/05							
28	28/05							
29	29/05							
30	30/05	36.24			25	SE	25	19
31	31/05	32.82			26.5	SW	26	20

3.3 Basic Infiltration Rate of the Soil

Infiltration refers to water moving into soil from rainfall or irrigation and is the first stage of water movement in the soil. Infiltration starts as soon as the first drop of rainfall touches the ground surface and continues even after precipitation ceases until the soil is filled to field capacity (Ahmed 1982). The double ring cylinder infiltrometerwas used. The cylinder consistsof two concentric cylinders opened at both endswith one edge of both cylinder sharpened to an angle of about 30^{o}c to allow for easy entry or penetration into the soil. Both

cylinders were 300 mm high with a diameter of 230mm for the outer ring and 155mm for the inner ring. The cylinders were then set in place concentrically and then pressed firmly into the soil after which a wooden plank was placed over the cylinder and tampered with a hammer until the cylinder were driven to a depth of about 150mm,after which the volume of the cylinder above the soil surface was measured. (Diameter, depth). A gauge was then fixed to the inner wall of the inner cylinder so that the level changes that occur could be measured. The irrigation water was collected and poured quickly into the infiltrometer to an approximate depth of 100m above the soil surface.

When the water surface had settled, the initial gauge reading and the time were taken. Additional measurements were taken at periodic interval of 5 minutes for the first 4-6 readings expending to 30-60 minutes' intervals after 8-9 reading. The measurement was continued until two consecutive readings over one to two hours' period were approximately the same. The data obtained were analyzed by graphical method logarithmicplot of cumulative infiltration againstcumulative time.

3.4 Experimental Site

This experiment was carried out at Farin-gida,farm plot of the National Water Resources Institute Mando, Kaduna.

3.4.1 Experimental Set up

The experimental set up consist of one (1) horse power (hp)pump,Amainline hose whichconnect through the inlet of the pump to a 200L reservoir tank filled to the brim with water. A pressure gauge attached to the sub main pipe to keep pressure of water entering the sub main pipe constant. The sub main pipe receive water from the pump outlet and

delivered to the lateral line. The lateral line takes water to the riser pipe at 1m high above the ground.The water gets through the riser pipe and get on to the sprinkler head where itrotate and spread water (see fig 3.1).

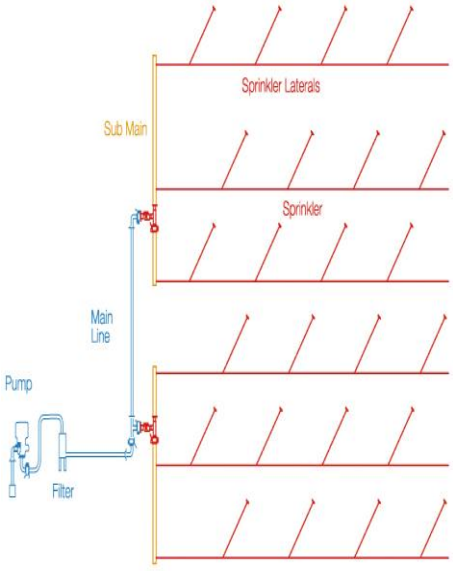


Fig: 3.1Sprinkler System Layout.

3.4.2 Discharge Measurement Set Up

The measurement of discharge was put up for nine different operating pressures of 1.0, 1.5, 2.0,2.5,3.0,3.5,4.0,4.5and5.0 kg/cm^2. The required operating pressure at the nozzle was adjusted by the valve and bye pass arrangement. To measure the discharge for both sprinkler, nozzle was dipped into a 20 liters' bucket and the time taking to fill the bucket is noted by stop watch. The observations were replicated thrice to get accurate results. The water collected in bucket was measured with the help of graduated cylinder and then converted into discharge per hour.



Plate 3.1 Sprinkler discharge measurement setup

3.4.3 Radius of Throw Measurement Set Up

The radius of throw for either of the sprinkler was measured at different pressure ranging from 1.0 To 5.0 kg/cm^2 with an increment of 0.5kg/cm^2 pressure. This was thus, measured by the measuring tape from the center of the sprinkler head to the end water throw.

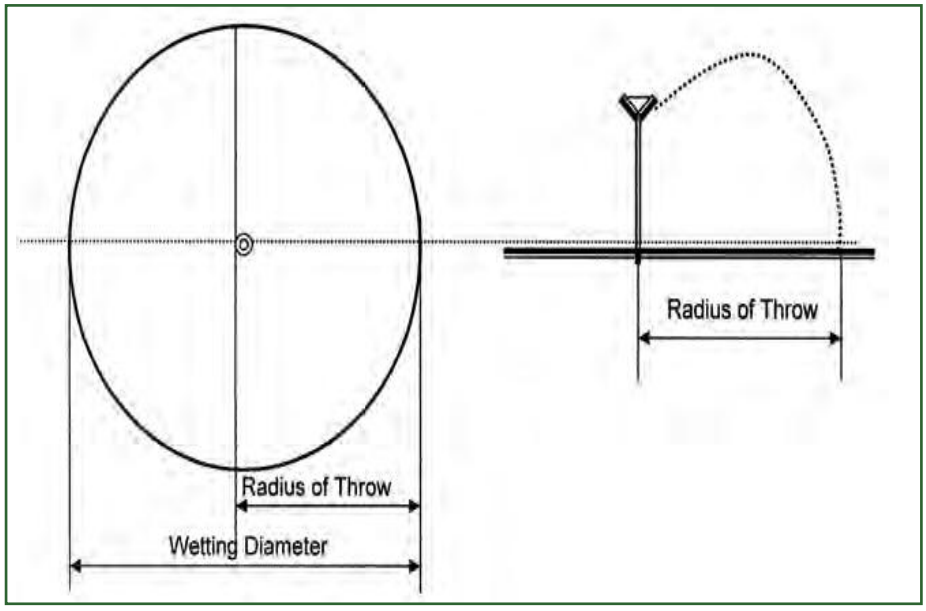


Fig 3.2; Line Diagram for Radius of Throw of Mini Sprinkler System

3.4.4 Relationship Between PressureVs Discharge/PressureVs Radius of Throw

Themathematicalrelationships(linear,logarithmic,power,andexponential) between the parameters were developed from observation data on pressure discharge and radius of throw, and the best fit equation is decided on the basis of regression coefficient (r^2). The value of r^2 which would be found higher is to be used to plot a curve relationship between the above two parameters.

3.4.5 Precipitation Rate

This is the speed at which a sprinkler or an irrigation system applies the water. In determining the precipitation rate for the two sprinklers, the sprinkler nozzles were operated at pressure of 1.0-5.0kg/cm^2 with 0.5kg/cm^2 increase in pressure. And, the volume of precipitation collected in catch cans were measured with the help of a measuring cylinder. And the precipitation rate computed by the equation 3.1

$$\text{PR}\left(\frac{\text{mm}}{\text{hr}}\right) = \frac{\text{Discharge}\left(\frac{\text{m}^3}{\text{h}}\right)\text{X}\,1000}{\text{wetted area in m}^2} \qquad 3.1$$

3.4.6 Water Distribution Pattern of Sprinklers on the Soil

The water distribution pattern in the sprinkler were determine by conducting a test using precipitation depth in catch cans placed at grid of 3x3 m spacing for the two sprinklers. The average depth of water collected at each sampling point were computed. And, the observed x,y coordinates values were obtained from the GIS conducted, these values in relation to the depths(z coordinate) of water in each test were used to draw contours using surfer v.8.0 .



Fig.3.3 Catch Can Experimental setup for volume and Depth of Water for Mini Sprinkler

3.4.7Uniformity Coefficient (UC)

$$UC = 1 - \frac{\sum X}{n.m} \text{ x } 100 \qquad 3.2$$

Where UC = Uniformity coefficient

x = total absolute value of deviation from average amount of water measure in all catch cans.

m = average amount of water in catch cans

n = number of catch cans

CHAPTER FOUR

RESULTS AND DISCUSSION

4.0 Results

The mini sprinklers were evaluated for their hydraulic performance. The experimental results obtained during the period of the study were tabulated and analysedusing statisticalsoftware.

4.1 Soil Sample Test

The result of the soil sample test reveal that the study site is covered by the ferruginous tropical soils considered to be the zonal soils developed under the prevailing climatic conditions. The water holding capacity is good and the basic rate of intakes of water by the soil is moderate (see table 4.1).

