EFFECT OF DEFICIT IRRIGATION UNDER DRIP IRRIGATION METHOD ON THE YIELD AND WATER USE EFFICIENCY OF ONION (*Allium cepa* L.) AT FOGERA DISTRICT, NORTHWESTERN ETHIOPIA

M.Sc THESIS

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HAWASSA UNIVERSITY

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A THESIS SUBMITTED TO THE DEPARTMENT OF WATER RESOURCES & IRRIGATION ENGINEERING, FACULTY OF BIO SYSTEMS AND WATER RESOURCES ENGINEERING,

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ABBREVATIONS AND ACRONOMYS

ASAE	American Society of Agricultural Engineers
ATVET	Agricultural Technical Vocational Education and Training
CV	Coefficient of Variation
CWUE	Crop Water Use Efficiency
EARO	Ethiopian Agricultural Research Organization
EIAR	Ethiopian Institute of Agricultural Research
ET_C	Crop Evapotranspiration
ET_o	Reference Evapotranspiration
EU	Emission Uniformity
FAO	Food and Agriculture Organization
FAOSTAT	Food and Agriculture Organization Statistics
FC	Field Capacity
GIR	Growth Irrigation Requirement
IWUE	Irrigation Water Use Efficiency
K_C	Crop Coefficient
LSD	Least Significance Difference
MARC	Melkassa Agricultural Research Center
MC	Moisture Content

NIR	Net Irrigation Requirement
NPS	Nitrogen Phosphorus Sulfur
PWP	Permanent Wilting Point
RAW	Readily Available Water
RD	Root Depth
SAS	Statistical Analysis System
TAW	Total Available Water
UC	Uniformity Coefficient
WP	Water Productivity
WUE	Water Use Efficiency

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Effect of Deficit Irrigation under Drip Irrigation Method on Yield and Water Use Efficiency of Onion (*Allium cepa* L.) at Fogera District, Northwestern Ethiopia

ABSTRACT

Water has been identified as one of the scarce inputs, which can severely restrict agricultural production and productivity unless it is carefully conserved and managed. Deficit irrigation improves water productivity and irrigation management practices resulting in water saving by maintaining soil moisture content below optimum level throughout growth season. Hence, a field experiment was conducted in Amhara region, South Gonder zone, at Fogera district during the dry season of 2020 using deficit irrigation under drip irrigation method to evaluate the effect of deficit irrigation practices on yield and water use efficiency (WUE) of onion. The experiment was carried out in randomized complete block design with three irrigation treatments (drip irrigation at 100%, 80% and 60%ET_C*) and three replications. Drip irrigation at 100%*ET_c gave *very highly significant onion yield (26.8 t* ha^{-1}*), as compared to 80% and 60%*ET_c *irrigation treatments. However, irrigation water use efficiency was found highest (6.2 kg* m^{-3}*) with drip irrigation at 80%ETc. The amount of water saved at 80% and 60%*ET_c *under drip irrigation method were 90mm, and 179.9mm respectively over 100% drip irrigation method and this may sufficient to irrigate 0.2 to 0.4 hectare of additional area of onion crop as compared to that of 100%*ET_C *drip irrigation method. Therefore, this study suggests that farmers in the study area, having limited amount of water for irrigation, should adopt deficit irrigation under drip irrigation method.*

Key words: Deficit irrigation, increase in yield, water saved, water use efficiency.

1. INTRODUCTION

1.1. Background

The ever increasing world population and the demand for additional water supply by industrial, municipal and agricultural sectors exert a lot of pressure on renewable water resources (Valipour, 2014). The Growing competition for water from domestic and industrial sectors is likely to reduce its availability for irrigation. Thus, the need to meet the growing demand for food will require increased crop production from less and less water.

Although available in abundance in some regions, river basins of arid and semi-arid regions are facing problem of water scarcity as well as decline of water quality, due to population growth and increased water use (Vorosmarty *et al.,* 2010). Increasing fresh water scarcity has called for researchers into new irrigation technologies with the purpose of improving water use efficiency in plant (Wang *et al.,* 2017).

Worldwide, more than 80% of the total area under irrigation by surface irrigation, whereby water over the field by gravity using basin, furrow, or border strip techniques. However, this irrigation method is to recognize as being relatively inefficient in terms of water application and often requires large volumes of water (Tagar *et al.,* 2012).

Under conditions of scarce water supply, Application of deficit irrigation could provide greater economic returns than maximizing yield per unit of water. The deficit irrigation has been considered worldwide as a way of maximizing water use efficiency by eliminating irrigation that has little impact on yield (Enchalew, et al., 2016). With deficit irrigation the crop is exposed to a certain level of water stress either during a particular period or throughout the whole growing season. The response of onion to water deficit has been reported by Nigatu A, et al., (2010) that showed deficit irrigation to increase the water use efficiency of onion.

Drip irrigation is one of the most efficient forms of irrigation technology that will allow applying light and frequent irrigation. The experience from many countries showed that farmers who switch from surface irrigation to drip systems can cut their water use by 30% t0 60% and crop yields often increase at the same time (Nigatu A, et al., 2010). Therefore, the objectives of this study were to determine water productivity of onion and investigate the effect of deficit irrigation levels on yield of onion bulb under deficit drip irrigation and full conventional furrow irrigation.

Onion (*Allium cepa* L.) belongs to the family Alliaceae. Onion is an important vegetable bulb crop cultivated in tropical and subtropical parts of the world, which ranks second next to tomato (FAO, 2012). China and India are the world's largest producers of onion, followed by USA, Netherland, Egypt and, Iran (FAOSTAT, 2014).

In Ethiopia, onion is one of the most bulb vegetables produced by smallholder farmers mainly as a source of cash income (Lemma and Shemeles, 2003). Onion is one of the important vegetable crops in Ethiopia for home consumption, income source of farmers, and contributes to the national economy as export products (Getachew and Asfaw, 2000).

Onion is traditionally grown at the recommended spacing of 40 cm x 20 cm x 10 cm in Ethiopia (Lemma and Aklilu, 2003). However, these recommendations cannot be directly adopted for the soil and growing conditions of the all of the Amhara region, which are different from the conditions in the research conduct area.

