DEVELOPMENT OF A DRIP IRRIGATION SYSTEM FOR A SMALL SCALE FARMING SYSTEM

ORISABINONE, Toluwalase

ABE/12/0820

SUBMITTED TO

DEPARTMENT OF AGRICULTURAL AND BIORESOURCES ENGINEERING,
THE FEDERAL UNIVERSITY OYE, OYE-EKITI,
EKITI STATE, NIGERIA.

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF
BACHELOR OF ENGINEERING (B.Eng.) IN AGRICULTURAL AND
BIORESOURCES ENGINEERING

NOVEMBER, 2017

DEVELOPMENT OF A DRIP IRRIGATION SYSTEM FOR A SMALL SCALE FARMING SYSTEM

ORISABINONE, Toluwalase.
ABE/12/0820

DEPARTMENT OF AGRICULTURAL AND BIORESOURCES ENGINEERING,
FEDERAL UNIVERSITY OYE, OYE-EKITI,
EKITI STATE, NIGERIA.

NOVEMBER, 2017

DECLEARATION OF ORIGINALITY

This project is all my own work and has not been copied in part or in whole from any other source except where duly acknowledged. As such, all use of previously published work (from books, journals, magazines, newspapers and the internet) has been acknowledged within the main report to an entry in the references list.

I understand that cheating and plagiarism constitute breach of the university regulations and will be dealt with accordingly.

Copyright

ORISABIMONE TOLUWALASE

Signed:

Date: 13/12/2017

Office Stamp

CERTIFICATION

This is to certify that this project entitled **"Development of a drip irrigation system for small scale farming system"** was carried out by Orisabinone Toluwalase submitted in partial fulfillment of the requirements for the award of the degree of Bachelor of Agricultural and Bioresources Engineering of Federal University Oye-Ekiti, during the academic year 2012-2017.

Dr. Omofunmi Olorunwa Eric ……………………… 13/12/17
(Supervisor) Signature Date

Engr. Ilesanmi Oluwaseun ……………………… 13/12/2017
(Co. Supervisor) Signature Date

Engr. Professor K. J. Simonyan **Date** 30/11/17
(External Examiner)

DEDICATION

I dedicate this project to God Almighty who saw me through the course of the project actions, which without him it would have not been a success

ACKNOWLEDGEMENTS

First of all, I will like to give thanks to God who kept me in His infinite mercies and helped me during the course of my project.

Special thanks to Dr. Omofunmi Olorunwa Eric and Engr. Ilesanmi Oluwaseun, my project supervisors and co-project supervisors and also Engr. Falodun, for overseeing and coordinating the project, as it would not have been a success without their support, guidance and fatherly advice. Their constructive scrutiny and criticisms were really helpful throughout the course of the project.

My acknowledgment also goes to my HOD Dr, Engr. A.O Olaniyan for his fatherly advice and support throughout my stay in the school and also to Agricultural and Bioresources departmental lectures and technologist including the non-academic staffs for training me and equipping me for the future at hand.

Finally my acknowledgement would not be complete without the mention of the contribution of my parents, Mr. and Mrs Segun Orisabinone, my siblings and friends, for the motivation, support and encouragement. I am really grateful. I also acknowledge my school mates and friends for their support and assistance given to me during the period of my project and stay in school

ABSTRACT

Water conservation and food security are some of the problems facing developing countries. The challenges of water conservation could be tackled by adopting the drip irrigation method. The drip irrigation system is an irrigation system that involves the artificial application of water to the base or root zone of plants in a controlled slow frequent and steady manner. This study was developed drip irrigation system for rural farmer on a small sale plot of an area of 7m X 5m with a water source of head tank which was filled up by use of water hose from a tank to the reservoir. The emitters were improvised using the hospital flow drip device. The performance evaluation was determined using volumetric measurements. The results showed that the distribution uniformity and application rate were 1.04 and 17 mm/hr respectively. The cost of the constructing the drip irrigation system was =N=37,350. The performance indicates that no maintenance is required. Hence, the equipment is thereby recommended for small holding farmers

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

Gravimetric water content	(θg)
Volumetric water content	(θv)
Density	ρ
Lowest quartile	(Avg_{LQ})
Total average	Avg_T
Percentage	%
Meter square	m^2

CHAPTER ONE

INTRODUCTION

1.1 GENERAL INTRODUCTION

Agriculture accounts for about 70 – 80% use of available water in the world (Duhrkoop *et al.*, 2009). However, dwindling water availability has made it necessary to improve on the way water is used in Agriculture, in order to make water available to farmers throughout the season to ensure food security. The increased competition for water among agricultural, industrial and domestic consumers creates the need for continuous improvements in techniques for judicious use of water in crop production. Efficient water use is becoming increasingly important and alternative water application methods such as drip and sprinkler irrigation may contribute substantially in making the best use of the scarce available water for crop production. (Asenso, 2011).

Irrigation is the artificial application of water to the soil or plant, in the required quantity and at the time needed, is a risk management tool for agricultural production. The risk of yield reduction due to drought is minimized with irrigation. Irrigation is widely carried out through surface, sub-surface and pressurized systems, characterized by the mode of transport of the water onto the point of application (Keller and Bliesner, 1990). When water is applied on the surface, a considerable amount is lost through evaporation, run off and deep percolation making it less efficient. Field application efficiency in most traditional irrigation methods is still very low, typically less than 50 % (sprinkler irrigation) and often as low as 30 % (surface irrigation) (Molden *et al.* 1998). Excessive application of water generally entails losses because of surface run-off from the field and deep percolation below the root zone within the field. Both run-off and deep percolation losses are difficult to control under furrow irrigation system, where a large volume of water is applied at a single instance. An alternative water application method such as the drip irrigation method allow for much more uniform distribution as well as more precise control of the amount of water applied and also decreases nutrient leaching (Asenso, 2011)

1.2 DRIP IRRIGATION

Drip irrigation is defined as "the slow, frequent application of small volumes of irrigation water to the base or root zone of plants" (Smeal, 2007). More widespread adoption of this technology in recent years began in the late 1960s to early 1970s. Drip irrigation also commonly referred to as micro-Irrigation, trickle irrigation, low volume irrigation or xerigation. This is a method of irrigation which efficiently delivers water to the soil surface or the root zone; this is done by having water drip slowly from emission devices, most commonly called "drip emitters"

Drip irrigation is quickly becoming the standard irrigation method for many applications such as home gardens and landscapes, greenhouses, vineyards, row crops and orchards. The technology and materials have seen some significant changes throughout the years, but the basic concepts have generally remained constant.

1.3 ADVANTAGES OF DRIP IRRIGATION SYSTEM

The advantages of the drip irrigation method are as follows:

- When water resources are scarce and costly, a much larger highly-targeted zone can be watered rather than covering the whole field with water.
- Because the watered zone is shadowed by the plant itself, evaporation is minimal and the consumption is lowered.
- The required moisture level in the root zone is maintained and the plant gets its water from the soil without using much energy. This is an important advantage that facilitates effective growth.
- Fertilizers can be used via the dripping system (where and when they are required), reducing the volume needed.
- The land between the plant rows remain dry and unwanted plant growth is prevented.
- The surface of the soil is dry which enables processing, medication, harvest and transfer work to be executed more easily and with minimal effort.
- Foliage remains dry, thus reducing the risk of disease. Moisture is spread through the root zone, contributing to properly aired soil.
- The output of each nozzle can be controlled with great efficiency, high water application efficiency and lower labor cost due to the automated system.

1.4 PROBLEM STATEMENT

The project has a goal/objective of developing and designing a drip irrigation system for a small scale farm. In this regard the use of high cost equipment are being left behind and the use of simple tools/equipment and lesser materials which will be affordable for small scale farmers are being used so as to ensure that a small scale farmer can still use the drip irrigation system. Small scale Farmers complaining of low conservation of water and flooding of their farm are meant to use the drip irrigation to solve this problem but due to the cause of the cost required, the feel reluctant to use this approach of irrigation. In response to this problem, this study proposes to investigate the drip system to make the small scale farmers able to use the drip system. It is planned to carry out method of reducing the cost of the equipment used for the drip equipment by selecting lesser but durable and last longing materials for the components of the drip system and also to determine the hydraulic parameters of the system as a whole.

1.5 OBJECTIVES OF DRIP IRRIGATION SYSTEM

1.5.1 General Objective

Using hospital flow drip as dripper or emitter to evaluate the performance of a drip irrigation system

1.5.2 Specific Objectives

- Construction of a Drip irrigation System using hospital flow drip
- Performance evaluation of a constructed Drip irrigation System using hydraulic parameters such as; distribution uniformity, emitter spacing, precipitation rate, clogging susceptibility,

1.6 JUSTIFICATION

The main motive if this project is to design an irrigation system that is capable of dripping water to the root zone of crops with respect to the crop and water requirement of the crop and also conserve water in the process also minimizing cost for small scale farmers

This is as result of the fact that not all farmers are financially buoyant and also there could be water erosion on the soil if the water is not properly metered to the required rate.

Therefore, it is required that an irrigation system is able to drip water where, when and amount needed and also conserve soil and conserve water at the same time. The goal of this system is to achieve a drip irrigation system for a small scale farm and conserve water hence resulting in better productivity

1.7 SCOPE OF WORK

This study is covered the construct a drip irrigation system and also determine the performance evaluation using hydraulic parameters such as distribution uniformity and application rate.