Table 4.1: Physical Properties of the soil at faringida

Profile	Depth	Particle Size Distribution			Texture	Color	Bulk Density	Total Porosity	Moisture Retention			Basic Infiltration	Moisture Content
	Cm	S%	S1%	C%			gcm^{-1}	%	%	%	%	cm/hr	%
FG P1	0-14	35.4	30.0	34.6	SCL	DB	1.35	47.2	20.10	14.40	2.02	5.63	36.1
	14-43	35.6	30.0	34.4	SCL	B	1.37	48.3	22.50	14.40	8.30		36.4
	43-92	21.2	46.0	32.8	SCL	B	1.30	51.1	22.20	13.60	2.12		33.5
	92-160	21.6	46.0	32.4	SCL	B	1.27	52.1	22.20	13.60	2.12		32.3

Table 4.2: Chemical Properties ot Soils atFarin Gida Area

Profile	Depth	pH	Exchangeable Bases Ca Mg K Na				TEB	CEC	ESP	OC	OM	TN	AP	Ece	SAR
			(……..……..….Cmol(+)kg^{-1}……..……..…)						%	gkg^{-1}	$Mgkg^{-1}$	gkg^{-1}	$Mgkg^{-1}$	dSm^{-1}	
FG P1	0-14	5.31	3.22	0.71	0.70	0.21	4.84	8.84	6.9	3.90	6.90	0.60	2.45	0.040	0.075
	14-43	5.30	3.32	0.79	0.79	0.20	4.66	8.21	6.2	3.40	7.50	0.58	2.80	0.030	0.076
	43-92	6.01	3.22	0.61	0.61	0.12	4.72	8.50	8.1	4.58	7.90	0.40	3.48	0.020	0.201
	92-160	6.12	2.23	0.65	0.65	0.14	3.77	8.15	9.3	4.60	8.00	0.52	3.23	0.030	0.221

4.2 Pressure Discharge Relationship

The result of the performance discharges for 14mm diameter iron and plastic mini sprinkler system operated at 1.0- 5.0kg/cm^{2}pressure is 8.9- 40.0L/min for iron, and 11.1 -52.6L/min for plastic.With5.63cm/hr constant infiltration rate of the soil,the minimum and maximum discharges were obtained at 1.0kg/cm^{2}and 5.0kg/cm^{2}as 8.9 & 11.1, and 40.0 & 52.6 respectively. Similarly, the performance discharges for 8mm diameter iron and plastic is 8.40-38.5L/min for iron and 9.1-41.7 L/min for plastic at 1.0-5.0kg/cm^2. The result reveal an increase in discharges as the operating pressure increases. (See appendix iii &iv). Analysis of Variance (ANOVA) reaveala p-value of 7.7415E-06, table 4.2b and 2.8062E-07, table 4.3b.The p values are both less than alpha value of (0.05),the differences shows that they are statistically significant.Which means that there is little difference between the performance of both sprinklers,both indicating that the higher the pressure, the higher the discharges. See table 4.3 & 4.4

Table 4.3: ANOVA table for Pressure Vs Discharge values for 14mmm diameter nozzle size

Summary	Count	Sum	Average	Variance
Plastic Made	9	228.5	25.3888889	164.001111
Iron Mae	9	189.7	21.0777778	93.79694444

ANOVA
RESULT

Source of Variation	SS	Df	Ms	F	P – Value	F – Critical
Rows	2017.06	8	252.1325	44.5026966	7.7415E – 06	3.43810123
Columns	83.63555556	1	83.6355556	14.7621102	0.0049213	5.31765507
Error	45.3244444	8	5.66555556			
Total	2146.02	17				

Table 4.4: ANOVA table for Pressure vs Discharge values for 8mm diameter nozzle size

Summary	Count	Sum	Average	Variance
Plastic Made	9	201.5	22.3888889	120.223611
Iron Made	9	177.7	19. 7444444	116.210276

ANOVA RESULT

Source of Variation	SS	Df	Ms	F	P – Value	F – Critical
Rows	1873.47	8	234.18375	104.0752	2.8062E – 07	3.43810123
Columns	31.4688889	1	31.4688889	13.9853095	0.00570787	5.31765507
Error	18.0011111	8	2.25013889			
Total	1922.94	17				

The graphical representation of pressure vs discharge relationship as depicted in table 4.2 and 4.3

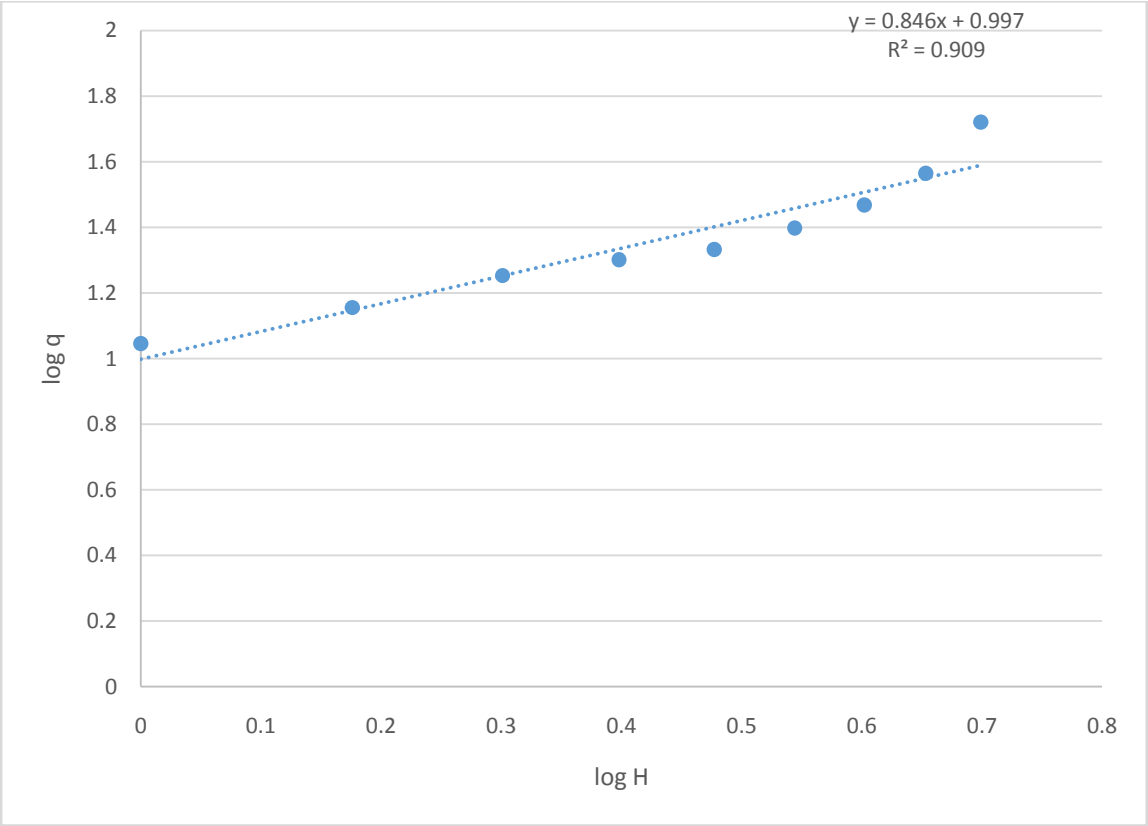


Figure 4.1a: Pressure-Discharge Relationship of plastic made sprinkler with 14mm diametter nozzle.

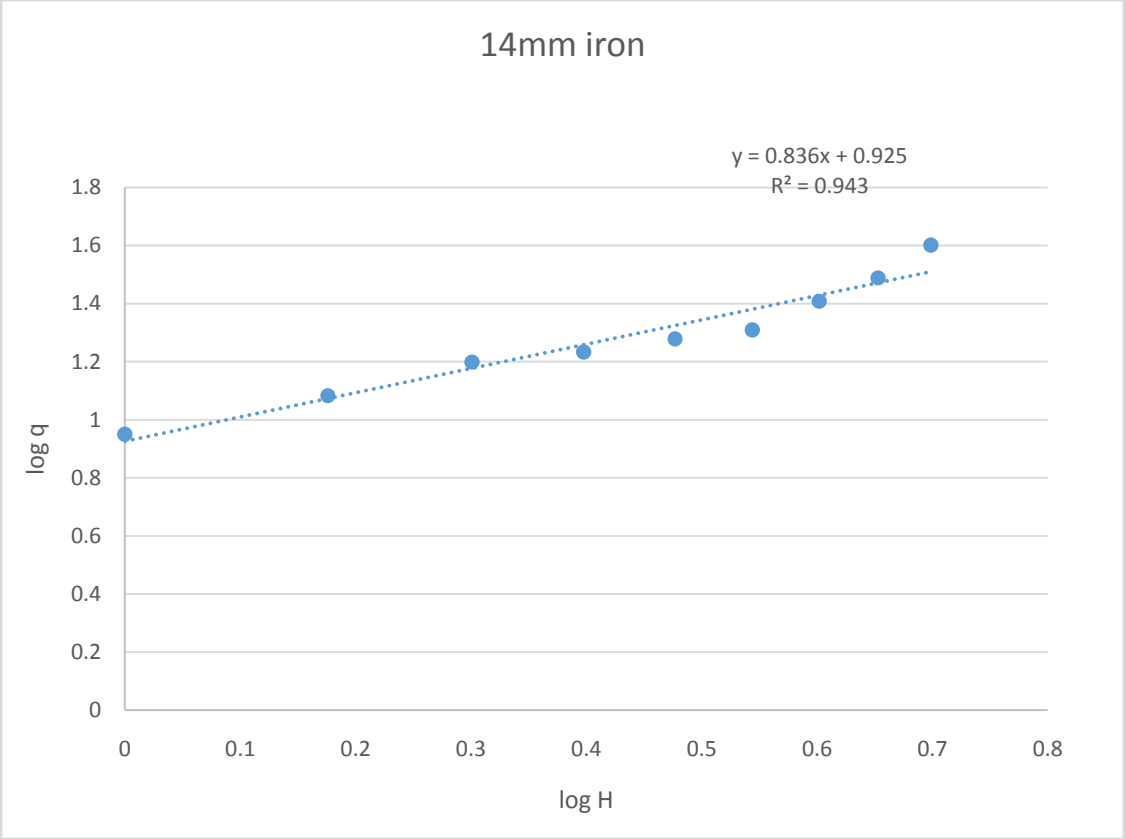


Figure 4.1b: Pressure-Discharge Relationship of iron made sprinkler with 14mm diametter nozzle

The relationship between the operating pressure and discharge under the two mini-sprinklers (plastic and iron) were developed in the form of linear function. The best fit relationship between the operating pressure head (H) and discharge (Q) of mini sprinkler were determined in form of the linear equations.