Under conditions of scarce water supply, Application of deficit irrigation could provide greater economic returns than maximizing yield per unit of water. The deficit irrigation has been considered worldwide as a way of maximizing water use efficiency by eliminating irrigation that has little impact on yield (Enchalew, et al., 2016). With deficit irrigation the crop is exposed to a certain level of water stress either during a particular period or throughout the whole growing season. The response of onion to water deficit has been reported by Nigatu A, et al., (2010) that showed deficit irrigation to increase the water use efficiency of onion.

Drip irrigation is one of the most efficient forms of irrigation technology that will allow applying light and frequent irrigation. The experience from many countries showed that farmers who switch from surface irrigation to drip systems can cut their water use by 30% t0 60% and crop yields often increase at the same time (Nigatu A, et al., 2010). Therefore, the objectives of this study were to determine water productivity of onion and investigate the effect of deficit irrigation levels on yield of onion bulb under drip irrigation.

In Fogera district onion is mainly grown as irrigation crop, during the dry season. In the dry season, stunted growth and poor bulbing of onion occurred as a result of dry soils. Moisture supply for the best production of onion must be uniform during the growing season. In addition, there is also temperature fluctuation, weed and insect infestation.

In general, in the study area, information on onion and its interaction with different irrigation methods application for optimum bulb yield and other agronomic practices is limited. Therefore, plant variety and irrigation have to be regulated for higher yields depending on the purpose of production. Thus, the knowledge of the relationships among these factors and yield is helpful to maximize onion yield through selection of proper deficit irrigation level and irrigation Method. Systematic investigation of different irrigation level and methods has a great importance to come up with relevant recommendations that can maximize onion bulb yield.

1.2. Statement of problem

In Fogera district, irrigation development is expanding year to year for growing vegetables, fruits and specifically onions under irrigation. Most of the farmers of this study area apply conventional furrow irrigation method which wastes water. On the contrary in the study area there is water shortage for irrigation and low water use efficiency but the surrounding farmers need to expand their irrigated land to be food secured. In order to allocate the scarce water resources among competing users, applying deficit irrigation under drip irrigation which maximizes Water use efficiency and crop water productivity using available water for onion production is an obligatory work. All the irrigation methods have no equal efficiency in water saving and contribution for yield increment. Therefore, suitable irrigation method and deficit level selection for specific area and crop is required to increase production and the water usage efficiency. Farmers also do not know which irrigation method and deficit level is efficient to increase productivity and water use efficiency.

Irrigation is the main solution to improve crop production and productivity thereby contributing towards food security, self-sufficiency and export market but water resources are limited to benefit from irrigation practice. Hence, there is a need to achieve maximum crop production and productivity by identifying and applying more efficient irrigation method.

1.3. Objectives

1.3.1. General objective

To identify the effects of Deficit irrigation under drip irrigation methods on yield and water use efficiency of onion (Bombay red variety).

1.3.2. Specific objectives

- ❖ To determine the water use efficiency and water saving irrigation level for onion production.
- ❖ To identify the effect of deficit irrigation levels on bulb yield of onion under drip irrigation
- ❖ To identify the best water productivity of irrigation level on onion under deficit drip irrigation.

1.4. Research questions

- Do different deficit irrigation levels have an impact on water use efficiency and water saving?
- Do different deficit irrigation levels under drip irrigation have an impact on onion yield?
- Which deficit irrigation level is more efficient for maximum onion yield?

1.5. Significance of the study

Efficient use of water by irrigation system is becoming increasingly important in arid and semi-arid regions with limited water resources. This study will provide information about the efficient irrigation water application level to cultivate onion crops by focusing on productivity and water use efficiency. Therefore, the result of this study will serve to teach the surrounding community in order to apply the efficient irrigation water application in the area. It can also serve as an input for planning of appropriate irrigation methods which increase production and save water. In addition, it will provide information for further improvement and investment approaches for implementing agencies. So, farmers in the study area will be benefited from this study. The study will be used as a benchmark and entry point for development works and future studies.

1.6. Scope of the study

The study was done at district level and covered many parameters. In the study, yield and yield parameters of onion, Soil moisture determination, water use efficiency and water usage analysis were done.

2. LITERATURE REVIEW

2.1. Water Resources of World

Water covers about two-thirds of the Earth's surface, but it is a scarce resource as most of it is unavailable and too salty for use. Only 2.5% of the world's water is not salty, and two-thirds of that is locked up in the icecaps and glaciers. About 20% of the fresh water is not accessible, and much of it arrives at the wrong time and place, as monsoons and floods. Currently, less than 0.08% of all the Earth's water is available for humans use. But, of this small proportion of available water more than two-third is used for agriculture (FAO, 2000).

2.2. Irrigation Potential of Ethiopia

Development of irrigation has been expanding and intensifying agriculture to improve food security at household and community levels. Irrigation farming is not just an application of water on crops to supplement deficit rainfall but the type of system of irrigation used is a key reason in determining successful irrigation farming. Expanding irrigation development on various scales is one of the best alternatives to consider for reliable and sustainable food security development.

Modern irrigated agriculture in Ethiopia dates back to 1960 when it started with the production of industrial crops (sugar and cotton) on large-scale farms by private investors in the Awash area and Modern small-scale irrigation through communal schemes started only in the 1970s to fight major droughts and famines (Awulachew *et al.* 2005).

However, local farmers had already been practicing traditional irrigation during the dry season using water from river diversions for subsistence crop production (Awulachew, 2006). Irrigation and improved agricultural water management offer opportunities to cope with the impact of climatic variability and to enhance productivity per unit of land and to increase the production volume. The irrigated area has increased rapidly in 1995 it was 75, 000 ha and in 2003 it had increased to 200, 000 ha (Diao and Pratt, 2007).

Consequently, the use of resource for the development of irrigation potential in pastoralist areas requires innovations, as it poses significant changes related to pastoralists' traditional lifestyles such as sedentary farming, voluntary settlement from degraded highlands, and small to large-scale commercial agriculture. To improve the food security of the country, the country gives more emphasis to small-scale irrigation development activities involving farmers in different phases (Awulachew, 2019). This demonstrates that there are strategies for ongoing irrigation-based development actions for accelerated and sustained development to end poverty in the country.