CHAPTER 2

LITERATURE REVIEW

2.1 PREAMBLE – WATER CONSERVATION

Water conservation includes all the policies, strategies and activities made to sustainably manage the natural resource fresh water, to protect the water environment, and to meet the current and future human demand. Population, household size, and growth and affluence all affect how much water is used. Factors such as climate change have increased pressures on natural water resources especially in manufacturing and agricultural irrigation (Defra, 2013). Many US cities have already implemented policies aimed at water conservation, with much success (US(EPA), 2013).

The goals of water conservation efforts include:

- Ensuring availability of water for future generations where the withdrawal of freshwater from an ecosystem does not exceed its natural replacement rate.
- Energy conservation as water pumping, delivery and wastewater treatment facilities consume a significant amount of energy. In some regions of the world over 15% of total electricity consumption is devoted to water management.
- Habitat conservation where minimizing human water use helps to preserve freshwater habitats for local wildlife and migrating waterfowl, but also water quality. (Hermoso, Abell, Linke, and Boon, 2016)

For crop irrigation, optimal water efficiency means minimizing losses due to evaporation, runoff or subsurface drainage while maximizing production. An evaporation pan in combination with specific crop correction factors can be used to determine how much water is needed to satisfy plant requirements. Flood irrigation, the oldest and most common type, is often very uneven in distribution, as parts of a field may receive excess water in order to deliver sufficient quantities to other parts. Overhead irrigation, using center-pivot or lateral-moving sprinklers, has the potential for a much more equal and controlled distribution pattern. Drip irrigation is the most expensive and least-used type, but offers the ability to deliver water to plant roots with minimal losses. However, drip irrigation is increasingly affordable, especially for the home gardener and in light of rising water rates. Using drip irrigation methods can save up to 30,000 gallons of water per year when replacing irrigation systems that spray in all directions. There are also cheap effective methods similar to drip irrigation such as the use of soaking hoses that can even be submerged in the growing medium to eliminate evaporation.

As changing irrigation systems can be a costly undertaking, conservation efforts often concentrate on maximizing the efficiency of the existing system. This may include chiseling compacted soils, creating furrow dikes to prevent runoff, and using soil moisture and rainfall sensors to optimize irrigation schedules (UNEP, 2011).Usually large gains in efficiency are possible through measurement and more effective management of the existing irrigation system. The 2011 UNEP Green Economy Report notes that "improved soil organic matter from the use of green manures, mulching, and recycling of crop residues and animal manure increases the water holding capacity of soils and their ability to absorb water during torrential rains", which is a way to optimize the use of rainfall and irrigation during dry periods in the season (UNEP, 2011)

2.2 DRIP IRRIGATION

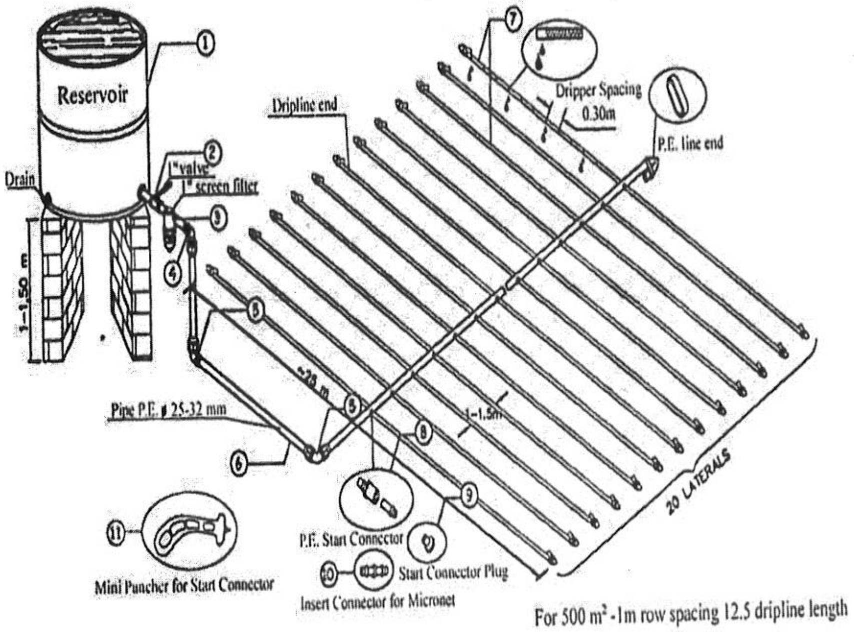
Drip irrigation is defined as "the slow, frequent application of small volumes of irrigation water to the base or root zone of plants" (Smeal, 2007).

Africa's regions with extensive periods of drought and inadequate rainfall contribute to the continent's food shortage problem. While nature cannot be controlled, society does have the ability to develop and practice more efficient water usage techniques in order to improve water supply management.

One type of technology that may contribute to the improvement of water supply management and the associated food crisis is drip irrigation. Drip irrigation systems (DIS) have discharge points or sufficiently small holes in sections of hose such that filtration is a primary concern (Burt and Styles, 1994). These systems commonly use low flow rates and low pressures at the emitters and are typically designed to only wet the root zone and maintain this zone at or near an optimum moisture level (James, 1988).

Hence, there is a potential to conserve water losses by not irrigating the whole field. Obvious advantages of drip irrigation include a smaller wetted surface area, minimal evaporation and weed growth, and potentially improved water application uniformity within the crop root zone by better control over the location and volume of water application (Hoffman and Martin, 1993). Drip systems are also commonly designed to include fertigation and automation capabilities. In recent years, low-pressure drip irrigation (LPDI) systems have been developed for smaller farming areas. For many subsistence farmers, a standard pressurized system is too expensive and complicated, as pressurized systems are intended for large areas of land, and therefore do not match the needs of small subsistence farming (Bustan, 2008. These systems are economical and fairly simple to use, thus they are appropriate for subsistence farming in rural areas of developing countries.

LPDI systems work with gravity-power and are low water pressure; there is no longer a need for operation by an outside power source, thus reducing the initial cost. With the bottom of the water reservoir sitting at 1-2 m above the ground, these systems can generate a flow of about 1 m^3/h (Phocaides, 2007). Dov Pasternak, a drip irrigation specialist from Israel, has combined the LPDI system with an appropriate crop mix to create the African Market Garden (AMG), but for this design the bottom was set at a height of 0.80 m above ground. The AMG generates revenue for small farmers and has been implemented in West African countries such as Senegal, Ghana and Niger.



Source: Bustan, 2008

Figure 2.1 LPDI System

A major benefit of drip is the ability to apply small amounts of water at high frequency intervals. This provides the opportunity to maintain the soil moisture at a specified moisture content and changes the focus of irrigation scheduling away from "irrigating at a frequency which does not affect output quantity/quality" to "irrigating on a schedule which maximizes output quality/quantity". This change in emphasis may produce benefits depending on the specific crop response to moisture stress. However, where the crop is relatively insensitive to moisture stress and when the available moisture content is high the benefits of more frequent irrigation are likely to be minor if present at all.

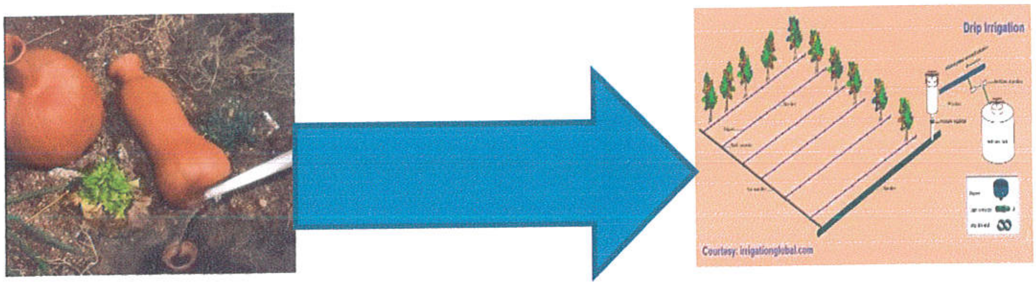
Hence, many researchers (Hanson and Patterson, 1974; Wendt et al., 1977; Bucks et al., 1981) have found that drip irrigation does not increase yield compared to other application systems where both the volume and timing of the water applied for evapotranspiration is non-limiting. Drip systems provide not only the potential to irrigate more frequently but also the ability to more readily maintain specific moisture deficits at a level below field capacity either for part or all of the irrigation season. Irrigating to maintain a specified root zone soil moisture deficit provides the opportunity for increased soil moisture storage from rainfall during the irrigation season.

The potential water application efficiency of drip irrigation systems is often quoted as greater than 90% (Golberg et al., 1976; Hoffman et al., 1990; Keller and Karmeli, 1975; Jensen, 1983). However, as with all irrigation systems, the ability to achieve high levels of efficiency is a function of the design, installation and management practices. Losses of water in drip irrigation systems principally occur through evaporation from the soil surface, surface run-off and deep drainage. Evaporation losses are generally small in subsurface irrigated systems due to a limited wetted surface area. Run-off losses are also normally small due to the low application rates. However, excessive watering periods and the use of shallow subsurface drip on low infiltration soils (e.g. Sodic soils) can result in appreciable tunneling of flows to the surface creating surface ponding and the potential for localized run-off.