	Relationship	**Regression coefficient**
Plastic	y = 0.8466x + 0.9977	r^2 = 0.9096
Iron	y = 0.8361x + 0.9257	r^2 = 0.9438

Where,0.9977, 0.9257 are the discharge coefficient of the sytem,0.8466, 0.8361 are the slope of the system ,0.9096, 0.9438 are the regression coefficient of the system respectively for plastic and iron.

Thus, the relationship between the operating pressure and discharge is said to be inform of power relationship (Vermerien and Jobling 1980), the r^2 values found in power relationship are 0.91 and 0.95 respectively. In this investigation, keeping operating pressure and discharge relationship inform of linear function,(Howell and Barinas 1980). The r^2values found are 0.9096 and 0.9438. There is no significant difference between the r^2 values of power and linear relationship.The linear model (which is an offshoot of Polynomial relationship) is found to be better in this investigation with r^2 values of 0.9096 and 0.9438 respectively.

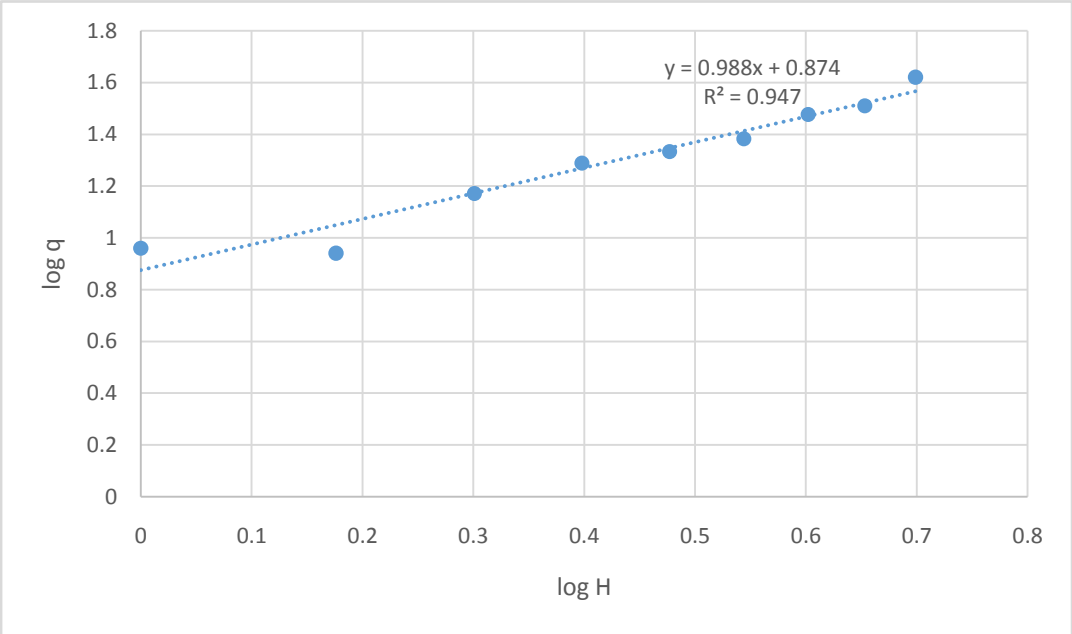


Figure 4.2a: Pressure-Discharge Relationship of plastic made sprinkler with 8mm diameter nozzle.

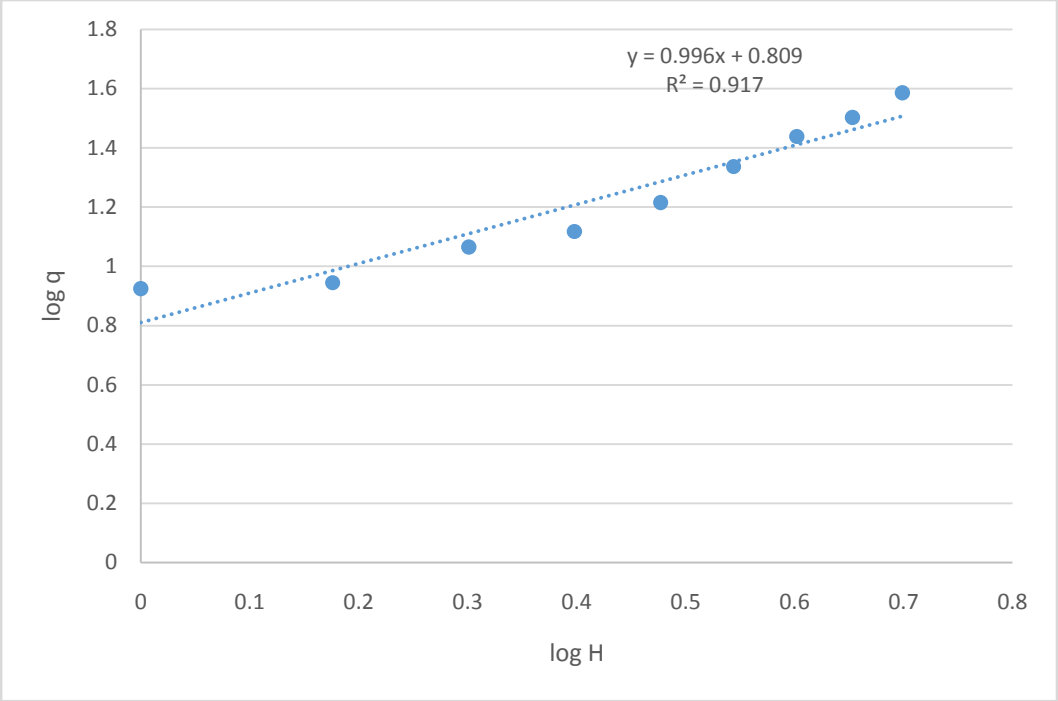


Figure 4.2b: Pressure-Discharge Relationship of iron made sprinkler with 8mm diameter nozzle.

Similarly, the relationship between the operating pressure and discharge under the two mini-sprinklers (plastic and iron) were developed in the form of linear function. The best fit relationship between the operating pressure head (H) and discharge (Q) were determined in the form of these linear equations.

Relationship		**Regression coefficient**
Plastic	y = 0.9888x + 0.8743	r^2 = 0.9471
Iron	y = 0.9969x + 0.8099	r^2 = 0.9176

Where 0.8743,0.8099 are the discharge coefficient constant of the system,0.9888,0.9969 are the slopes of the system and 0.9471,0.9176 are the regression coefficient of the system respectively for plastic and iron.

Also, the relationship between the operating pressure and discharge is said to be inform of power relationship (Vermerien and Jobling 1980), the r^2 values found in power relationship are 0.91 and 0.95 respectively. In this investigation, keeping operating pressure and discharge relationship inform of linear function, (Howell and Barinas 1980). The r^2values found are 0.9471 and 0.9176. There is no significant difference between the r^2 values of power and linear relationship.The linear model (which is an offshoot of Polynomial relationship) is found to be better in this investigation with r^2 values of 0.9096 and 0.9438 respectively for plastic and iron.

4.3 Pressure Radius of Throw Relationship

The observations of radius of throw for the two mini sprinkler nozzles (Plastic and iron 8mm and 14mm diameter nozzle sizes) were recorded for different operating pressure range of 1.0 to 5.0kgcm^{-2}, with an increment of 0.5kgcm^{-2}.The radius of throws and the wetted areas for 8mm and 14mm nozzle sizes were observed. The minimum radius of throw and the wetted area is 2.6cm and 21.24cm^2,andthe maximum is 11.0cm and 380.18cm^2 for 8mm iron,min radius and area is 2.4cm and 18.09cm^{2}and max is 14.5cm and 660.61cm^{2}for 14mm iron. Similarly, for 8mm plastic, min radius and wetted area is 1.8cm and 10.18cm^2 and max radius and wetted area is 8.2cm and 211.32cm^2. And, for 14mm plastic, min radius and areas is 2.0cm and 12.26cm^2 and max radius and area is 8.2cm and 211.32cm^2. However, wider radius of throw was observed with the iron sprinklers as shown by the graphs of their performances. Fig 4.2a and 4.2b.