2.3. Description of irrigation methods

Irrigation can benefit the poor people specifically through higher production, higher yields, lower risks of crop failure, and higher and all year-round farm and non-farm employment (Samson *et al*., 2010). Irrigated agriculture sector is the largest water user in the world, consuming about 80-90% of available freshwater (Steduto *et al.*, 2012), yet with poor water use efficiency, on average not exceeding 45% of the applied amount (Hamdy *et al.*, 2003). Numerous strategies are available for improving water use efficiency, including the use of improved irrigation methods (Huang *et al.*, 2006). In addition, water use efficiency can be improved with precise delivery systems for water conveyance, allocation, and distribution (Hamdy *et al.*, 2003), since the application efficiency of different irrigation methods varies: e.g., for surface (furrow) irrigation is 60-90%, for sprinkler irrigation it is 65-90% and for drip irrigation, it is 75-90% (Fairweather *et al.*, 2003).

An improvement in water use efficiency can be achieved through more precise irrigation methods combined with proper irrigation scheduling, irrigation scheduling not only on crop water requirements but designed and managed to make sure optimal use allocated water (Huang *et al.,* 2006). Furthermore, the soil texture may represent an important and determining factor for the performance of a particular irrigation method (Verbeten, 1998). Compared with furrow irrigation, drip irrigation can substantially improve water use efficiency by minimizing deep percolation and evaporative losses of water (Jha *et al.,* 2016).

2.4. Drip irrigation

Drip irrigation also known as trickle irrigation is a localized irrigation method allows water to drip slowly to the roots of plants, either onto the soil surface or directly onto the root zone, through a network of valves, pipes, tubing, and emitters. The basic concepts of drip irrigation systems are to deliver near-optimal soil moisture content in the root zone of the plant. Innovation of low cost, small-scale technologies and water storage units has dramatically improved the lives of millions of poor farm families in developing countries (Keller and Roberts, 2004). In the modern drip irrigation system, water is supplied near the rootzone. Drip irrigation saves water because only the plants root receives moisture. Little water is lost to deep percolation if the proper amount is applied.

The purpose of drip irrigation is to apply water to the root of plants in regular low volumes in an attempt to meet the crop water requirement. With this purpose in mind, it is essential that the emitter flow variation and/or the uniformity of water distribution be known, particularly since irrigation time and rate are ultimately based upon on these variables.

2.5. Performance Indicators of Drip Irrigation System

2.5.1. Co-efficient of variation (CV)

Co-efficient of variation determines the flow rate uniformity of the drippers (Soomro *et al.*, 2012).

$$Cv = \frac{\sigma}{q_{avg}} \tag{2.1}$$

Where, σ = Standard deviation of emitter flow rate

q_{avg} = average emitter flow rate

2.5.2. Emission uniformity, uniformity coefficient and flow variation

The most indicators of the uniformity of water application to a field are dependent on the irrigation system are the emission uniformity (EU), emitter flow variation (qvar), uniformity coefficients (UC) and coefficient of variation (CV). In surface drip irrigation systems, uniformity can be evaluated by direct measurement of emitter flow rates.

Emission uniformity

The emission uniformity is affected by the variation of pressure head due to elevation changes and head losses along the lines, as well as by water temperature, manufacture's variation, grouping of emitters, clogging, variability in soil hydraulic characteristics, and emitter spacing (Sachin *et al.*, 2013). The emission uniformity relationship introduced by Karmeli et al. (1985) and they indicated that emitter flow uniformity could also be applied to system uniformity using the following equation.

$$EU = \left(\frac{q_{min}}{q_a}\right) * 100 \tag{2.2}$$

Where, EU = Emission uniformity in percent

q_{min} = average of the lowest one fourth of the field data emitter discharges (Lh^{-1})

q_a = average of all the field data emitted discharges (Lh^{-1})

Uniformity coefficient

Drip irrigation system uniformity is often described in terms of the coefficient of variation, which is the ratio of the standard deviation to the mean (ASAE, 1985). This can be expressed as the statistical uniformity coefficient (UC) and is given as: -

$$UC = \left(1 - \frac{S_q}{q_a}\right) * 100 \quad (2.3)$$

Where, UC= uniformity coefficient, (%)

S_q = represents the standard deviation (average absolute deviation of all emitters flow from the average emitter flow, (Lh^{-1})

q_a= average /mean/ emitter flow rate (Lh^{-1})

Emitter flow variation

The emitter flow is controlled by the hydrostatic pressure at the emitter. This means when a pressure variation in the drip irrigation line there would be an emitter flow variation along the irrigation line. According to Wu (1983), the emitter flow variation, q_{var}, is calculated using

$$q_{var} = \left(\frac{q_{max} - q_{min}}{q_{max}}\right) \quad (2.4)$$

Where, q_{max}= the maximum emitter flow rate (l/hr)

q_{min} = the minimum emitter flow rate (l/hr)

In general, in drip irrigation, water is conveyed in a pipe network to the points where it infiltrates into the soil. Therefore, the uniformity of application depends entirely on the uniformity of the distribution and discharge rates throughout the system. The variation in discharge rates between the different distributors is a function of the pressure variations within the system and discharge characteristics of distributors.

2.6. Origin and Description of Onion crop

The primary origin of onion is Central Asia with secondary center in Middle East and Mediterranean Region (Birhanu Melese, 2016). Onion is an herbaceous biennial monocot cultivated as an annual. Onions are usually grown from seed, and flowering and seed production are important for crop production (Brewster, 1994).

The onion bulb consists of the swollen bases (sheaths) of bladed leaves surrounding swollen bladeless leaves. Each leaf consists of a blade and sheath; the blade may or may not be distinctive. Major bulb features are uniformity of shape, size and skin color, pungency and dry matter (Rabinowitch, 2018). Onion roots are shallow, most occur within 15-20 cm of the surface, and seldom extends horizontally beyond 50 cm. Onion roots are short lived, being continuously produced.

2.7. Ecological requirements of onion

Altitude

Onion can grow between 500 and 2400 meter above sea level. Nevertheless, according to Lemma and Herath (1994), the best growing altitude in Ethiopia is between 700 and 1800 m above sea level.