2.2.1 History of Drip irrigation System

Early forms of drip irrigation can be tracked back to ancient times where clay pots were filled with water and then buried in the ground, this allowed the water to gradually leak out and into the root zone of nearby vegetation. The first formal development of drip irrigation supplies began around 1866 in Afghanistan, where they tested the drip irrigation and drainage system by using various type of clay pipe. A researcher at Colorado State University, Mr. E.B House, began applying subsurface water directly to the root zone in 1913. Perforated pipe was first used for irrigation in Germany around 1920

After World War II (WWII), the ability to mold plastic became widespread and more cost effective. This helped pave way for innovations in the manufacturing of drip irrigation system components. At this time, polyethylene (PE) tubing, also referred to as "micro tubing" or "spaghetti tubing", and early versions of emitters(drippers), became more common and began to be installed throughout the US and Europe



Source: Depot, 2017

Figure 2.2 Stages of development of the drip system

In Israel, Simcha Blass and Yeshayahu Blass were innovating in the area of emitter design. They created a method that allowed water to flow through longer and wider passageways inside of the emitter. These labyrinths as they were called, resulted in less clogging. The velocity of water moving through labyrinths, and resulting turbulence, helps to slow it down, creating a “drip”. In 1959 Kibbutz Harzerim partnered with Blass to form a company called Netafim, to further develop and test this concept. Netafim was then able to patent the first irrigation rapidly expand to Australia, North America and South America in late 60’s.

Drip irrigation options have also expanded to include compatible devices such as micro-sprayers, bubblers and misters, which deliver water in a different manner than drip emitters. These emitters with a wider water dispersion are generally used on plants and ground cover with wider root zones. Subsurface drip irrigation (SDI) uses permanently or temporarily buried dripline or drip tape located at or below the plant roots. This type of drip irrigation tubing has emitters embedded within the tubing spaced evenly apart. It is becoming popular for row crop irrigation, especially in areas where water supplies are limited or recycled water is used for irrigation. Careful study of all the relevant factors like land topography, type of soil, water supply characteristics, crop and climate conditions is needed to determine the most suitable drip irrigation system and components to be used in a specific installation. (Depot, 2017)

Modern drip irrigation has arguably become the world's most valued innovation in agriculture since the invention of the impact sprinkler in the 1930s, which offered the first practical alternative to surface irrigation. Crops are now growing in desert climates which would not have been feasible without drip irrigation. Water conservation efforts in some regions of the world susceptible to drought have incorporated drip irrigation as the primary method of watering crops. Crop yields in virtually all environments have significantly increased while utilizing less water due to drip irrigation technology.

Dr. Daniel Hillel, a research scientist at Columbia University's Earth Institute, was recently named the 2012 recipient of the World Food Prize honoring "individuals who have advanced human development by improving the quality, quantity or availability of food in the world." He has worked in Turkey, Pakistan, Sudan and other Middle Eastern countries to spread drip irrigation technology to all who could benefit from it. Described as the "Father of Sustainable Water Management", he promoted agricultural development which does not rely on industry for fuel, pesticides to control pests and chemicals to increase soil fertility. (Hillel, 2004)

Drip irrigation is still evolving, and advancements are still being made in materials and techniques. Growers are increasingly becoming aware of how precious water is as a resource, how its efficient usage and management can assist agriculture, and how drip irrigation technology can positively affect society as a whole. Drip irrigation has truly become, and will continue to be, a benefit to us all. (Depot, 2017)

2.2.2 Performance Evaluation of a drip irrigation system

The performance of drip irrigation systems is heavily influenced by the uniformity of flow through each emitter along a drip line. However, unlike other systems, the uniformity of drip irrigation systems is not only a function of the design characteristics but is also significantly affected by installation, maintenance and management practices.

Therefore, measuring application uniformity in drip irrigation systems is an important component of performance evaluation and the assessment of the likely system longevity (Sadler et al., 1995).

Discharge uniformity may be assessed by measuring discharge from a number of emitters using a catch can methodology. For subsurface systems, this involves excavating the soil around the emitter and collecting the water quantity discharged (Sadler et al., 1995). Pressure may be measured at the flush point or end of the lateral using a standard pressure gauge or at specific points along the lateral using a needle point pressure gauge inserted directly through the tape or tube. Where an assumption of no plugging can be made, the models used for the design and evaluation of drip irrigation systems may also be used to evaluate the application uniformity of subsurface systems based on the measured pressures and the system design characteristics (Phene et al., 1992; Feng and Wu, 1990; Wu and Yue, 1991; Wu, 1992). Root zone recharge may be measured directly using soil moisture sensors, such as tensiometer, gypsum block and capacitance probe. In this case, sensors should be placed in vertical grid pattern along a radial axis from the emitter to measure both lateral and vertical soil water movement.

Soil moisture sensing is also commonly used to identify deep drainage losses and variations in wetted pattern due to application rate and period of watering (Or, 1995).A wide range of irrigation uniformity coefficient is commonly used in performance evaluation (Jensen 1983). Camp et al. (1997) evaluated the appropriateness of various uniformity coefficients for drip irrigation systems including the traditional Christiansen (1942) equation as used by a number of workers. Acceptable flow rate 10 – 20 % (Qvar), uniformity coefficient (UC) should be greater than 90% and coefficient of variation (CV) between 1-20%. (Bralts et al.1987).

2.2.3 Types of drip irrigation system

There are various types of drip irrigation systems. Some of them make use of small sprinkler parts to drip water to small types of areas while some of the systems utilize flexible tubing to drip water on the bottom of the plants (Doityourself, 2017). Some of them are:

2.2.3.1 Porous Soaker Hose Systems

This system is quite easy to operate and mainly used in hedges, rows of shrubs and garden beds, but might prove to be difficult to use in lawns. They are made of recycled automobile tires, which has numerous tiny holes in it. These porous hoses end up sweating water along their entire length and very durable in nature.

2.2.3.2 Emitter Drip System

This type of irrigation system is made of a number of hoses throughout the garden. Each hose has a number of evenly spaced emitters in them, say about 15 inches apart. They end up releasing small drops of water into the soil and are particularly good for landscapes with shrubs. These emitters clog easily. It is best way to avoid this by bringing these hoses inside during the winter season.

2.2.3.3 Watermatic Drip System

This is one of the most important types of drip irrigation system. This drip irrigation system helps in achieving water conservation by minimizing evaporation. It makes use of devices such as micro spray heads, which is used for trees and flower beds. This irrigation can even be utilized in areas of water conservation, where recycled water is used for irrigation purposes.

2.2.3.4 Micro Misting Sprinklers

These sprinklers are mainly built for vineyards and orchards, but are now starting to be used in backyards as well. This type of system provides water to the roots evenly, saving water and helping trees to increase their yields. One of their main advantages is that the mist helps in keeping the shallow roots cool and refreshes the flowers; protecting the buds and flowers from the frost in the spring weather. Furthermore, they also prove to be quiet inexpensive, 40 of them costs as much as one impact sprinkler.

2.2.4 Factors that affect the choice of an irrigation method

The suitability of the various irrigation methods, i.e. surface, sprinkler or drip irrigation, depends mainly on the following factors (Brouwer, Prins, kay, & Heibloem):

I. Natural conditions,
II. Type of crop,
III. Type of technology,
IV. Previous experience with irrigation,
V. Required labor inputs,
VI. Costs and benefits.

i. Natural conditions that affect choice of drip irrigation

The natural conditions such as soil type, slope, climate, water quality and availability, have the following impact on the choice of an irrigation method:

Soil type: sandy soils have a low water storage capacity and a high infiltration rate. They therefore need frequent but small irrigation applications, in particular when the sandy soil is also shallow. Under these circumstances, sprinkler or drip irrigation are more suitable than surface irrigation. On loam or clay soils all three irrigation methods can be used, but surface irrigation is more commonly found. Clay soils with low infiltration rates are ideally suited to surface irrigation. when a variety of different soil types is found within one irrigation scheme, sprinkler or drip irrigation are recommended as they will ensure a more even water distribution.

slope: sprinkler or drip irrigation are preferred above surface irrigation on steeper or unevenly sloping lands as they require little or no land levelling. An exception is rice grown on terraces on sloping lands.

Climate: strong wind can disturb the spraying of water from sprinklers. Under very windy conditions, drip or surface irrigation methods are preferred. In areas of supplementary irrigation, sprinkler or drip irrigation may be more suitable than surface irrigation because of their flexibility and adaptability to varying irrigation demands on the farm.

Water availability: water application efficiency is generally higher with sprinkler and drip irrigation than surface irrigation and so these methods are preferred when water is in short supply. However, it must be remembered that efficiency is just as much a function of the irrigator as the method used.