More so, the ANOVA result for both 8mm and 14mm reveal p-values of 0.00933 and 0.002116 respectively.The p-values are less than the alpha value of (0.05). The radius of throw are statistically significant in relation to the operating pressures.

Table 4.5: ANOVA table for Radius of throw values for 14mm diameter nozzle size

Summary	Count	Sum	Average	Variance
Plastic Made	9	81.1	9.011111	16.59611
Iron Made	9	45.8	5.08888	4.69361

ANOVA RESULT

Source of Variation	SS	Df	Ms	F	P – Value	F – Critical
Rows	154.4	8	19.3	9.6998	0.002116	3.43810123
Columns	69.2272	1	69.227	34.7921	0.0049210.000363	5.31765507
Error	15.9177	8	1.9897			
Total	239.545	17				

Table 4.6: ANOVA table for Radius of throw values for 8mm diameter nozzle size

Summary	Count	Sum	Average	Variance
Plastic Made	9	74.8	8.311111	7.4511
Iron Made	9	40.3	4.47777	3.3919

ANOVA RESULT

Source of Variation	SS	Df	Ms	F	P – Value	F – Critical
Rows	80.2144	8	10.0268	12.2839	0.00933	3.43810123
Columns	66.125	1	66.125	81.0107	1.8522E – 05	5.31765507
Error	6.53	8	0.81625			
Total	152.8694	17				

The graphical representation of pressure of throw relationship is depicted in fig 4.2a and 4.2b.

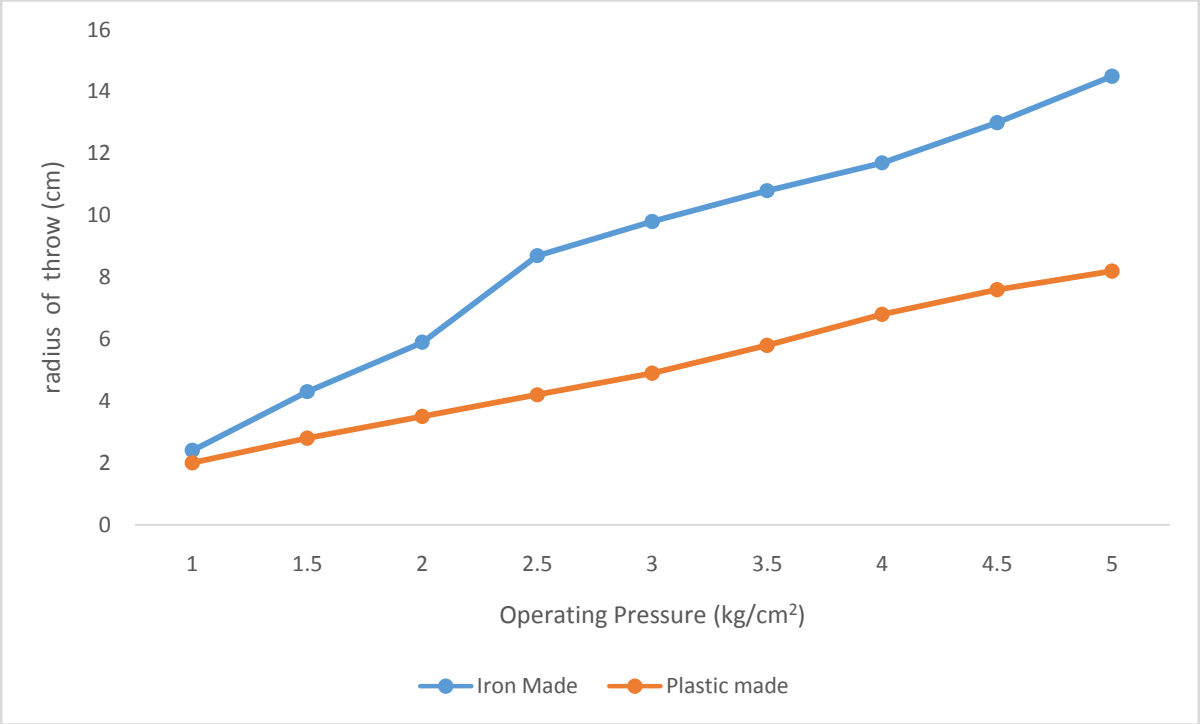


Figure 4.2a: Pressure-Radius of Throw Relationship of Mini-Sprinkler for Different Nozzles under Study.

	Relationship	**Regression coefficient**
Iron	$R = 7.162H^3 – 1.181H^2 + 0.96H – 3.894$	$r^2 = 0.993$
Plastic	$R = 0.708H^3 + 0.283H^2 – 0.028H + 1.104$	$r^2 = 0.998$

Where,
R = Radius of Throw
H= Operating Pressure

As operating pressure increases from 1.0 to 5.0kg/cm^2 the radius of throw increases from 2.4 to 14.5 cm, and 2.0 to 8.2 cm for Iron and plastic nozzles respectively. The data shows a maximum throw of 14.5 cm was observed for Iron and 8.2 cm for Plastic at operating pressure of 5.0 kg/cm^2. There is an exhibited increase in the radius of throw of mini-sprinkler nozzles as the operating pressure increases. Pressure-radius of throw relationship was established for the two mini-sprinkler nozzles in the form, power, polynomial and

exponential function. The best fit relationship between the operating pressure head (H) and radius of throw (R) of mini-sprinkler was determined in the form of the polynomial equations above. The regression coefficients (r^2) show that 99% of the changes in the radius of throw for both iron and plastic nozzles are explained or attributed to changes in the operating pressure. It therefore implies that it is only 1% of the changes in the radius of throw that is not explained or not caused by operating pressure.

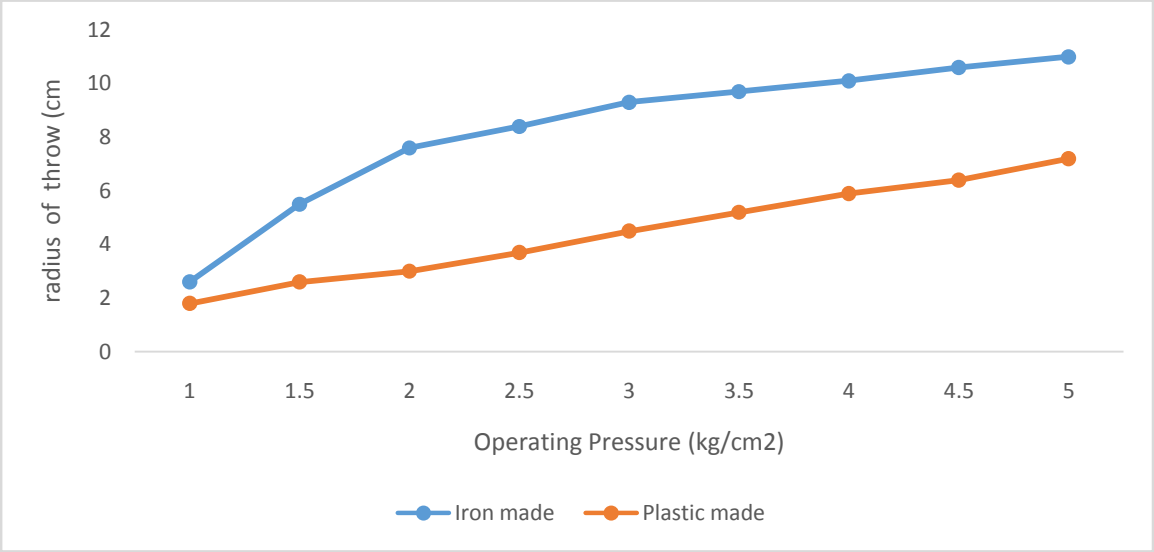


Figure 4.2b: Pressure Radius of throw relationship of Mini Sprinkler wit 8mm diameter nozzle sizes.

	Relationship	**Regression coefficient**
Iron	$R = 11.720H - 2.936H^2 + 0.258H^3 - 6.381$	$r^2 = 0.998$
Plastic	$R = 0.922H + 0.144H^2 - 0.015H^3 + 0.796$	$r^2 = 0.998$

Here also, operating pressure increases from 1.0 to 5.0kg/cm^2 while the radius of throw increases from 2.6 to 11.0 cm and 1.8 to 7.2 cm for Iron and plastic nozzles respectively. The data show a maximum throw of 11.0 cm was observed for Iron and 7.2 cm for Plastic at operating pressure of 5.0 kg/cm^2. There is an exhibited increase in the radius of throw of

mini-sprinkler nozzles as the operating pressure increases. Pressure-radius of throw relationship was established for the two mini-sprinkler nozzles in the form of power, and exponential function. The best fit relationship between the operating pressure head (H) and radius throw (R) of mini-sprinkler was determined in the form of the polynomial equations above. The regression coefficients (r^2) show that 99% of the changes in the radius of throw for both iron and plastic nozzles are explained or attributed to changes in the operating pressure. It therefore implies that it is only 1% of the changes in the radius of throw that is not explained or not caused by operating pressure.