Temperature

According to Shanmugasundaram and Kalb (2001), onion seedlings grow the best at temperatures between 20 and 25°C. For optimum vegetative growth, a temperature between 18 and 22°C is needed, however, plants will still grow at temperatures as low as 10 and as high as 27°C (Comrie, 1997). From bulb initiation up to harvesting, higher temperatures between 25 and 28°C are required.

Soil

Onion can be grown in all types of soils, but for higher yield well drained friable loam soil with a pH of 6.0-6.8 is good (Brewster, 1994). Soils with high water holding capacity are better able to provide moisture to the shallow rooting system and adequate moisture is critical for uniform seedling emergence.

2.8. Importance of Onion production

Onion is by far the most important of the bulb crops cultivated commercially in nearly most parts of the world. Onion is produced on small and large scale in Ethiopia. It occupies an economically important place among vegetables in the country. Onion contributes substantially to the national economy, apart from overcoming local demands. It is used almost daily as a spice and vegetable in the local dish regardless of religion, ethnicity, and culture (CSSE, 2006). It has distinctive flavor, pungency, is eaten as fried, boiled, roasted or raw in salad as vegetable, and is widely used as a condiment in preparation of soups, savory dish, canned food product, salads and sandwiches. Moreover, it is also processed as pickle, chutney, and sauces and consumed in dehydrated form (Muhammad S.J, 2004).

2.9. Potentials and constraints of onion production in Ethiopia

The country has a great potential to produce onion throughout the year both for local consumption and for export because of presence of underground and surface water potential, which can be used, for the production of horticultural crops including onion (Selesh, 2010). Moreover, the Ethiopian Agricultural Research Institute has made efforts towards improvement of varieties and released different improved varieties including Adama Red, Bombay Red, Red Creole, Melkam, Mermiru Brown, Nasik Red and Nafis (Lemma and Aklilu, 2003).

The production and efficiency of horticultural crops including onion is significant poorer than other African countries. Generally, in Ethiopia, as well as in Amhara Region the production of onion is very low due to insufficient availability of quality seeds, technologies used and inappropriate cultural practices (Nikus and Mulugeta, 2010). Onion is produced by traditional farming practices where the farmers lack improved onion production technologies. Improved onion seeds are inadequate because of lack of seed production system in the region.

Furthermore, due to favorable tropical conditions in Ethiopia, which favor the development of pests, onion is suffering from various diseases and insect pests throughout the country including in Amhara Region. The most common diseases occurred in Ethiopian onion farms are purple blotch, onion neck rot and powdery mildew, which are caused by the fungi Alternariaporri, Botrytis cineraria and Peronospora destructor, respectively (Lemma and Aklilu, 2003). The damages caused by pests are further interested because most onion-growing farmers do not use the exact pesticides and the recommended rates for the control of pests. Some traders mix pesticides with other substances (adulteration) which may either reduces their effectiveness or damage the crop plants and so sustain economic losses for onion growing farmers.

2.10. Deficit irrigation

Under conditions of scarce water supply, application of deficit irrigation (DI) could provide greater economic returns than maximizing yields per unit of water. The DI has been considered worldwide as a way of maximizing water use efficiency (WUE) by eliminating irrigation that has little impact on yield (Enchalew, et al., 2016). With DI, the crop is exposed to a certain level of water stress either during a particular period or throughout the whole growing season Kirda C (2000). A variety of crops have been found to benefit from DI strategy and many researchers pointed out that yield loss that may result from DI is offset by the benefits of reduced water use. The response of Onion to water deficit has been reported by Nigatu A et al., (2010) that showed DI to increase the water use efficiency of onion.

The challenge for the coming decades will, therefore, be the task of increasing food production with less water, particularly in countries with limited water, land resources and inefficient water use (FAO, 2002). Therefore, development of new irrigation scheduling techniques which are not necessarily based on full crop water requirement is important.

The main objective of deficit irrigation is to increase the water use efficiencies (WUE) of a crop by eliminating irrigation's that have little impact on yield (Kirda, 2002). The resulting yield reduction may be small compared with the benefits gained through diverting the saved water to irrigate other crops for which water would normally be insufficient under traditional irrigation practices.

Drip irrigation is one of the most efficient forms of irrigation technology that will allow applying light and frequent irrigation. The experience from many countries showed that farmers who switch from surface irrigation to drip systems can cut their water use by 30% to 60% and crop yields often increase at the same time (Nigatu A et al., 2010). Therefore, the objectives of this study were to identify the effect of deficit irrigation on water efficiency and yield of onion bulb under drip irrigation and full furrow irrigation.

2.11. Water use efficiency

Increasing freshwater scarcity has called for researchers into developing new irrigation technologies with the purpose of improving water use efficiency in plants (Wang *et al.,* 2013). Increased water use efficiency (WUE) in agriculture plays an important role in maintaining food security and, it is one of the important goals in water use management (Deng *et al.,* 2006).

Water-use efficiency (WUE) is generally defined in agronomy as the ratio of crop yield (usually economic yield) to water used to produce the yield. WUE is a measure of the productivity of the water consumed by the crop. In areas with limited water resources, where water is the greatest limitation to production, WUE is the main criterion for evaluating the performance of production systems (Kirda, 2002). Bekele and Tilahun (2009) indicated that deficit irrigation increased the water use efficiency of onion. The water use efficiency was calculated by dividing harvested yield in kg by unit volume of water (kgm^{-3}).

Approaches to dealing with water scarcity include efforts to improve crop water use efficiency (WUE) by changing irrigation methods (furrow, drip, and sprinkler), applied amounts (deficit irrigation), crops, tillage practices, and other management methods (Nazirbay *et al.,* 2007).

Two kinds of water use efficiencies, namely, crop water use efficiency (CWUE) and irrigation water use efficiency (IWUE) are determined as:

- CWUE= Ya/ETc (2.5)
- IWUE=Ya/IW (2.6)

Where: Ya - yield ($kgha^{-1}$),

Etc - crop water requirement (m^3ha^{-1}), and

IW - irrigation water applied (m^3ha^{-1})

2.12. Crop Water Requirement Estimation methods

The term crop water requirement (CWR) is defined as the amount of water required to compensate the evapotranspiration loss from the cropped field. The CWR refers to the amount of water that needs to be supplied, while crop evapotranspiration refers to the amount of water that is lost through evapotranspiration (Allen *et al*., 2015).