Water quality: surface irrigation is preferred if the irrigation water contains much sediment. The sediments may clog the drip or sprinkler irrigation systems. If the irrigation water contains dissolved salts, drip irrigation is particularly suitable, as less water is applied to the soil than with surface methods. Sprinkler systems are more efficient that surface irrigation methods in leaching out salts.

ii. Type of crop

Surface irrigation can be used for all types of crops. Sprinkler and drip irrigation, because of their high capital investment per hectare, are mostly used for high value cash crops, such as vegetables and fruit trees. They are seldom used for the lower value staple crops. Drip irrigation is suited to irrigating individual plants or trees or row crops such as vegetables and sugarcane. It is not suitable for close growing crops (e.g. rice).

iii. Type of technology

The type of technology affects the choice of irrigation method. In general, drip and sprinkler irrigation are technically more complicated methods. The purchase of equipment requires high capital investment per hectare. To maintain the equipment a high level of 'know-how' has to be available, also, a regular supply of fuel and spare parts must be maintained which - together with the purchase of equipment - may require foreign currency.

Surface irrigation systems - in particular small-scale schemes - usually require less sophisticated equipment for both construction and maintenance (unless pumps are used). The equipment needed is often easier to maintain and less dependent on the availability of foreign currency.

iv. Previous experience with irrigation

The choice of an irrigation method also depends on the irrigation tradition within the region or country. Introducing a previously unknown method may lead to unexpected complications. It is not certain that the farmers will accept the new method. The servicing of the equipment may be problematic and the costs may be high compared to the benefits.

v. Required labor inputs

Surface irrigation often requires a much higher labor input - for construction, operation and maintenance - than sprinkler or drip irrigation. Surface irrigation requires accurate land levelling, regular maintenance and a high level of farmers' organization to operate the system. Sprinkler and drip irrigation require little land levelling; system operation and maintenance are less labor-intensive. (Brouwer, Prins, kay, & Heibloem)

vi. Costs and benefits

Before choosing an irrigation method, an estimate must be made of the costs and benefits of the available options. On the cost side not only the construction and installation, but also the operation and maintenance (per hectare) should be taken into account. These costs should then be compared with the expected benefits (yields). It is obvious that farmers will only be interested in implementing a certain method if they consider this economically attractive.

2.2.5 Classification of drip irrigation system

Drip irrigation systems can be classified as: Traditional drip irrigation system, Subsurface drip irrigation (SDI) and Low cost alternative systems.

A traditional drip irrigation system: contains a main line and sub-main lines/header (to carry water to drip lines), laterals or drip lines (to distribute water to the outlets at base of plants), emitters (outlets to plants), a pump or pressure source, a control valve (to turn system on and off), a check valve (to prevent backflow into water source), a fertilizer injector (to apply fertilizer directly into irrigation water), a filter and a pressure regulator. More sophisticated system can include air vents, meters, timers, controllers and/or drains.

A subsurface drip irrigation system: is similar to the system described above; however the irrigation of crops is conducted through buried plastic tubes containing embedded emitters located at regular spacing's. This system is less vulnerable to damage during cultivation or weeding and it is unaffected by wind. In addition, places water close to the rooting zone (limiting evaporative loss). (University of Arizona, 2011) SDI is most widely used for the irrigation of annual row and field crops in the United States.

Low cost alternative drip irrigation system: One of these is called Pepsee and is used in India. It does not require micro tubes or emitters to place water directly to the root zone instead the lateral. However, this system has a limited life period, cannot withstand high pressure of flow of water and supply an unequal distribution of water. In Rajasthan and Gujarat, local NGOs began promoting low cost drip irrigation among cotton growers. Farmers saw that by using pipes and micro tubes, they can water an acre of cotton even with this restricted pumping time. (Asenso, 2011)

2.2.8 Impact of drip irrigation on crops

Agricultural water usage can be cut by at least 50 percent with proper irrigation systems. One of the most widely-recognized ways of dealing with this problem is drip irrigation, which has been primarily developed by Israel. Drip irrigation allows a controlled amount of water to slowly flow through tubes to the base of a plant through small emitters or pores in the tubes. These tubes can run above or below ground in order to prevent evaporation. Because of its ability to control precise target location, pressure, quantity and timing of water flow, drip technology increases irrigation efficiency. It is especially useful for trees and shrubs that do not require tilling soil, but can be used anywhere. Drip irrigation has 90 percent field application efficiency, compared with 60 percent efficiency for surface irrigation and 75 percent efficiency for sprinkler irrigation, as demonstrated from a study at MIT. While significantly reducing water usage in fields, drip irrigation can increase crop yields by 20 to 90 percent, according to National Geographic.

Benefits of drip irrigation beyond water and energy conservation include increased plant health, design flexibility and increased crop uniformity. Additionally, with less water leaking into the soil, there is less weed competition. Ultimately, the technology also allows farmers to save money on utilities and on labor.

Various studies, organizations and international institutions have named drip technology as a key component in impacting resource saving, cost of cultivation, crop yield and farm profitability in India and throughout the world. India and China have been the global leaders in implementing drip technology, where micro-irrigation methods have expanded 111-fold and 88-fold, respectively, in the past twenty years. Anil Jain, Managing Director of Jain Irrigation, expects India's market for drip technology to increase by one1 million hectares per year, according to National Geographic.

The 18 percent of global agricultural land with irrigation systems in place yield almost half of the world's food supply. However, out of the 2.6 km, two million of global farmland, less than four percent, currently utilize drip technology as its primary irrigation method, according to the MIT study. While building this infrastructure is more costly than traditional irrigation methods, it ends up saving money in the long term. Because of high costs, companies such as iDE have started to develop low-cost drip systems catered toward small farmers in recent years. "iDE's suite of systems ranges from $5 bucket kits for home gardens to $25 drum kits for 100-square meter plots (about 400 plants) to $100 shiftable drip systems that can irrigate 0.2 hectares (half an acre), including plots on terraced hillsides. More than 600,000 of iDE's low-cost drip systems have been sold in India, Nepal, Zambia and Zimbabwe," according to National Geographic. (University of Arizona, 2011)

There are several international initiatives to spread drip technology. The International Atomic Energy Agency has signed 19 countries onto its technical cooperation project to promote drip irrigation systems. USAID and the U.N. also promote drip irrigation usage across the globe.

2.2.6 Maintenance of drip irrigation

Drip irrigation systems are a necessary part of any modern greenhouse facility. The simplest drip irrigation system includes pressure regulator, filter, tubing and emitters (drippers). It provides a controlled and uniform distribution of water and nutrients between plants located along the irrigation line. However, emitters are prone to clogging from deposits of calcium carbonate, algae or bacteria, so irrigation lines require maintenance for better and longer service.

The drip system filter should be checked every day and cleaned if necessary. Disc and screen filters are available on the market. The preference should be given to disc filters, as they are more resistant to clogging and easier to clean through back flushing. Check lines for leaks.

A pH higher than 6.0, and high EC may lead to precipitation of calcium and magnesium salts, which will clog the emitters. Precipitates may build up to the end of the season even when precautions have been taken. Partially clogged emitters may still conduct feeding solution, but they will distribute nutrients unevenly among the plants. Therefore, the lines should be flushed with acid at the end of each season to remove build-up.

Nitric acid is a most efficient solubilize although sulphuric and phosphoric acids can be used too. Flushing lines for one hour with pH 4.5 solution is usually effective enough. However, you can leave the solution overnight if you have a particularly tough precipitate build up. Flush the lines with water afterward. Avoid precipitate build-up through preventive measures rather than drastically eliminating it at the end of the season.

Mineral precipitates are relatively easy to remove compared to the organic slime formed by bacteria and algae. The preventive measure would be injections of chlorine or commercial bacterial control agents. Use 2 ppm chlorine daily to "rinse" at the end of irrigation cycle and 30 ppm if slime becomes a problem.

If there is already a lot of algae and bacteria growing in the pipeline, emitters can be plugged worse when the slime begins to break off and gets carried downstream. Therefore, it is very important to flush the lines extensively before irrigating again. Automatic valves flushing several liters of the feeding solution at the end of each irrigation cycle are not expensive and can be installed at the end of each drip line. This will prevent any build-up of particles or slime at the end of drip lines. To eliminate all microorganisms in your irrigation system; at the end of growing period inject sulphuric acid (pH 5) through one injector and 50 ppm chlorine through a second injector downstream from the sulphuric acid injection leave the solution overnight and flush it out the next morning.

2.3Soil and plant water concepts

2.3.1 Soil water content

Soil water content is expressed as the mass of water in unit mass of soil (gravimetric) or as volume of water in unit volume of soil (volumetric) (Jalota *et al.*, 1998).

Gravimetric water content (θg) is measured by weighing the soil when wet (mwet) and again after drying at 105°C (mdry).

θg = (mwet - mdry) / mdry [1]

Volumetric water content (θv) is the volume of liquid water per volume of soil, and can be calculated from θg using bulk density (ρ):

θv = volumewater / volumesoil [2]

= (mwater / ρwater) / (msoil / ρsoil)

= $\theta g \times \rho$soil / ρwater (where ρwater is usually assumed =1.0 g/cm3).

2.3.2 Field capacity

Field capacity is defined as the water content of the soil following drainage of a saturated soil profile underlain by dry soil for about 24 - 48 hours depending on soil types (Hardy, 2004). The soil water potential at field capacity is variously defined as around -0.1 bar to -0.3 bar (-0.01 to -0.03 MPa) depending on soil texture and whether the soils have been homogenised or they are structured (as in the field condition) (NEH, 1991). The permanent wilting point is the soil water content at which plants are unable to absorb soil water, and wilt permanently (Ley *et al.*, 2006). The soil water potential at this point is usually considered to be -15 bars (Sankara and Yellamanda, 1995), although the actual value will depend on plant type and the demand for water. The available water in a soil is the amount of water that can be utilized by plants for their growth and development. It is commonly taken to be the difference between the water contents at field capacity and the permanent wilting point.