4.4 Precipitation Rate of Mini Sprinkler Head / Application Rate

The volume of water was collected in catch can placed at each grid spacing of 3x 3 m. The precipitation rate of sprinklers was estimated at different operating pressure range of 1.0 to 5.0kgcm^{-2}. The average precipitation rate in (mm/hr) were computed from the volume of water collected in catch can and the wetted area(s) covered by the sprinkler throw were computed and tabulated. For 8mm plastic and iron, the maximum and minimum application rate were obtained to be 157.47mm/hr and971.95mm/hr,for 8mm iron,238.32mm/hr and 1010.77mm/hr. for 14mm plastic,257.46mm/hr and10.14.39mm/hr. for 14mm iron, 313.76mm/hr and 1235.3mm/hr.(see table 4.7-4.10). As the operating pressure increases from 1.0 to 5.0 kgcm^{-2}, the average precipitation rate of single mini sprinklerhead increases for all nozzle. It is also seen that as the nozzle size increase, the precipitation rate increases.

Table 4.7: Precipitation rate for mini sprinkler as influenced by operating pressure with 8mm nozzle sizes

Operating Pressure	Iron made sprinkler								
Kg/cm^2	Wetted Area(s) (cm^2)	Wetted Area(s) (m^2) x 10^{-3}	Mean d(mm)	Mean d (m) x10^{-3}	Vol (m^3) x 10^{-3}	Time (Min)	Time (hr)	Discharge m^3/h x 10^{-3}	PR(mm/hr)
1.0	21.24	2.124	3.98	39.80	0.08454	10	0.167	0.50622	238.32
1.5	95.05	9.505	6.10	61.00	0.57981	10	0.167	3.47180	365.30
2.0	181.48	18.148	9.50	95.00	1.72406	10	0.167	10.32370	568.86
2.5	212.70	22.170	10.45	104.30	2.31230	10	0.167	13.84610	624.50
3.0	271.75	27.175	11.88	118.80	3.22840	10	0.167	19.33170	711.38
3.5	295.63	29.563	12.78	127.80	3.77820	10	0.167	22.62400	765.28
4.0	317.35	31.735	14.30	143.00	4.53810	10	0.167	27.17430	856.29
4.5	353.04	35.304	15.85	158.50	5.59560	10	0.167	33.50660	949.09
5.0	380.18	38.018	16.88	168.80	6.41740	10	0.167	38.42750	1010.77

Table 4.8: Precipitation rate for mini sprinkler as influenced by operating pressure with 8mm Nozzle ϕ Values

Operating Pressure	Plastic made Sprinkler								
Kg/cm^2	Wetted Area(s) (cm^2)	Wetted Area(s) (m^2) x 10^{-3}	Mean d (mm)	Mean d (m)	Vol (m^3) x 10^{-3}	Time (Min)	Time (hr)	Discharge m^3/h x 10^{-3}	PR(mm/hr)
1.0	10.18	1.018	2.63	26.30	0.02677	10	0.167	0.16030	157.47
1.5	21.24	2.124	5.93	59.30	0.12595	10	0.167	0.75420	355.08
2.0	28.28	2.828	7.73	77.30	0.21860	10	0.167	1.30898	462.86
2.5	43.01	4.301	9.60	96.00	0.41289	10	0.167	2.47200	574.75
3.0	63.63	6.363	11.35	113.5	0.72220	10	0.167	4.32450	679.60
3.5	84.96	8.496	11.95	119.5	1.01527	10	0.167	6.07950	715.57
4.0	109.37	10.937	13.75	137.5	1.50384	10	0.167	9.00500	823.35
4.5	208.70	12.870	15.33	153.3	1.97297	10	0.167	11.81420	917.96
5.0	162.88	16.288	16.23	162.3	2.64380	10	0.167	15.83110	971.95

Table 4.9: Precipitation rate for mini sprinkler as influenced by operating pressure with 14mm ϕ Nozzle Values

Operating Pressure	Iron made sprinkler								
Kg/cm²	Wetted Area(s) (cm²)	Wetted Area(s) (m²)	Mean d (mm)	Mean d (m) x10^{-3}	Vol (m^3)x 10^{-3}	Time (Min)	Time (hr)	Discharge m³/h	PR(mm/hr)
1.0	18.09	1.809	5.24	52.40	0.09479	10	0.167	0.56760	313.76
1.5	58.09	5.809	9.14	91.40	0.53094	10	0.167	3.17930	547.31
2.0	109.37	10.937	10,83	108.30	1.18448	10	0.167	7.09270	648.51
2.5	237.82	23.782	11.65	116.50	2.77060	10	0.167	16.59040	697.60
3.0	301.76	30.176	12.84	128.40	3.87459	10	0.167	23.20110	768.86
3.5	366.48	36.648	13.16	131.60	4.82290	10	0.167	28.87960	788.03
4.0	430.11	43.011	16.43	164.30	7.06670	10	0.167	42.31560	983.83
4.5	530.99	53.099	17.46	174.60	9.27109	10	0.167	55.51550	1045.51
5.0	660.61	66.061	20.63	206.30	13.62840	10	0.167	81.60720	1235.30

Table 4.10:Precipitation rate for mini sprinkler as influenced by operating pressure with for 14mm ϕ Nozzle Values

Operating Pressure	Plastic made sprinkler								
Kg/cm²	**Wetted Area(s) (cm²)**	**Wetted Area(s) (m²)**	**Mean d(mm)**	**Mean d(m) x10^{-3}**	**vol (m³)x 10^{-3}**	**Time (Min)**	**Time (hr)**	**Discharge m³/h x 10^{-3}**	**PR(mm/hr)**
1.0	12.60	1.260	4.30	43.0	0.05418	10	0.167	0.32440	257.46
1.5	24.60	2.460	6.78	67.8	0.16679	10	0.167	0.99870	405.97
2.0	38.80	3.880	8,77	87.7	0.34028	10	0.167	2.03760	525.15
2.5	55.42	5.542	10.61	106.1	0.58801	10	0.167	3.52100	635.33
3.0	75.44	7.544	12.30	123.0	0.92791	10	0.167	5.55630	736.52
3.5	105.70	10.570	12.72	127.2	1.34450	10	0.167	8.05080	761.67
4.0	145.29	14.529	13.37	133,7	1.94253	10	0.167	11.6320	800.61
4.5	181.48	18.148	16.46	164,6	2.98716	10	0.167	17.8870	985.62
5.0	211.32	21.132	16.94	169.4	3.57976	10	0.167	21.4360	1014.39

4.6 Distribution Pattern of Mini Sprinkler Head

The distribution pattern of the mini sprinklers water throw on the soil for both 8mm and 14mmsprinklers was found to be uniformly distributed. The contour plot of the distributionsarewidely space and at an equal interval, indicating a gentle slope. The p-values obtained from the ANOVA result for both 8mm and 14mm distribution pattern of sprinklers show p-values of 0.96615,0.99291 for 8mm plastic and iron and p-values of 0.997019,0.99097 for 14mm plastic and iron respectively. In both case, the p-values are higher than the alpha value of (0.05) used for the analysis. This distribution is not statistically significant.More so, the uniformitycoefficient (uc)of the system as evaluated usingChristiansen equation reveal 96.99%,97.9% plastic and iron for 8mm and 96.7%,97.2% plastic and iron for 14mm diameter nozzle respectively.

Table 4.10: Distribution Pattern of mini Sprinkler depth of water as influenced by operating pressure for 8mm ϕ Nozzle Size

Operating Pressures	**Plastic made Sprinkler**					**Iron made Sprinkler**				
kg/cm²	**dcc1 (mm)**	**dcc2 (mm)**	**dcc3 (mm)**	**dcc4 (mm)**	**Mean dcc (mm)**	**dcc5 (mm)**	**dcc6 (mm)**	**dcc7 (mm)**	**dcc8 (mm)**	**Mean dcc (mm)**
1.0	2.10	2.50	2.90	3.00	2.63	3.50	3.30	4.40	4.70	3.98
1.5	5.10	6.60	6.60	5.40	5.93	5.70	6.70	6.20	5.80	6.10
2.0	7.00	7.50	8.10	8.30	7.73	8.80	9.80	9.60	9.80	9.50
2.5	9.60	9.30	9.70	9.80	9.60	10.00	10.50	10.50	10.00	10.43
3.0	11.00	11.30	11.50	11.60	11.35	11.90	11.90	11.80	11.90	11.88
3.5	11.90	12.00	12.30	11.60	11.95	12.50	12.70	12.90	13.00	12.78
4.0	13.50	13.60	13.90	14.00	13.75	14.00	14.20	14.50	14.50	14.30
4.5	15.00	15.20	15.40	15.70	15.33	15.70	15.90	15.90	15.90	15.85
5.0	16.00	16.20	16.20	16.50	16.23	16.70	16.90	16.90	17.00	16.88
UC	96.99%					97.9%				

Table 4.11: ANOVA Result for 8mm Distribution pattern for Plastic Made

Group	Count	Sum	Average	Variance
dcc 1	9	91.2	10.1333	21.66
dcc 2	9	94.2	10.4666	19.59
dcc 3	9	86.6	9.6222	22.0919
dcc 4	9	95.9	10.6555	20.6352