The growth and yield of any crop is related to the amount of water used. The variable amount of water contained in a soil and its energy state are important factors affecting growth of plants (Hillel, 2004). A procedure for calculation of crop evapotranspiration for well-watered conditions using the ET_o approach is recommended by (Allen *et al*.,1998).

$$ET_c = ET_o \times K_c \tag{2.7}$$

Where, ET_c = crop evapotranspiration(mm/day); K_c = crop coefficient; ET_o = reference evapotranspiration(mm/day)

Some of empirical methods employed to determine reference evapotranspiration are discussed below.

FAO penman-Monteith equation

The ETo can be estimated using the Penman-Monteith equation. The equation uses standard climatological records of solar radiation (sunshine), air temperature, humidity and wind speed. To ensure the integrity of computations, the weather measurements should be made at 2 m (or converted to that height) above an extensive surface of green grass, shading the ground and not short of water. The updated values of crop coefficients are determined from (Allen *et al*. 1998).

Various crop growth stages and their respective lengths are identified for the locations of interest, and then K_c for the various stages of the crop is determined. K_c values are then adjusted for frequency of wetting condition for rain or irrigation. Then crop coefficient curves are developed to determine Kc values for periods of any length, like monthly or daily periods. Crop ET is then calculated for well-watered conditions for each period of interest as the product of ET_o and K_c. Having ET_c and all necessary meteorological data, the CWR can be computed with the aid of CROPWAT program.

The calculation can be done using CROPWAT model. The ETo is calculated based on the FAO Penman-Monteith method (Allen *et al*., 1998) as:

$$ET_o = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{T + 273} U_{2(e_s - e_a)}}{\Delta + \gamma(1 + 0.34U_2)} \tag{2.8}$$

where, ETo is reference evapotranspiration (mm/day), Rn is net radiation at the crop surface (MJ/m2/day), G is soil heat flux density (MJ/m2/day), T is mean daily air temperature at 2 m height (°C), U2 is wind speed at 2 m height (m/s), es is saturation vapor pressure (kPa), ea is actual vapor pressure (kPa), es - ea is saturation vapor pressure deficit (kPa), Δ is slope of vapor pressure curve (kPa/°C), Y is psychrometric constant (kPa/ °C).

Based on the comparative studies of the ET_o methods and recommendations of a panel of experts and researchers organized in FAO, Rome, in 1990, the Penman Monteith equation has been adopted as the globally best performing method of estimating evapotranspiration.

2.13. Soil moisture content determination methods

Plant growth depends mainly on the soil moisture between field capacity and permanent wilting point which is known as available soil moisture. According to Hansen, *et al*., (1980), in irrigated regions, the capacity of the soil to store available water for use of growing crops is special importance and interest, because the depth of water to apply in each of irrigation and the interval between irrigation are both influenced by storage capacity of the soil. Therefore, measuring soil moisture helps to detect if there is a water shortage that can reduce yields or if there is excessive water application that can result in water logging or leaching of nitrates below the root zone. There are different methods of estimating or measuring soil moisture content in the soil. Some of them are gravimetric method, tension meter, time domain reflectometry, electrical porous blocks, and neutron probe.

Gravimetric method

Gravimetric method is the only direct means to assess soil moisture and it is therefore essential for calibrating instruments used in the indirect methods (Sharma et al., 2018). This method involves taking a soil sample from the field, accurately weighing it, completely drying it out in an oven at 105^{oC} for about 24 hours, re-weighing the dry sample and calculating soil moisture percentage from the weight loss. The accuracy of gravimetric method depends on the number of samples taken and, on the skill, used in obtaining and handling the samples. The use of this technique ensures accurate measurements at low cost and is not dependent on salinity and soil type, and relatively very easy to calculate. The main advantage of this method is that it requires relatively simple, inexpensive equipment, and one labor. Soil water content most commonly is expressed as percent water by weight, percent water by volume, or millimeters of water per meter depth of root zone. The soil moisture content is calculated using the following equation as stated by Michael (1997).

$$MC(\%) = \frac{Wws - Wds}{Wds} * 100 \quad (2.9)$$

Where, MC (%) - Moisture content (%)

W_{ws} - Weight of wet soil (gm)

W_{ds} - Weight of dry soil (gm)

Tensiometer Method

Tensiometers measure the tension or the energy with which water is held by the soil. It consists of a porous point or ceramic cup measuring device (Sharma et al., 2018). The essential parts of a tensiometer consist of the porous cup with a reservoir of water inside, the connecting tube, and the sensing element of a vacuum gauge or a mercury manometer.

The shape and size of the ceramic cup can be variable and the accuracy depends on the gauge or transducer used (Muñoz-Carpena, 2004). These tubes are installed into the soil at the depth at which the soil moisture measurement is required. At this depth, the water in the tensiometer eventually comes to pressure equilibrium with the surrounding soil through the ceramic tip. When the soil dries, soil water is pulled out through the tip into the soil, creating a tension or vacuum in the tube. As the soil is rewetted, the tension in the tube is reduced, causing water to reenter the tip, reducing the vacuum.

Tensiometers do not provide direct information on the amount of water held in the soil. Tension measurements are useful in deciding when to irrigate, but they do not indicate how much water should be applied (Alderfasi and Nielsen 2001). A special curve named soil moisture characteristic curve (Moisture Content Vs. soil suction curve), plotted from tensiometer readings is an indirect measure of soil moisture content.

3. MATERIALS AND METHODS

3.1. Description of the study area

The experiment was carried at Woreta ATVET College fruit and vegetable farm in Amhara, Ethiopia. The experiment site is located between 11° 53’ N latitude and 37° 42’ E longitude. The area has a warm humid climate with mean monthly minimum, maximum temperatures and average total annual rainfall of about 13.5^{0}C, 26.1^{0}C and 1205 mm respectively. The altitude of the study site is 1815 meters above sea level (m.a.s.l.). Soil in Fogera district is black vertisol with a clay content of 71.25%; slightly acidic (pH 5.90). The total N and available P contents of the soil are medium, while the organic matter content is low (Tilahun et al., 2013).