2.3.3 Yield threshold depletion

Yield threshold depletion (YTD) is the amount of water that can be depleted from the soil before there is an effect on yield or quality of crop. If the YTD is known, the soil water balance can also show the maximum time allowable between irrigation. Commonly, a crop should be irrigated before reaching the YTD level. YTD depends upon soil, plant and climatic factors. Crops differ in their sensitivity to water stress.

2.3.4 Soil water balance

The soil water balance can be variously expressed. For irrigation research:

$$ASW1 - ASW2 = P + I - (ET + Ro + D) \qquad [3]$$

ASW is available soil water at times 1 and 2, (ASW1 - ASW2) is the change in soil water during the interval tl to t2, and P = precipitation, I = irrigation, ET = evapotranspiration, Ro = surface runoff and D = deep percolation beyond the root zone, all for the interval tl to t2 (Sankara and Yellamanda, 1995). If ASW1 is the desired state and ASW2 is the present state, then irrigation required to return the soil water to the desired state (the replenishment of water use in the period), (ASW1 -ASW2) can be estimated by assuming R0 and D are zero.

$$\text{Irrigation requirement} = ET - (I+P) \qquad [4]$$

In budgeting approaches to irrigation scheduling, ET is estimated from potential evaporation combined with the use of a crop coefficient (Hartz, 1999). Sankara and Yellamanda (1995) suggested a simplified water balance equation, used by Burt (1999) to calculate the components of the water balance when water was applied to a bare soil surface:

$E = I - D$, where E = Evaporation, I = Irrigation and D = Drainage. This equation is used to calculate E later in this thesis.

2.3.5 Water balance approaches in irrigation scheduling

The soil water balance represents the integrated amount of water in the soil at a particular time. The water balance method is an indirect way of monitoring water status, using simplifications of the soil water balance equation. It is used to estimate crop water use (Goldhamer and Snyder, 1989) from climatic data (Allen *et al.*, 1998). Climatic parameters including solar radiation, temperature, relative humidity and wind have either direct or indirect effects on crop water use through their influence on evaporation and transpiration (Howell *et al.*, 1986). Various methods of estimating crop water use from meteorological information are used (Bowel *et al.*, 1986). The combination of soil evaporation (E) and transpiration (T) make up the total water use, which is commonly referred to as evapotranspiration (ET). Estimation of evapotranspiration generally uses four factors: reference evapotranspiration (ETr) based on a specific type of crop, a crop factor (Kcb) that describes both the dynamic seasonal and developmental change in the crop evapotranspiration in relation to ETr, a soil factor (Kcs) which describes the effect of low soil water content on transpiration and has close relationship with crop growth parameters such as rooting depth and the soil factor (Kso), which describes the evapotranspiration amount from either rainfall or irrigation, The crop water use is represented by the following equation (Allen *et al.* 1998):

$$\mathrm{ETc} = \mathrm{ETr}\,[(\mathrm{Kcb}\ \mathrm{Kcs}) + \mathrm{Kso}] \qquad [5]$$

Reference evapotranspiration (ETr), expressed in mm/day, can be estimated by different methods such as modified Blaney-Criddle method, the modified Jensen-Haise method, the Penrnan-Monteith combination equation, or directly by pan evaporation. Evaporation pans of various designs have been widely used throughout the world as an index of reference evapotranspiration (ETr). To calculate the particular crop water use or crop evapotranspiration, crop coefficient values are used. The crop coefficient (Kc) value varies between crops and growth stages. Crop evapotranspiration (ETc) is calculated by multiplying crop coefficient (Kc) and reference evapotranspiration (ETr) (Qassim and Ashcroft, 2001).

The water balance approach was developed in irrigation to estimate ET from large areas. Its application is difficult under drip irrigation because of the multidimensional water application pattern (Lazarovitch *et al.*, 2007).

2.3.6 Water use efficiency

Generally, plant growth is directly related to transpiration (T), although under field conditions changes in soil moisture result from both T and soil evaporation (E) (Hillel, 2004). E and T are commonly summed to give evapotranspiration (ET), which can either be measured as a change in soil water or estimated as discussed above. Both farmers and scientists are concerned with water use efficiency. In irrigated crops, efficiency of water use can be affected by the method, amount, and timing of irrigation. Water use efficiency has been defined in various ways and it is important to understand the differences. Loomis (1983) defined it as the ratio of dry matter produced (Y) per unit of water transpired by a crop (T), in equation 7 expressed as kg/mm or kg/ha/mm.

$$WUE=Y/T. \qquad [6]$$

This approach given the biomass production relative to the water actually used by the plant, and should more correctly be termed the, transpiration efficiency" (TE). The TE of different crops may vary with differences in photosynthetic mechanism (C3, C4, and CAM) and vapour pressure deficit (van Keulen, 1975; Lof, 1976).

$$WUE=Ye/ET. \qquad [7]$$

The term Ye / ET given the agronomic yield of the system relative to total water use, and is a more correct use of the term 'water use efficiency' or agronomic water use efficiency (Loomis, 1983). Soil surface modifications such as tillage and retaining surface residue may influence WUE by reducing soil evaporation (E) and increasing crop transpiration (T) (Hatfield *et al.*, 2001). One potential advantage of SDI is reduced soil evaporation (Solomon, 1993). Loch *et al.* (2005) described water use efficiency as the amount of water transpired relative to the amount of irrigation applied (t yield/ML water), which could be called irrigation efficiency. He noted that factors such as poor soil structure, profile salinity; and irrigation management that restrict the expansion and efficiency of the plant root system will all reduce water use efficiency.

Overall agronomic efficiency of water use (Fag) in irrigated systems is defined by FAO (1997) using an adaptation of the soil water balance:

$$Fag = P/U, \qquad [8a]$$

where P is crop production (total dry matter or the marketable yield) and U is the volume of water applied. The components of U are expressed by the following equation:

$$U = R + D + Ep + Ec + Tw + Tc, \qquad [8b]$$

where R is the volume of water lost by runoff from the field, D the volume drained below the root zone (deep percolation), Ep the volume lost by evaporation during the conveyance and application to the field, Ec the volume evaporated from the soil surface, Tw the volume transpired by weeds and Tc the volume transpired by the crop. Overall irrigation efficiency is calculated by multiplying the efficiencies of the components. For a system, which includes reservoir storage, water conveyance, and water application, the overall irrigation efficiency is defined as

$$Eo = (Es)\ X\ (Ec)\ X\ (Ea). \qquad [8c]$$

where Es = reservoir storage efficiency, Ec = water conveyance efficiency, Ea = irrigation application efficiency. In all agricultural systems, low water use efficiency can occur when soil evaporation is high in relation to crop transpiration. Early growth rate is slow (eg. crop establishment stage), water application does not correspond to crop demand, and also shallow roots are unable to utilize deep water in the profile. This was demonstrated by Patel and Rajput (2007) during the early growth phase of potato. These problems are especially pronounced in intensive vegetable production (Gallardo *et al.*, 1996).

Irrigation control may increase water use efficiency (yield / water used) (Upchurch *et al.*, 1990), water 'use' here meaning the sum of ET and deep percolation. The role of irrigation scheduling in improving water use efficiency is considered below.

2.3.7 Irrigation scheduling to improve water use efficiency

Irrigation scheduling means applying water at intervals based on the needs of the crop, with the primary objective of managing soil water within defined limits. It is the process by which an irrigator determines the timing, amount and quality of water to be applied to the crop (Qassim and Ashcroft, 2001; Bierman, 2005). Vazquez *et al.* (2005) illustrate the difficulty in trying to precisely apply irrigation water with drip irrigation. They compared scheduling using crop evapotranspiration (ETc) with volumetric soil water content measured by TDR, maize in a silty clay loam. The surface drip had drainage during crop establishment when water was applied at a higher rate than crop evapotranspiration. Sensors must be placed in the active root zone in proximity to the emitter. Sensor placement in SDI systems varies, but is mostly located midway between emitters (Howell and Meron, 2007).

CHAPTER 3

MATERIALS AND METHODOLGY

3.1 DESCRIPTION OF STUDY AREA

3.1.1 Introduction

This Chapter describes the materials utilized for the field trials necessary for obtaining the requisite data presented in this study. The methods adopted for the field trials, have also been described. The study area characteristics, relevant equations and statistical Tools and measures of performance of drip irrigation systems have also been presented.

3.1.2 Location of the study area

The field experiment was conducted at the Department of Agricultural Engineering Farm at Federal University Oye-Ekiti, from 5th May to 18th September 2017. The field is located at latitude 7° 47’ 29 N and longitude 5° 30’ 31 E. The site has an area of $35m^2$. The site has not been under serious cultivation. Source of water for the experiment was from the borehole at the front of the engineering workshop at the Engineering Faculty.