Source of Variation	SS	Df	Ms	F	P – Value	F – Critical
Between Group	5.5386	3	1.8462	0.08793	0.96615	2.9011
Within Group	671.817	32	20.9943			
Total	677.3564	35				

Table 4.12: ANOVA Result for 8mm Distribution pattern for Iron Made

Group	Count	Sum	Average	Variance
dcc 1	9	97.93	10.88111	21.3125
dcc 2	9	101.9	11.3222	18.9119
dcc 3	9	102.7	111.41111	17.8261
dcc 4	9	102.6	11.4	18.1

Source of Variation	SS	Df	Ms	F	P – Value	F – Critical
Between Group	1.70729	3	0.5691	0.02989	0.99291	2.9011
Within Group	609.2041	32	19.0376			
Total	610.9911	35				

Table 4.13a: Coordinate of 8mm Plastic

X	Y	Depth
324856	1164990	2.63
324899	1164912	5.93
324978	1164956	7.73
324992	1164868	9.60
325122	1164845	11.35
325162	1164989	11.95
325122	1164845	13.75
325161	1164734	15.33
325003	1164746	16.23

Table 4.13b: Coordinate of 8mm Iron

X	Y	Depth
324856	1164990	3.98
324899	1164912	6.10
324978	1164956	9.50
324992	1164868	10.43
325122	1164845	11.88
325162	1164989	12.78
325122	1164845	14.30
325161	1164734	15.85
325003	1164746	16.88

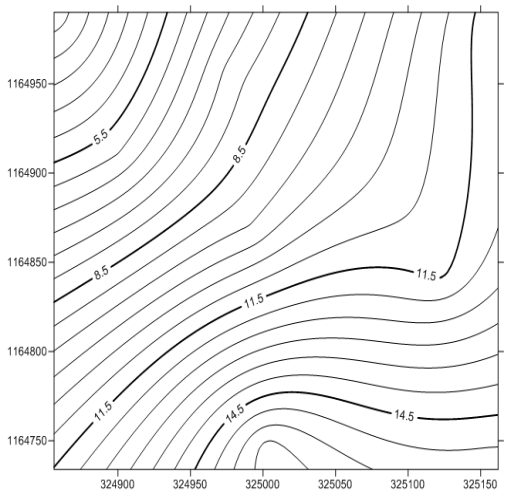


Fig. 4.4ai: Contour graph of 8mm Plastic

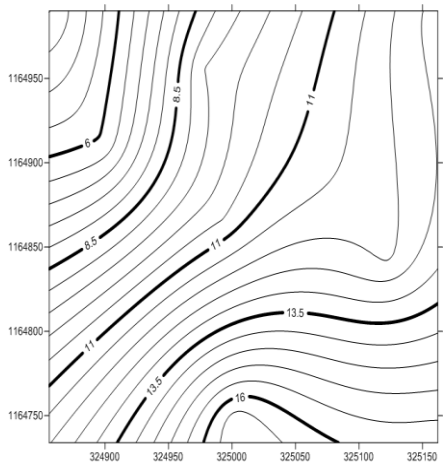


Fig. 4.4aii:C

Table 4.14: Distribution Pattern of mini sprinkler depth of water as influenced by operating pressure for 14mm ϕ Nozzle Size

Operating Pressures	Plastic made Sprinkler					Iron made Sprinkler				
kg/cm²	dcc1	dcc2	dcc3	dcc4	Mean dcc	dcc5	dcc6	dcc7	dcc8	Mean dcc
1.0	2.90	4.80	4.70	4.80	4.30	4.90	5.47	4.90	5.70	5.24
1.5	6.30	6.40	7.15	7.26	6.78	8.65	9.50	9.42	9.00	9.14
2.0	8.20	8.39	8.89	9.60	8.77	9.00	11.35	11.60	11.35	10.83
2.5	10.90	10.80	10.76	9.98	10.61	11.00	11.60	12.00	12.00	11.65
3.0	12.20	11.96	12.85	12.20	12.30	12.70	12.86	12.90	12.90	12.84
3.5	12.35	12.86	12.86	12.79.	12.72	13.40	13.10	13.07	13.07	13.16
4.0	14.30	13.20	13.90	13.50	13.37	15.40	16.60	16.90	16.80	16.43
4.5	16.76	16.25	16.81	16.00	16.46	17.25	17.10	17.80	17.68	17.46
5.0	17.00	16.90	16.95	16.92	16.94	21.30	20.00	20.50	20.70	20.63
UC	96.7%					97.2%				

Table 4.15: ANOVA table for 14mm Distribution pattern for Plastic Made

Group	Count	Sum	Average	Variance
dcc 1	9	100.91	11.2122	22.3093
dcc 2	9	102.17	11.3522	17.9644
dcc 3	9	104.85	11.65	17.4496

dcc 4	9	103.05	11.45	15.5683

ANOVA Result

Source of Variation	**SS**	**Df**	**Ms**	**F**	**P – Value**	**F – Critical**
Between Group	0.91354	3	0.30451	0.016619	0.997019	2.901112
Within Group	586.3329	32	18.3229			
Total	587.24645	35				

Table 4.16: ANOVA Result for 14mm Distribution pattern for Iron Made

Group	**Count**	**Sum**	**Average**	**Variance**
dcc 1	9	113.6	12.6222	24.5263
dcc 2	9	117.58	13.0644	19.0495
dcc 3	9	119.09	13.2322	21.92699
dcc 4	9	119.2	13.2444	21.01525

Source of Variation	**SS**	**Df**	**Ms**	**F**	**P – Value**	**F – Critical**
Between Group	2.28491	3	0.76164	0.035213	0.99097	2.901119
Within Group	692.1442	32	21.62951			
Total	694.42908	35				

Table 4.17a: Coordinate of 14mm PlasticTable 4.17b: Coordinate of 14mm Iron

X	Y	Depth
324856	1164990	4.30
324899	1164912	6.78
324978	1164956	8.77
324992	1164868	10.61

325122	1164845	12.30
325162	1164989	12.72
325122	1164845	13.73
325161	1164734	16.46
325003	1164746	16.94

X	Y	Depth
324856	1164990	5.24
324899	1164912	9.14
324978	1164956	10.83
324992	1164868	11.65
325122	1164845	12.84
325162	1164989	13.16
325122	1164845	16.43
325161	1164734	17.46
325003	1164746	20.63

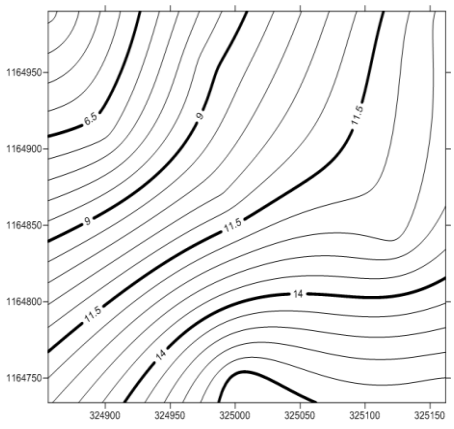


Fig. 4.4bi:Contour graph of 14mm Plastic

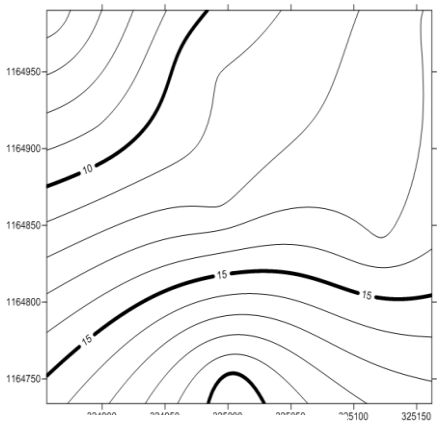


Fig. 4.4bii:Con

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Summary

Basically, the investigation in this research is valid for both plastic and iron made mini-sprinkler irrigation system, the performance discharges, and radius of throw for 14mm diameter iron and plastic mini sprinkler systems operated at 1.0- 5.0 kg /cm^2 pressure are 8.4- 40L/min and 2.4-14.5cm respectively for iron and 9.4-52.6L/min and 1.8-8.2cm respectively.

A pressure discharge relationship developed for the parameters using linear model gives a 0.9977,0.9257 discharge coefficient of the system. The slopes were obtained as 0.8466, 0.8361 and the regression coefficient (r^2) values were obtained to be 0.9096, 0.9438 for 14mm plastic and iron respectively.

The minimum radius of throw and the wetted area is 2.6cm and 21.24cm^2,andthe maximum is 11.0cm and 380.18cm^2 for 8mm iron, min radius and area is 2.4cm and 18.09cm^2 and max is 14.5cm and 660.61$cm^2$for 14mm iron. Similarly, for 8mm plastic, min radius and wetted area is 1.8cm and 10.18cm^2 and max radius and wetted area is 8.2cm and 211.32cm^2. and, for 14mm plastic, min radius and areas is 2.0cm and 12.26cm^2 and max radius and area is 8.2cm and 211.32cm^2.The maximum and minimum application rate were obtained to be 157.47mm/hr and 971.95mm/hr, For 8mm iron,238.32mm/hrand 1010.77mm/hr. for 14mm plastic,257.46mm/hr and 10.14.39mm/hr. For 14mm iron, 313.76mm/hr and 1235.3mm/hr. (See table 4.7-4.10). As the operating pressure increases from 1.0 to 5.0 $kgcm^{-2}$, the average precipitation rate of single mini sprinkler head increases for all nozzle. It is also seen that as the nozzle size increase, the precipitation rate increases.