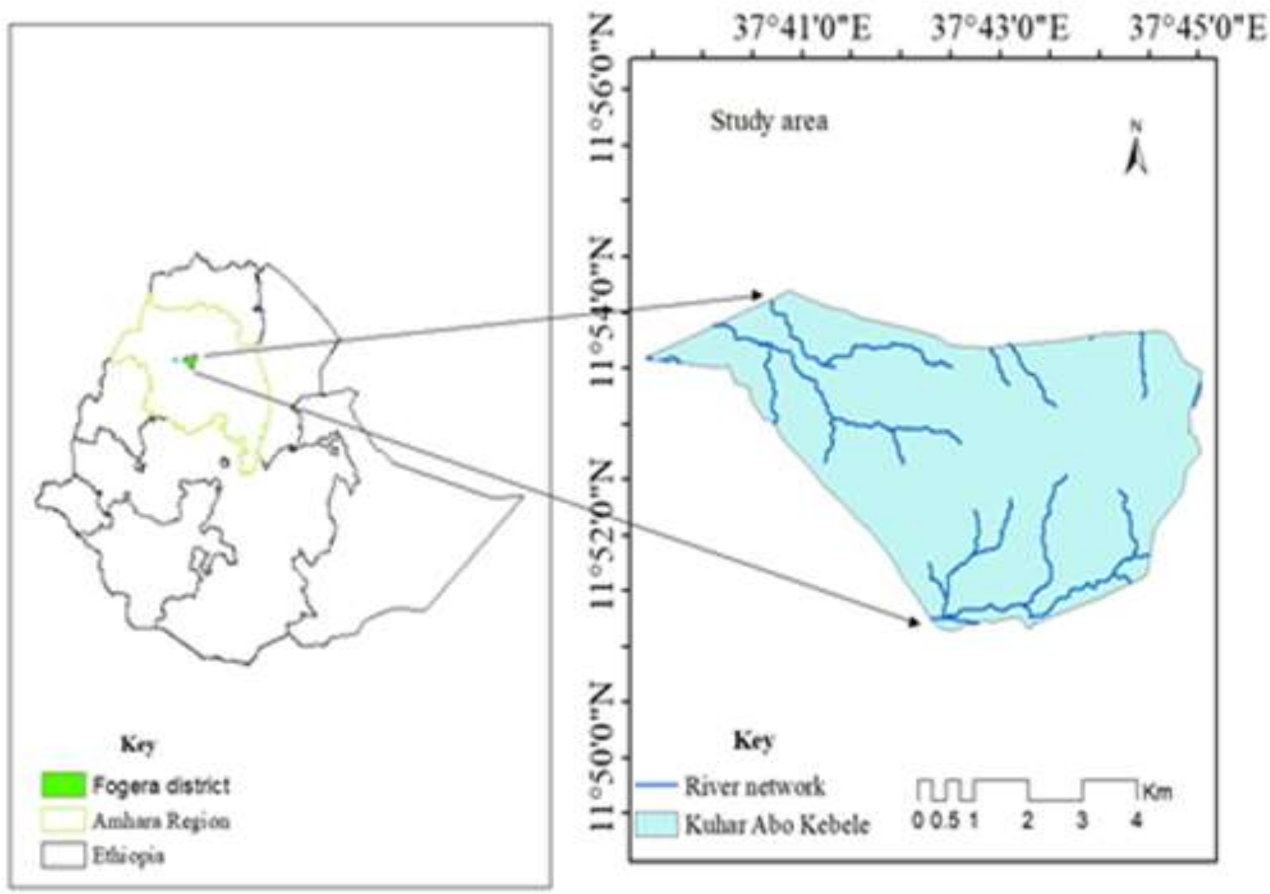

Figure 3.1 Map of the study area

3.2. Experimental Design and Treatments

The experiment was laid out in the arrangement using randomized complete block design (RCBD) with three treatments replicated three times. The irrigation types those were used for the experiment were drip irrigation at different water application levels. The Treatments include 100%ETc, 80%ETc, and 60%ETc, in drip irrigation. Depending up on irrigation level value there is no standard value put but different researchers use different values. The design of the irrigation level was in line with Teferi (2015) he used the same level of deficit.

Table 3.1: Treatments setting for the experiment

Treatments	Explanations
T1	100% ET_C irrigation water requirement through drip irrigation method
T2	80% ET_C irrigation water requirement through drip irrigation method
T3	60% ET_C irrigation water requirement through drip irrigation method