Figure 3.1 Map of Nigeria showing Ekiti State in South-Western Nigeria

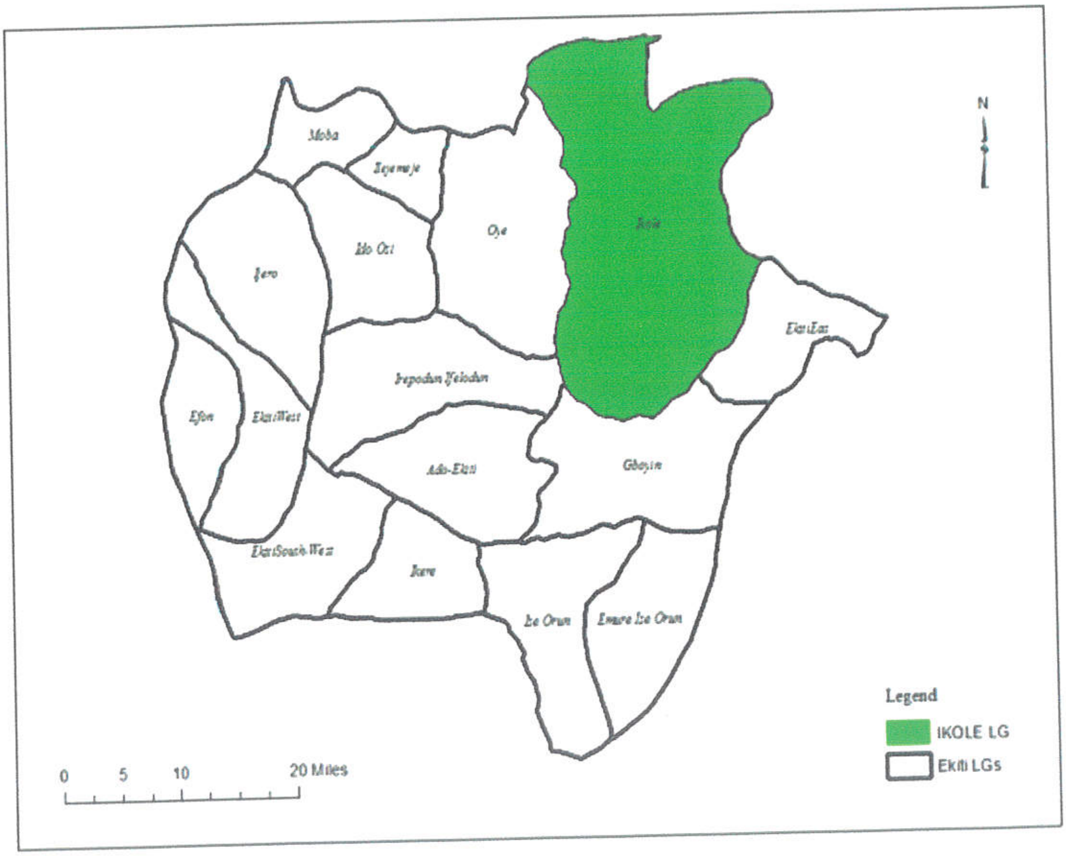


Fig 3.2 Map of Ekiti State showing the Study Area (Ikole)

3.2 MATERIALS SELECTION

The materials selected for each component part of the drip irrigation is presented in Table 3. 1.

The major material used for the construction of essential components of this were polyvinyl chloride (PVC pipes) and steel as shown in table 3.1

Table 3.1 Material selection

S/N	Irrigation Component	Material
1	Mainline	PVC
2	Lateral	PVC
3	Emitters	Rubber and PVC
4	Valve	PVC
5	T-pipe connector	PVC
6	End cap	PVC
7	Storage Tank	Steel
8	Filter	Rubber

3.2.1 Selection criteria

The choice of components used for this project is based on the following factors:

(1) Efficiency of equipment

(2) Simplicity of design, and

(3) Cost

The polyvinyl chloride was selected based on easily coupled, assembly, resists oxidation and corrosive attack and availability.

3.2.2 Materials

The materials used for the experiment were as follows;

- 1 inch (0.0254m) PVC pipe
- ¾ inch (0.01905) PVC pipe
- ¾ inch (0.01905)end caps
- 1 inch (0.0254m) end caps
- 1 inch (0.0254m) elbow
- 1 – ¾ inch convertible T-pipe
- 1 Storage tank (1000L capacity)
- Open and close valve 1 inch (0.0254m)
- Water hose
- Measuring tape
- Measuring cylinder (1000cm^3)
- Collection cans

3.3 SYSTEMS DESCRIPTION AND OPERATIONAL PRINCIPLES

Drip irrigation system basically requires flexible micro-tubings as well as poly-tubings and PVC pipes suitably fitted with nozzles to deliver water to individual plants. Also needed are filter and pressure regulator to clean the water of suspended impurities and a device to maintain desirable head to permit flow of water respectively.

- **Head tank** to store water as well as to create water pressure. Head tank is a cylindrical shape is made of metallic materials; it is used to store water as well as to create water pressure thereby giving it a pressure head.

Figure 3.3 Storage Tank

- **Filter**: Irrigation water passes through filter which removes suspended impurities from water. With provision of filter nozzles which have perforations do not get clogged.
- **Mains pipes and tubings:** Mains are P.V.C. pipes of appropriate diameter which convey water from the source of water supply to the drip irrigation area. These pipelines or tubings are made of P.V.C. (Polyvinyyl chloride) or polyethylene or alkaethylene materials with its dimensions are shown in Table 3.2. They are laid on the surface or underground.
- **Laterals or trickle lines**: They carry water along the row of crop or trees or plants. It is about 3m in length and are fitted with flush or end cap. Their spacing on the sub-mains is so adjusted that for each row of crop or trees a lateral runs along side. These pipelines or tubings are made of P.V.C. (Polyvinyyl chloride). Its dimensions are shown in Table 3.2

Figure 3.4 Lateral lines fixed with Hospital Drip Flow

- **Nozzle or emitter or dripper and micro-tubings**: An emitter has perforations to release water at the plant's root zone drop- by-drop and water released may vary 2 to 10 litres per hour depending upon requirement of a crop. The emitter use for this project is the **flow drip** used in hospitals; adult-sized with a hose diameter of 3mm. The emitters are fixed on the laterals at appropriate intervals to supply the water at the root of the plants or crops to be grown. Sometimes a smaller micro-tubing can be attached to the lateral or tubing which run out to the individual plants. At the end of each micro-tubing an emitter is attached which regulates the water flow. As shown in figure 3.5.

Figure 3.5 Hospital Flow Drip

- **Valve or discharge regulator**: It is provided on the sub-main at a junction from where a lateral takes off. Capacity of the valve is fixed in accordance with the size and number of emitters or nozzles used on a lateral. The automatic valve at the head of the lateral is adjusted to deliver a measured quantity of water and supply stops automatically thereafter.

- **End or flush cap**: It is fitted at the end of laterals to prevent wastage of water or to flush the pipe network.

Table 3.2: The component parts and dimensions of the Drip Irrigation System

S/N	**Component**	**Dimension**	
		Diameter(cm)	Length(m)
1	Mainline	2.54	2.5
2	Lateral	1.91	2.5
3	Emitters	-	-
4	Valve	2.54	-
5	T-pipe connector convert	2.54-1.91	-
6	End cap(mainline)	2.54	-
7	End cap(lateral)	2.54	-
8	Storage Tank	55	96
9	Filter	-	-

3.4 DESIGN CONSIDERATION

The drip irrigation system was designed to meet the following:

(1) Low cost
(2) Use locally-available materials
(3) Portability and ease of assemble / disassembly
(4) Repeatability and ease of operation
(5) Low maintenance requirements
(6) Water is to apply uniformly to all plants.
(7) Water is apply directly to the plant root zone

3.5 DESIGN CALCULATIONS

3.5.1 Hydraulic parameters

Hydraulic parameters needed for evaluation of effectiveness of drip irrigation system and it includes distribution uniformity, the desired water application rate, clogging susceptibility and emitter spacing.

3.5.1.1 Distribution Uniformity

Uniformity, a performance characteristic of irrigation systems, is a measure of the evenness of the applied water throughout the irrigation system. Distribution uniformity (DU), sometimes called emission uniformity (EU), is an index that describes how evenly or uniformly water is applied throughout the field. It is used to determine if emitter is delivering the same amount of water during irrigation or it is required maintenance.

Steps to determining distribution uniformity

a. Set up containers under emitters to collect water.
b. Use a quantity of containers that is evenly divisible by 4.
c. Place the containers evenly along and across the drip system.
d. Collect water in the containers. Be careful to not overtop the containers!
e. Make sure you record the run time.
f. Measure the water volumes in milliliters (ml).

Determination of Distribution Uniformity (DU)

a. Sort the list of volumes from largest to smallest.
b. Calculate the average of the lowest quartile (Avg_{LQ})
c. Calculate the average of all of the measurements (total average or Avg_T).
d. Divide the average of the lowest quartile ((Avg_{LQ}) by the total average (Avg_T) to get distribution uniformity (DU).

$$\mathrm{DU} = \frac{Avg_{LQ}}{Avg_T} \tag{9}$$

3.5.1.2 Precipitation (application) rate

Water application rates for irrigation systems are typically given in milliters per hour (ml/hr) but drip system application rates are in drops per minute (drops/min). So, we'll have to convert the drip rate to inches per hour.