More so, the uniformity coefficient (Uc) for 8mm diameter plastic and iron is 96.9% and 97.9% respectively for 14mm diameter Uc is 96.7% and 97.2%.

This reveals that both systems evenly distribute water effectively and with high correlation to its operating pressure.

5.2 Conclusion

The study area is covered by the ferruginous tropical soils considered to be the zonal soils development under the prevailing climatic conditions. They are highly weathered and marked laterised by the loss of silica. The resulting free metal oxides from the high proportion of clay fraction often coat the quartz and crystalline clay particles of kaolimite. They may be classified as cambisols.

The bulk density of the surface soil varies from 1.27-1.35g /cm^3.Thewater holding capacity (moisture retention) is good and the basic infiltrationrate of the soil is 5.63cm/hr(see table 4.1).

For agricultural purpose, the soil may be described as sandy clay loam. It is suitable for cereal, especially maize and millet production. The land treatment may be described as straight row farming that is a type of farming where ploughing, planting, cultivation and other farm operations are carried out without regards to the slope of the land (Chow 1964).

The inferences drawn from the study reveals that both systems evenly distribute water effectively with high efficiencies to its operating pressure. Increase in operating pressure, increases the discharges, radius of throw, and precipitation rate of the system.

The system discharges better water applicability with wider water spread / coverage on farm lands irrespective of the slope of the land. Sprinklers should be encouraged by the

government, to be used by small scale farmers. The mass irrigation method which waste lots of water and washes away the top soil in most cases (erosion) should be discouraged.

If sprinkler usage is encouraged in the country, the notion of water conservation from agricultural usage will be born. The ideal that crops could do well with limited quantity of water will be ensured in the minds of the small scale farmer. The recurring problems of bringing the water from source to distribute uniformly on farms will be restored, and the commonest problems of competition for water especially among neighbouring irrigators sharing same water source which is often settled politically, militarily, and diplomatically will be arrested technically through sprinkler systems. This could become a national policy.

5.3 Recommendations

From the investigation, the tables of value show that the iron made mini-sprinkler has the largest discharge for both 8mm diameter and 14mm diameter nozzle sizes used in the investigation; a wider radius of throw and a high precipitation rate. Iron made sprinkler is thereby recommended for heavy irrigation works involving large areas of coverage with extremely heavy soils with intake rates moderate.

- Similarly, the plastic made sprinkler is thereby recommended for light irrigation work involving crops with restricted roots systems such as lettuce, sugar beef, potato, vegetables etc. plantation and to produce uniformity of application since little or no wind will act against its performance.
- Mini sprinklers can be applicable to all slope type either gentle or undulating, the use of this system should be encouraged, and use by our local farmers. This will continue to save their time, scarce water in water prone area,and labor.

- Mini sprinkler system could be encouraging in gully, undulating hills and engulfed areas.

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APPENDICES

APPENDIX I

Pressure Vs Discharge Values for 14mm ϕ Nozzle size

Operating Pressure (kg/cm²)	Time taken to fill 20L Bucket in (s) using plastic made sprinkler with 14mm diameter nozzle	Mean Time in minutes	Discharges L/min	Time taken to fill 20L Bucket in (s) using iron made sprinkler with 14mm diameter nozzle	Mean Time in minutes	Discharges in L/Mins.
(H)	**Mean**	**Mean**	**(Q)**	**Mean**	**Mean**	**(Q)**
1.0	107	1.80	11.1	134	2.23	8.90
1.5	84	1.40	14.3	90	1.65	12.10
2.0	67	1.12	17.9	76	1.27	15.80
2.5	60	1.00	20.0	70	1.17	17.10
3.0	56	0.93	21.5	63	1.05	19.00
3.5	48	0.80	25.0	59	0.98	20.40
4.0	41	0.70	29.4	47	0.78	25.60
4.5	33	0.60	36.7	39	0.65	30.80
5.0	23	0.40	52.6	30	0.50	40.00

APPENDIX II

Pressure Vs Discharge Values for 8mm Φ Nozzle size.

Operating Pressure (kg/cm²)	Time taken to fill 20L Bucket in (s) using plastic made sprinkler with 8mm diameter nozzle	Mean Time in minutes	Discharges L/min	Time taken to fill 20L Bucket in (s) using iron made sprinkler with 8mm diameter nozzle	Mean Time in minutes	Discharges in L/Mins.
(H)	**Mean**	**Mean**	**(Q)**	**Mean**	**Mean**	**(Q)**
1.0	132	2.20	9.1	142	2.37	8.40
1.5	122	2.03	8.7	136	2.27	8.80
2.0	81	1.35	14.8	104	1.73	11.6
2.5	62	1.03	19.4	92	1.53	13.10
3.0	56	0.93	21.5	73	1.22	16.40
3.5	50	0.80	24.1	55	0.92	21.70
4.0	40	0.70	29.9	44	0.73	27.40
4.5	37	0.60	32.3	38	0.63	31.80
5.0	29	0.50	41.7	31	0.52	38.50

APPENDIX III

Radius of throw for mini sprinkler nozzles and respective wetted Area as influenced by operating pressure

Operating pressure	**Radius of throw (cm) And respective Wetted Area(cm^2)**			
Kg/cm^2	**Iron made sprinkler with 14mm ϕ nozzle size**	**Wetted Area for 14mm ϕ**	**Plastic made sprinkler with 14mm ϕ nozzle size**	**Wetted Area for 14mm ϕ**
1.0	2.4	18.09	2.0	12.26
1.5	4.3	58.09	2.8	24.60
2.0	5.9	109.37	3.5	38.80
2.5	8.7	237.82	4.2	55.42
3.0	9.8	301.76	4.9	75.44
3.5	10.8	366.45	5.8	105.70
4.0	11.7	430.11	6.8	145.29
4.5	13.0	530.99	7.6	181.48
5.0	14.5	660.61	8.2	211.32

APPENDIX IV

Radius of throw for mini sprinkler nozzles and respective wetted Area as influenced by operating pressure.

Operating pressure	**Radius of throw (m) And respective Wetted Area(cm^2)**			
Kg/cm^2	**Iron made sprinkler with 8mmϕ nozzle size.**	**Wetted Area for 8mmϕ**	**Plastic made sprinkler with 8mmϕ nozzle size**	**Wetted Area for 8mmϕ**
1.0	2.6	21.24	1.8	10.18
1.5	5.5	95.05	2.6	21.24
2.0	7.6	181.48	3.0	28.28
2.5	8.4	221.70	3.7	43.01
3.0	9.3	271.75	4.5	63.63
3.5	9.7	295.63	5.2	84.96
4.0	10.1	317.35	5.9	109.37
4.5	10.6	353.04	6.4	128.70
5.0	11.0	380.18	7.2	162.88

APPENDIX V

Precipitation rate for mini sprinkler as influenced by operating pressure with 8mm nozzle sizes

Operating Pressure	Iron made sprinkler								
Kg/cm²	**Wetted Area(s) (cm²)**	**Wetted Area(s) (m^2) x 10^{-3}**	**Mean d(mm)**	**Mean d (m) x10^{-3}**	**Vol (m^3) x 10^{-3}**	**Time (Min)**	**Time (hr)**	**Discharge m^3/h x 10^{-3}**	**PR(mm/hr)**
1.0	21.24	2.124	3.98	39.80	0.08454	10	0.167	0.50622	238.32
1.5	95.05	9.505	6.10	61.00	0.57981	10	0.167	3.47180	365.30
2.0	181.48	18.148	9.50	95.00	1.72406	10	0.167	10.32370	568.86
2.5	212.70	22.170	10.45	104.30	2.31230	10	0.167	13.84610	624.50
3.0	271.75	27.175	11.88	118.80	3.22840	10	0.167	19.33170	711.38
3.5	295.63	29.563	12.78	127.80	3.77820	10	0.167	22.62400	765.28
4.0	317.35	31.735	14.30	143.00	4.53810	10	0.167	27.17430	856.29
4.5	353.04	35.304	15.85	158.50	5.59560	10	0.167	33.50660	949.09
5.0	380.18	38.018	16.88	168.80	6.41740	10	0.167	38.42750	1010.77

APPENDIX VI

Precipitation rate for mini sprinkler as influenced by operating pressure with 8mm Nozzle ϕ Values