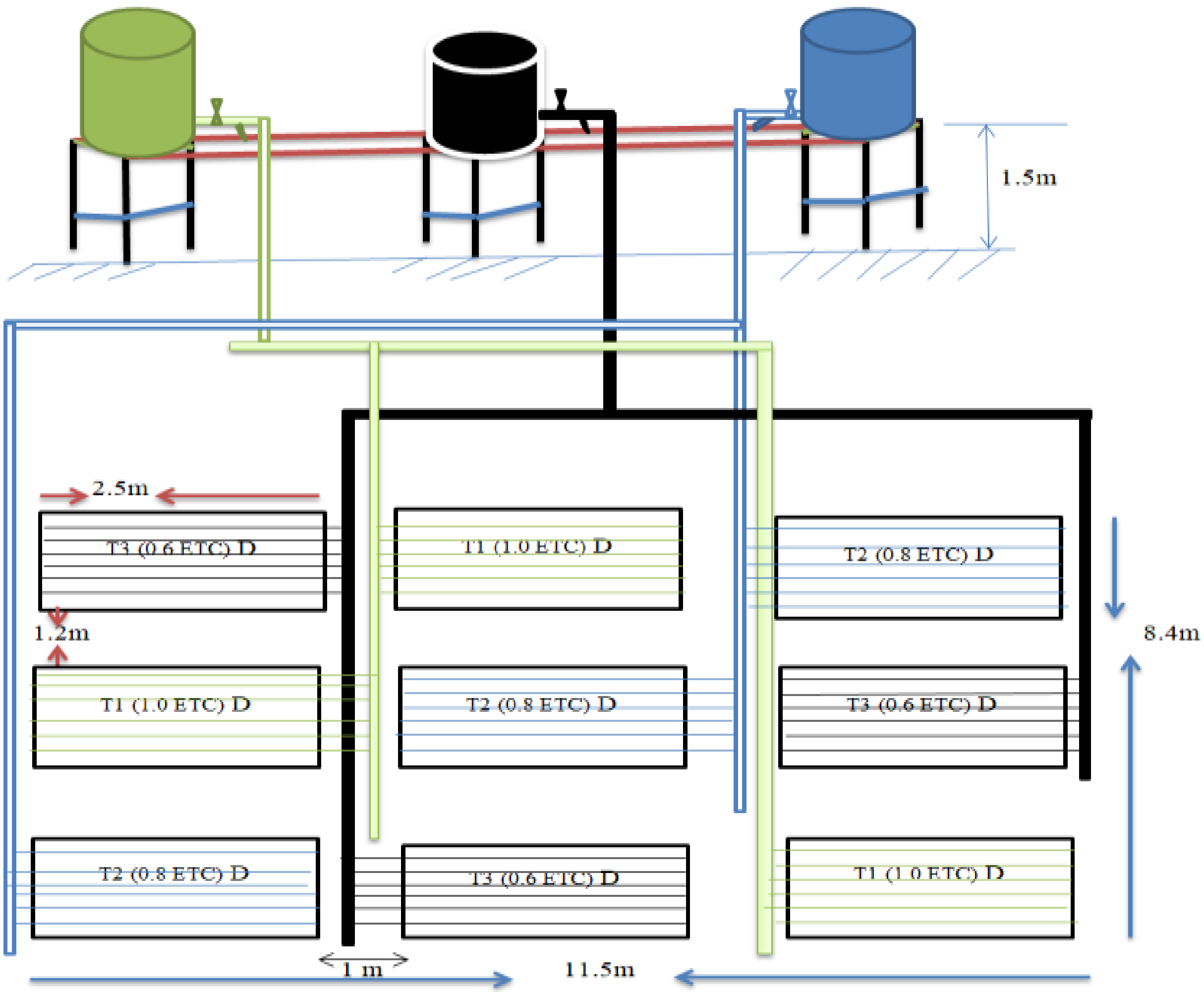

Figure 3.2 Lay out of block, treatment plots and randomization

3.3. Experimental Procedures

3.3.1. Land preparation and Seedling production

The field for nursery bed was ploughed and harrowed to bring it to a fine tilth and a seed bed was prepared. Bombay red onion variety was used for the study. Seeds were gained from Adet Agricultural Research Centre. Seeds of this cultivar were sown on 16th January 2020 on a well-prepared seed bed at Woreta ATVET College fruit and vegetable nursery site. After sowing; lightly covered with soil and then the bed was covered with dry grass mulch until emergence and watered using a watering can. NPS fertilizer were applied at the rate of 100 kg ha^{-1} at sowing and

Urea (46% N) were applied at the rate of 100 kg ha^{-1} half at sowing and the remaining half at 15-20 days after sowing to enhance growth of the seedlings (EARO, 2004). A week before transplanting, the amount of water to be supplied to the nursery seedbed was reduced in order to harden the seedlings to reduce transplanting shock. Before transplanting, the seedlings were watered to enhance easy uprooting and to prevent root damage. Seedlings were well acclimatized before transplanting.

3.3.2. Preparation of the experimental plots

Before transplanting Seedlings, the experimental field plot was ploughed three times using tractor, leveled and made ready by dividing the field in to 3 blocks and 9 plots for transplanting. Each block had 3 treatment plots. The plot size was 1.2 m x 2.5 m with 1m spacing between adjacent plot and 1.2 m between blocks. A plot consisted of six rows with a row length of 2.5 m. The seedlings were transplanted to field plots on 29th February 2020. One day before transplanting of seedlings, the seedling bed was irrigated for safe uplifting of seedlings. Transplanting was done late in the afternoon to reduce the risk of poor establishment. Vigorous, strong and healthy seedlings were selected. Seedlings were transplanted when they reach 12-15 cm height or 3-4 true leaf stages by carefully uprooting from nursery bed. Onion seedlings were transplanted with spacing of 20 cm between the rows and 10 cm between plants (Tegen et al., 2016). A row consisted of 25 plants and a plot consisted of 150 plants.

Phosphorus was applied as NPS at the rate of 100 kg ha^{-1} in single application as side dress at the time of planting and Nitrogen was applied in the form of urea at the rate of 150 kg ha^{-1}. 50% of the nitrogen was applied at the time of transplanting the seedlings, while the remaining half dose of nitrogen was applied four weeks after transplanting (EARO, 2004).

3.3.3. Drip irrigation system installation

Small scale drip system consists of stand, water tanker, main lines, sub main, laterals and emitters. Before installation, the plots were leveled manually to create uniform plots within the given treatment. The drip laterals were installed in such a way that the spacing between rows is equal to the spacing between the lateral and spacing between plants is equal to emitters spacing. Each plot consisted of six lateral lines; each lateral has 2.5 m length with 25 emitters, so that each emitter drops water to a single plant. Three water tankers were prepared and placed at a height of 1.5m above the ground surface to supply the required irrigation water to a block of experimental field. The water distribution system components were laid and connected to the water container and to the individual drip lines. The laterals of 12mm diameter were laid along the crop rows and each lateral served one row of crop. The end of the laterals, the main and sub main lines were closed with end cups to prevent out flow of water. The types of emitter used for this experiment were in lines. The spacing between drippers was 10cm. The discharge of emitter was 0.79l/s.

3.3.4. Irrigation water application

Water applications for full irrigation treatments (100%ET_C) were based on the estimated crop water requirement calculated over the growing period and those water deficit treatments 80% and 60%ETc were imposed as planned. Irrigation frequencies were the same for all treatments under drip irrigation, which varies from 1 up to 4 days interval based on growth stage.

Irrigation interval and depth of irrigation was determined based on allowable soil moisture depletion. Irrigation scheduling was determined based on tensio-meter reading and soil moisture monitoring using gravimetric method. Irrigation was applied to onion crop when about 30% of available soil moisture was depleted from the effective root zone. Prior to irrigation, available soil moisture content from drip with100%ET_c treatments were measured at 0-30cm and 30-60cm soil depths using the gravimetric method. The depth of water was varied based on growth stages of onion. Irrigation interval was calculated by dividing depth of application for crop evapotranspiration (ET_c). The amount of water applied at one irrigation time at each growth stages for full irrigation (100%ET_c) treatment was calculated.