1. Area irrigated (sq m)
2. Total number of emitters in the irrigated landscape area
3. Emitter flow rate (drops/min). This is the flow rate for each emitter

Application rate: $\frac{No.\ of\ emitters\ x\ flow\ per\ emitter}{Area\ of\ irrigation}$ (10)

Application rate = $\frac{Flow\ per\ emitter\ x\ 231.1}{emitter\ spacing\ x\ lateral\ spacing}$ (11)

3.5.1.3. Clogging Susceptibility

Clogging Susceptibility (%) = $(\frac{No\ of\ emitter\ clogged}{Total\ Number\ of\ emitters})$ x100 (12)

3.5.1.4 Emitter Spacing

Emitter spacing determined by the size of the drip zone and type of soil.

The ''Drip zone'' is the area of soil located directly under the leaves of the plant. It is also can be defined as the circle around the plant at the edge of the plant's leaves. The line at the edge of the leaves is called the '' drip line''.

Emitter Spacing: horizontal water movement x 1.9 (13)

Emitter spacing: = $\frac{Flow\ per\ emitter\ x\ 231.1}{Application\ rate\ x\ lateral\ spacing}$ (14)

3.6 EXPERIMENTAL PROCEDURE

3.6.1 LABORATORY/ WORKSHOP PROCEDURE

The isometric drawing of a drip irrigation system and Field layout Drip Irrigation System are presented in Figures 3.6 and 3.7, respectively which illustrates the system lucidly for a field crop. Various steps involved in installation are the following:

Water storage metallic drum was placed one metre above the ground level with the aided wooden support at the irrigation area. Hole about 2.54cm was made at side of the drum, closed to the bottom. The treaded end of the main pipe made of Polyethene material of 2.54cm diameter was inserted into the drum.

Water filter model of supreme water filter with regular cartridge SC-10W was installed along the main pipeline that has being fitted into the drum. Valve was connected to main pipeline by mean of connector.

PVC pipes (1.91cm diameters) of sub-mains and laterals of 1.91cm diameter were laid above ground. The valves were connected on the sub-mains to control discharge of water into lateral pipes. Holes of 0.3 cm diameter were made unto laterals by aided punching machine. Improvised emitters are connected at appropriate intervals (60cm) to laterals holes. At the end of laterals, flush caps were connected.

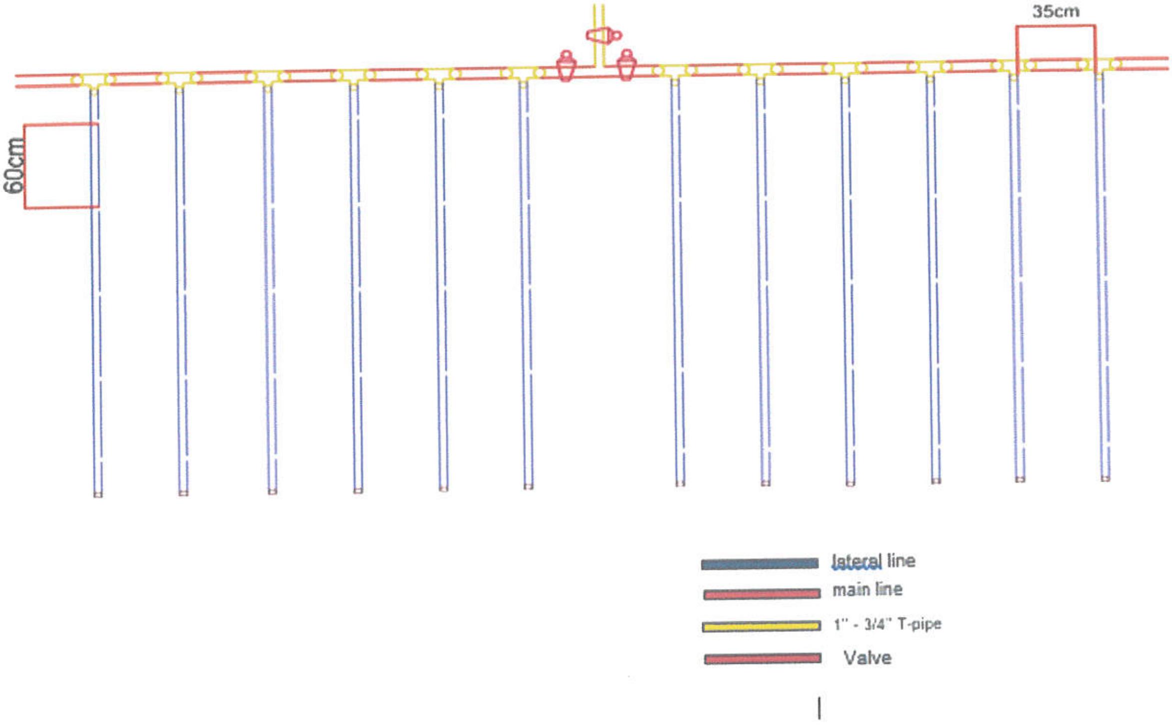


***Figure 3.6** Isometric Drawing of Drip Irrigation System*

3.7 FIELD PROCEDURE

The hydraulic evaluation of the continuous-flow drip irrigation system was conducted on 24th October, 2017 at 8.30 am. . The irrigated field area (7m x 5m) and lateral spacing was 0.35 m. The gate valve at the exit of the distributary tank was opened full which supplied water to the sub main pipes. The gate valves at the sub mains were opened at 50 % which delivered water to the laterals. Water was allowed to flow about 30 minutes to permit the pre-testing (Fig. 3.7). The total number of emitters is 60. Measuring cylinders were paced under emitters to collect water. The gate valves at the sub main pipes were opened at 50 % which delivered water through the laterals to the emitters. The drops from each emitter were run for 5 minutes. The volumes of water collected at each emitter were recorded. Determine the **precipitation rate** and **distribution uniformity** of irrigation systems were determined using volumetric measurements.

***Figure 3.7:** Field Layout Gravity Drip Irrigation System*

CHAPTER 4

RESULTS AND DISCUSSIONS

The average volume of water drops from the selected emitters was presented in Table 4.1.

Table 4.1: Average volume of water drops from the selected emitters

S/N	Selected Emitter	Volume of drop (ml)	Run Time (min)	Lateral spacing (m)	Area of Irrigated (m^2)
1	A_1	800	5	0.35	0.35
2	B_2	810	5	0.35	0.35
3	C_4	790	5	0.35	0.35
4	D_3	795	5	0.35	0.35
5	E5	805	5	0.35	0.35
6	F_2	810	5	0.35	0.35
7	G_4	800	5	0.35	0.35
8	H_2	795	5	0.35	0.35
9	J_5	800	5	0.35	0.35
10	K_4	805	5	0.35	0.35
11	L_3	800	5	0.35	0.35
12	M_4	790	5	0.35	0.35

4.1. Determination of Hydraulic Parameters: The performance of the drip irrigation system was evaluated by determining the Precipitation Rate (PR) and Distribution Uniformity (DU). The PR is the rate at which water is delivered to the irrigated area and is measured in mm per hour. The distribution uniformity of the delivering emitters was 1.04. The system has very high Du, which mean that every emitter is delivering almost the same amount of water during irrigation. Hence, the emitters do not need maintenance, while the PR was 17 mm/hr. These two hydraulic parameters are useful in calculation station run time and indicate how evenly water is applied to all areas of the irrigation. The emitter spacing was 60 cm distance apart. The component parts and dimensions of the Drip Irrigation System is presented in Table 4.2. While the cost of the portable, movable and gravity drip irrigation system is presented in Appendix 2.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSION

5.1.1 General Conclusion

The following conclusions were drawn from the study:

(1). Drip irrigation system was constructed

(2). every emitter is delivering almost the same amount of water during evaluation and

(3). Each emitter is delivered 17 mm per hour.

5.1.2 Possible Users

Considering the specifications for the design possible users are:

1. Small scale farmers.
2. Agric. Extension Agents (AES)
3. Non-Governmental Organizations (NGOs) in Agriculture.

5.1.3 Limitation

Even though the design is with no friction factor loss, there are other limiting factors to this design:

1. Clogging of the drip holes
2. Problems of weeding around the pipe lines.
3. Initial capital for the establishment of the design
4. Difficulty in adopting it for mechanized farming, but that does not totally rule it out.

5.2. RECOMMENDATIONS

- The study should be repeated in the dry season when soil moisture content can be effectively monitored.
- Further studies should focus on the design performance criteria.
- The experiment should be repeated to determine fertilizer (fertigation) application through the design system.

- Economic analysis should be under taken to determine cost and benefits of the effects of depth of pipe placement and depth of water application
- The study should be repeated using micro tubes instead of PVC pipes to so as to check economic

REFERENCES

agriinfo. (2017, february 2). *agri info*. Retrieved from (http://www.agriinfo.in/default.aspx?page=topic&superid=8&topicid=2242)

Allen, R.G., Pereira, L.S., Raes, D., and Smith, M. (1998) Crop evapotranspiration, guidelines for computing crop water requirements. FAO Irrig. And Drain. Paper 56, Roam, Italy

Asenso, E. (2011). *DESIGN AND EVALUATION OF A SIMPLE PVC DRIP IRRIGATION.* Kumasi.