Operating Pressure	Plastic made Sprinkler								
Kg/cm²	**Wetted Area(s) (cm²)**	**Wetted Area(s) (m^2) x 10^{-3}**	**Mean d (mm)**	**Mean d (m)**	**Vol (m^3) x 10^{-3}**	**Time (Min)**	**Time (hr)**	**Discharge m^3/h x 10^{-3}**	**PR(mm/hr)**
1.0	10.18	1.018	2.63	26.30	0.02677	10	0.167	0.16030	157.47
1.5	21.24	2.124	5.93	59.30	0.12595	10	0.167	0.75420	355.08
2.0	28.28	2.828	7.73	77.30	0.21860	10	0.167	1.30898	462.86
2.5	43.01	4.301	9.60	96.00	0.41289	10	0.167	2.47200	574.75
3.0	63.63	6.363	11.35	113.5	0.72220	10	0.167	4.32450	679.60
3.5	84.96	8.496	11.95	119.5	1.01527	10	0.167	6.07950	715.57
4.0	109.37	10.937	13.75	137.5	1.50384	10	0.167	9.00500	823.35
4.5	208.70	12.870	15.33	153.3	1.97297	10	0.167	11.81420	917.96
5.0	162.88	16.288	16.23	162.3	2.64380	10	0.167	15.83110	971.95

APPENDIX VII

precipitation rate for mini sprinkler as influenced by operating pressure with for 14mm ϕ Nozzle Values

Operating Pressure	Plastic made sprinkler								
Kg/cm²	**Wetted Area(s) (cm²)**	**Wetted Area(s) (m²)**	**Mean Vcc (ml)**	**Mean Vcc (L)**	**Mean Vcc (m³)**	**Time (Min)**	**Time (hr)**	**Discharge m³/h**	**PR(mm/hr)**
1.0	12.60	1.260	313.3	0.313	3.133	10	0.167	1.8761	1488.9
1.5	24.60	2.460	491.0	0.491	4.910	10	0.167	2.9401	1195.5
2.0	38.80	3.880	637.5	0.638	6.375	10	0.167	3.8174	983.9
2.5	55.42	5.542	855.8	0.856	8.558	10	0.167	5.1246	924.7
3.0	75.44	7.544	1072.5	1.073	10.725	10	0.167	6.4222	851.3
3.5	105.70	10.570	1146.8	1.147	11.468	10	0.167	6.8671	649.7
4.0	145.29	14.529	1485.0	1.485	14.850	10	0.167	8.8922	612.0
4.5	181.48	18.148	2295.0	2.295	22.950	10	0.167	13.7425	757.2
5.0	211.32	21.132	2655.0	2.655	26.550	10	0.167	15.8982	752.3

APPENDIX VIII

Precipitation rate for mini sprinkler as influenced by operating pressure with 14mm Φ Nozzle Values

Operating Pressure	Iron made sprinkler								
Kg/cm²	**Wetted Area(s) (cm²)**	**Wetted Area(s) (m²)**	**Mean d (mm)**	**Mean d (m) x10^{-3}**	**Vol (m^3)x 10^{-3}**	**Time (Min)**	**Time (hr)**	**Discharge m³/h**	**PR(mm/hr)**
1.0	18.09	1.809	5.24	52.40	0.09479	10	0.167	0.56760	313.76
1.5	58.09	5.809	9.14	91.40	0.53094	10	0.167	3.17930	547.31
2.0	109.37	10.937	10,83	108.30	1.18448	10	0.167	7.09270	648.51
2.5	237.82	23.782	11.65	116.50	2.77060	10	0.167	16.59040	697.60
3.0	301.76	30.176	12.84	128.40	3.87459	10	0.167	23.20110	768.86
3.5	366.48	36.648	13.16	131.60	4.82290	10	0.167	28.87960	788.03
4.0	430.11	43.011	16.43	164.30	7.06670	10	0.167	42.31560	983.83
4.5	530.99	53.099	17.46	174.60	9.27109	10	0.167	55.51550	1045.51
5.0	660.61	66.061	20.63	206.30	13.62840	10	0.167	81.60720	1235.30

APPENDIX IX

Precipitation rate for mini sprinkler as influenced by operating pressure with for 14mm ϕ Nozzle Values

Operating Pressure	Plastic made sprinkler								
Kg/cm²	**Wetted Area(s) (cm²)**	**Wetted Area(s) (m²)**	**Mean d(mm)**	**Mean d(m) x10^{-3}**	**vol (m³)x 10^{-3}**	**Time (Min)**	**Time (hr)**	**Discharge m³/h x 10^{-3}**	**PR(mm/hr)**
1.0	12.60	1.260	4.30	43.0	0.05418	10	0.167	0.32440	257.46
1.5	24.60	2.460	6.78	67.8	0.16679	10	0.167	0.99870	405.97
2.0	38.80	3.880	8,77	87.7	0.34028	10	0.167	2.03760	525.15
2.5	55.42	5.542	10.61	106.1	0.58801	10	0.167	3.52100	635.33
3.0	75.44	7.544	12.30	123.0	0.92791	10	0.167	5.55630	736.52
3.5	105.70	10.570	12.72	127.2	1.34450	10	0.167	8.05080	761.67
4.0	145.29	14.529	13.37	133,7	1.94253	10	0.167	11.6320	800.61
4.5	181.48	18.148	16.46	164,6	2.98716	10	0.167	17.8870	985.62
5.0	211.32	21.132	16.94	169.4	3.57976	10	0.167	21.4360	1014.39

APPENDIX X

Distribution Pattern of mini Sprinkler depth of water as influenced by operating pressure for 8mm ϕ Nozzle Size

Operating Pressures	**Plastic made Sprinkler**					**Iron made Sprinkler**				
kg/cm²	**dcc1 (mm)**	**dcc2 (mm)**	**dcc3 (mm)**	**dcc4 (mm)**	**Mean dcc (mm)**	**dcc5 (mm)**	**dcc6 (mm)**	**dcc7 (mm)**	**dcc8 (mm)**	**Mean dcc (mm)**
1.0	2.10	2.50	2.90	3.00	2.63	3.50	3.30	4.40	4.70	3.98
1.5	5.10	6.60	6.60	5.40	5.93	5.70	6.70	6.20	5.80	6.10
2.0	7.00	7.50	8.10	8.30	7.73	8.80	9.80	9.60	9.80	9.50
2.5	9.60	9.30	9.70	9.80	9.60	10.00	10.50	10.50	10.00	10.43
3.0	11.00	11.30	11.50	11.60	11.35	11.90	11.90	11.80	11.90	11.88
3.5	11.90	12.00	12.30	11.60	11.95	12.50	12.70	12.90	13.00	12.78
4.0	13.50	13.60	13.90	14.00	13.75	14.00	14.20	14.50	14.50	14.30
4.5	15.00	15.20	15.40	15.70	15.33	15.70	15.90	15.90	15.90	15.85
5.0	16.00	16.20	16.20	16.50	16.23	16.70	16.90	16.90	17.00	16.88
UC	96.99%					97.9%				

APPENDIX XI

Distribution Pattern of mini sprinkler depth of water as influenced by operating pressure for 14mm ϕ Nozzle Size

Operating Pressures	Plastic made Sprinkler					Iron made Sprinkler				
kg/cm²	dcc1	dcc2	dcc3	dcc4	Mean dcc	dcc5	dcc6	dcc7	dcc8	Mean dcc
1.0	2.90	4.80	4.70	4.80	4.30	4.90	5.47	4.90	5.70	5.24
1.5	6.30	6.40	7.15	7.26	6.78	8.65	9.50	9.42	9.00	9.14
2.0	8.20	8.39	8.89	9.60	8.77	9.00	11.35	11.60	11.35	10.83
2.5	10.90	10.80	10.76	9.98	10.61	11.00	11.60	12.00	12.00	11.65
3.0	12.20	11.96	12.85	12.20	12.30	12.70	12.86	12.90	12.90	12.84
3.5	12.35	12.86	12.86	12.79.	12.72	13.40	13.10	13.07	13.07	13.16
4.0	14.30	13.20	13.90	13.50	13.37	15.40	16.60	16.90	16.80	16.43
4.5	16.76	16.25	16.81	16.00	16.46	17.25	17.10	17.80	17.68	17.46
5.0	17.00	16.90	16.95	16.92	16.94	21.30	20.00	20.50	20.70	20.63
UC	96.7%					97.2%				

APPENDIX XII

Coordinate of 8mm Plastic

X	Y	Depth
324856	1164990	2.63
324899	1164912	5.93
324978	1164956	7.73
324992	1164868	9.60
325122	1164845	11.35
325162	1164989	11.95
325122	1164845	13.75
325161	1164734	15.33
325003	1164746	16.23

Coordinate of 8mm Iron

X	Y	Depth
324856	1164990	3.98
324899	1164912	6.10
324978	1164956	9.50
324992	1164868	10.43
325122	1164845	11.88
325162	1164989	12.78
325122	1164845	14.30
325161	1164734	15.85
325003	1164746	16.88

APPENDIX XIII

Coordinate of 14mm Plastic

X	Y	Depth
324856	1164990	4.30
324899	1164912	6.78
324978	1164956	8.77
324992	1164868	10.61
325122	1164845	12.30
325162	1164989	12.72
325122	1164845	13.73
325161	1164734	16.46
325003	1164746	16.94

Coordinate of 14mm Iron

X	Y	Depth
324856	1164990	5.24
324899	1164912	9.14
324978	1164956	10.83
324992	1164868	11.65
325122	1164845	12.84
325162	1164989	13.16
325122	1164845	16.43
325161	1164734	17.46
325003	1164746	20.63