Bralts, V.F.,D.M.Edwards, and I.P.Wu (1987) Drip irrigation design and Evaluation Based on Statistical Unifromity Concepts. Advances in irrigation. 4:67-117

Brouwer, C., Prins, M., kay, M., & Heibloem, M. (n.d.). *Irrigation Water Managment: Irrigation Methods.* Wageningen: Natural Resources Management and Enviroment Department.

Bustan, A. and D. Pasternak. (2008). African Market Garden. Encyclopedia of Water Science. Edition. 2.

Camp, C.R., Bauer, B.J., and Busscher, W.J. (1997) A comparison of uniformity measures for drip irrigation. Transactions of the ASAE 40(4): 1013- 1020.

Defra. (2013, January 24). *defra*. Retrieved from defra.gov.uk.

Depot, D. (2017, October 10). *Drip Depot Inc.* Retrieved from Drip Depot Website: https://www.dripdepot.com/artcle/the-history-of-drip-irrigation

Don Scott, H. (2000) Soil Physics: Agricultural and Environmental Applications, Iowa State University Publication.

Doityourself. (2017, december 25). *Do it yourself.* Retrieved from Do it yourself: (http://www.doityourself.com/stry/4-types-of-drip-irrigation-systems-explained)

Duhrkoop, A., Saathoff, F., and Dede, C., (2009). Material Investigation for an efficient auto regulative subsurface irrigation method with permeable pipes. Institute for environmental engineering, Rostock University, Germany.

engineers, c. (2017, 1 6). *civil engineers forum*. Retrieved from civil engineers forum website: www.civilengineersforum.com/drip-irrigation-advantages-disadvantages

FAO (1997) Small-scale irrigation for arid zones. Available at: www.fao.org/docrep/W3094E.

Feng, J. and Wu, I.P. (1990). A simple computerized drip irrigation design. Proc. 3rd Nat. Irrig. Symp., ASAE Publ. No. 04-90. p348-353. St. Joseph, MI.

forum, c. e. (2016, january 10). *civil engineers forum*. Retrieved from civil engineers forum.

Gallardo, M., Jackson,L.E., Schulbach, K., Snyder, R.L., Thompson, R.B., and Wyland, L.J. (1996) Production and water use in lettuce under variable water supply. Irri. Sci. 16:125 -137.

Goldhamer, D.A., and Snyder, R.L. (1989) Irrigation scheduling – A guide for efficient on-farm water management. Publication No: 21454, University of California.

Hatfield, J.L., Sauer, T.J., and Rueger, J.H. (2001) Managing soils to achieve greater water use efficiency: A review. Agron. J. 93: 271-280.

Hardy, S. (2004) Growing lemons in Australia- a production manual. Available at: www.dpi.nsw.gov.au

Hartz, T.K. (2000) Drip irrigation and fertigation management of celery. Celery Grower Guidelines, Vegetable Research and Information Center, University of California, Davis, USA.

Hermoso, V., Abell, R., Linke, S., and Boon, P. (2016). The role of protected areas for freshwater biodiversity: challenges and opportunities in a rapidly chnaging world. *aquatic Conservation: Marine and Freshwater Ecosystems*, 26(S1): 3-11.

Hillel, D. (2004) Soil and water- Physical principles and processes, New York and London: Academic press.

Howell, T.A., Bucks, D.A., Goldhamer, D.A., and Lima, J.M. (1986) Irrigation scheduling. Trickle irrigation for crop production design, operation and management. Eds.

Jalota, S.K., Romesh, K., and Ghuman, B.S. (1998) Hydraulic properties of soil: Methods in soil physics, New Delhi: Narosa Publishing House

Keller, J. and Bliesner, R.D. (1990). Sprinkle and Trickle Irrigation, Van Nostrand Reinhold, New York, 3-5, 86-96

Lazarovitch, N., Warrick, A. W.,Furman, A., and Simunek, J. (2007) Subsurface Water Distribution from Drip Irrigation Described by Mount Analysis, Vadose Zone J. 6: 116-123.

Ley, T.W., Stevens, R.G., Topielec, R.R., and Neibling, W.H. (2006) Soil water monitoring and measurements, Washington State University, Publication No: PNW0475

Loomis, R.S., Taylor, H.M., Jordan, W.R., and Sinclair, T.R. (1983) Crop manipulations for efficient use of water: An overview. Limitations to efficient water use in crop production. Eds. Published by ASA, CSA and SSSA.

Miyazaki, T. (2006) Water flows in soil. CRC Press Taylor and Francis Group, Pp: 27-28. Lal, R., and Shukla, M.K. (2004) Principles of Soil physics, Marcel, New York, USA.

Molden, D. J., M. El-Kady, and Z. Zhu, 1998: Use and productivity of Egypt's Nile water. In: J. Morris, M.L., Tripp, R. and Dankyi, A.A. 1999. Adoption and impacts of improved maize production technology: A case study of the Ghana Grains Development Project. Economics Program Paper 99-101. Mexico, D.F.: CIMMYT.

NEH - National Engineering Handbook- Irrigation, (1991) Soil-plant-water relationships, Soil Conservation Service, Department of Agriculture, USA.

Or, D. (1995). Soil water sensor placement and interpretation for drip irrigation management in heterogenous soils, Proc. Fifth Int. Micro-irrigation Congress. p214-21. ASAE, Orlando, Fl.

Phene, C. J., K. R. Davis, R. M. Mead, R. Yue, I. P. Wu, and R. B. Hutmacher, 1994: Evaluation of a Subsurface Drip Irrigation System, After Ten Cropping Seasons. ASAE. Pap. 932560 (winter meeting, Chicago, IL). ASAE, St. Joseph, MI

Prunty, L., and Casey, F.X.M. (2002) Soil water retention curve using a flexible smooth function. Vadose Zone J. 1:179- 185.

Qassim, A., and Ashcroft, B. (2001) Estimating vegetable crop water use with moisture – accounting method. Agriculture notes No- AG1192. DPI, Victoria.

Sadler, E.J., Camp, C.R., and Busscher, W.J. (1995) Emitter flow rate changes by excavating subsurface drip irrigation tubing. Proc. Fifth Int"l Microirrigation congress, Eds. Lamm, F.R. ASAE, St. Joseph, Michigan, 2-6 April, Orlando, FL, USA.Pp: 763-768.

Sankara, G.H., and Yellamanda, T. (1995) efficient use of irrigation water. Kalyani publishers, New Delhi.

Smeal, D. (2007). Drip Irrigation for Small Plots (a low-tech, low-cost, gravity system).2007. New Mexico Organic Farming Conference. Albuquerque. NM. February 16-17, 2007

UNEP. (2011, december 30). *Towards a Green Economy.* Retrieved from Pathways to Sustainable Development and Poverty Eradication: www.unep.org/greeneconomy

University of Arizona. (2011). *Subsurface Drip Irrigation Demonstration and research project.* Arizona: University of Arizona Press.

Upchurch, D.R., Wanjura, D.F., and Mahan, J.R. (1990) Automating trickle-irrigation using continuous irrigation canopy temperature measurements. Symposium on scheduling of irrigation for vegetable crops under field condition. Eds. Alvino, A. Acta Horticulturae 278: 299-324.

US(EPA). (2013). *Cases in Water Conservation: How Efficiency Program Help Water Utilities Save water and Avoid Costs.* united states.

Vazquez, N., Pardo, A. Suso, M.L., and Quesada, M. (2005) A methodology for measuring drainage and nitrate leaching of mineral nitrogen from arable land. Plant Soil 269: 297 -308.

wikihow. (2017, 1 4). *drip irrigation chapters.* Retrieved from drip irrigation: www.dripirrgation.com/drip_irrigation_chapters/22/drip_irrogation_pages/71

Williams, J., Prebble, R.E., Williams, W.T., and Hignett, C.T. (1983) The influence of texture, structure and clay mineralogy on the soil moisture characteristics. Australian J. Soil Research 21: 15-32.

Wu, I.P. (1992). Energy gradient line approach for direct calculation in drip irrigation design. Irrig. Sci. 13:21-29.

Wu, I.P. and Yue, R. (1991). Drip irrigation design using energy gradient line approach. ASAE Paper No. 91-2154. St. Joseph, MI.

APPENDIX

Appendix 1

Calculation of the Distribution Uniformity (DU), application rate and Emitter spacing

The area irrigated = 0.35 m^2

The lateral spacing = 0.35 m

No. Of Emitters = 60

Emitter coefficient = 75% = 0.75

Run time = 5 minutes

Total volume of emitters: 800+ 810+ 910 + 795 + 805 + 810 + 800 + 795 + 800 + 805 + 805 + 800 + 790 = 9,600 mm^3

1. Distribution Uniformity (DU)

$Avg_T = \frac{9600}{12} = 800$ cm^3

The average of the quartile (Avg_{LQ})

The quartile = 12/4 = 3

The least three volumes = 790, 795 and 800

The $(Avg_{LQ} = \frac{790+795+800}{3} = 828$ cm^3

$DU = \frac{Avg_{LQ}}{Avg_T} = \frac{828}{800} = 1.04$

2. Application Rate

Flow rate per emitter = 0.1 m^3/hr

$$\text{Application rate} = \frac{No.\ of\ emitters\ x\ flow\ per\ emitter}{Area\ of\ irrigation} = \frac{60\ x\ 0.1}{0.35} = 17\text{mm per hour}$$

3. Emitter spacing