For drip irrigation three water containers were put on stand at 1.5 m height. The first water container served drip with 100%ET_c. The second one was for 60%$ET_{c.,}$ and the third one was for 80%$ET_{c.}$ The amount of water filled in each water container was based on calculated irrigation water requirement at different growth stage. Since the experiment was done under controlled environment, the entire water requirement was covered by irrigation water. Green house covered with recommended plastic sheet was applied to protect the experimental site from rain fall.

Total available water

The total available water (TAW) for plant use in the root zone was computed as the difference in moisture content between field capacity and permanent wilting point as (Merriam et al., 1983).

$$TAW(mm) = \left(\frac{(FC - PWP) * \rho d * D}{100}\right) * \frac{1}{\rho_w} \quad (3.1)$$

Where, TAW - Total available water (mm)

FC - Field Capacity (%)

D - Effective root depth of crop (m)

PW P - Permanent wilting point (%)

ρd - Bulk density of soil (g/cm3)

ρ_w - Water density (g/cm3)

Readily Available Water (RAW)

The RAW is the amount of water that crops can extract from the root zone without experiencing any water stress. For maximum crop production, the irrigation schedule should be fixed based on

RAW. The permissible soil moisture depletion / RAW was taken as 100%ET_C and all other application levels was adjusted accordingly to their percentage proportion. The readily available water was determined based on the following equation, where permissible soil water depletion level was taken 30% as reported by Orta and Ener (2001) for higher yield of onion.

$$RAW = TAW * p \tag{3.2}$$

Where; RAW = readily available water (mm)

P = fraction for allowable soil moisture depletion

TAW = total available water (mm).

GROSS IRRIGATION

The gross requirement for drip irrigation was calculated by taking 90% of application efficiency. Gross irrigation requirement of onion crop was determined by equation (FAO, 1998).

$$GIR = \frac{NIR}{E_a} * 100 \tag{3.3}$$

Where, GIR = growth irrigation requirement (mm)

E_a = application efficiency (%)

3.3.5. Evaluation of irrigation systems

The overall application efficiency of the small-scale drip system relatively depends on the application losses and the uniformity of the distribution. In this study, randomly selecting five emitting points for each lateral of the drip systems, then the performance of the irrigation events is sought in terms of emission uniformity (EU), emitter flow variation (qvar), coefficient of variation (CV), and uniformity coefficient (UC). This evaluation was carried out to check uniform distribution of water in the drip system within and between blocks.

To determine the uniformity coefficient and coefficient of variation (CV), the emission uniformity and also emitter flow variation (qvar) in the drip systems, the discharge rate of the emitting devices was determined by collecting the water at the head, middle and tail end of the laterals, and measured in the graduated cylinder.

In general, in drip irrigation, water is conveyed in a pipe network to the points where it infiltrates into the soil. Therefore, the uniformity of application depends entirely on the uniformity of the distribution and discharge rates throughout the system. The variation in discharge rates between the different distributors is a function of the pressure variations within the system and discharge characteristics of distributors.

3.4. Data collection and analysis

Both primary and secondary data were collected based on the requirement of this research. The primary data such as soil sample, onion growth and yield parameters, discharge, moisture content of soil, applied water were directly collected from experimental field and then analyzed. The secondary data such as rain fall, altitude, sun shine duration, relative humidity, minimum and maximum temperature, wind speed etc were collected from Fogera rice research Centre, Fogera meteorological station, Fogera district agricultural office and Amhara Bureau of agriculture.

3.4.1. Soil sampling and analysis

Representative soil samples were collected from the experimental field randomly and diagonally using an auger at 30cm increments (0 –30 cm, and 30 – 60 cm) depth from different places of experimental field before planting as the root depth of onion reaches up to 50cm. The collected disturbed and undisturbed soil samples were properly labeled, packed and sent to Amhara design and supervision works enterprise laboratory service for analysis. Soil samples were taken for the analysis of bulk density, moisture content at field capacity (FC), permanent wilting point (PWP), pH, Electrical conductivity and texture.

Bulk density

Bulk density is influenced by the amount of organic matter in soils, their texture, constituent minerals, compactness of the soil and porosity. Knowledge of soil bulk density is essential for soil management, and information about it is important in soil compaction as well as in the planning of modern farming techniques (Pravin *et al.*, 2013).

Bulk density of soil at experimental site was determined by using Core method (FAO, 2020). This method uses a metal core of a known volume, which represents the volume of the soil for the purpose of the calculation of the soil bulk density. The bulk density was determined by taking undisturbed soil samples from effective root zone using core sampler. The core sampler was pushed into the soil to the 0-30 cm and 30-60 cm depth and then gently removed without altering the contents of the core. The core samples from different depths were taken from the experimental field to determine the bulk density. Soil bulk density can be determined by using FAO (2020) equation.

$$\rho_b = \frac{W_d}{V} \quad (3.4)$$

Where, ρ_b - Bulk density (g/cm^3)

W_d - Dry weight of soil (g)

V - Volume of core cutter (cm^3)

Soil moisture content

Soil water is held within the pore space, which is the space between soil particles. From the experimental site soil samples were taken for the analysis of bulk density, moisture content at field capacity (FC) and permanent wilting point (PWP). Bulk density of the soil was determined using five undisturbed soil samples collected by using core cylinder of 100cm^3 volume at 30cm depth interval. Field capacity and permanent wilting point of soil moisture content on dry weight and volume basis were determined from 5 soil samples collected from experimental site before ploughing. The analysis was made in the soil laboratory of Amhara design and supervision works enterprise.

In gravimetric moisture content determination method, soil moisture is measured by weighing a field moist soil and oven drying that soil for about 24 hours at a temperature of 105 °C to remove all water. The soil should then be weighed again to determine the dry weight. The difference between the wet and the dry weight is the amount of water in that soil (FAO, 2020). Gravimetric method was selected because it requires medium cost, medium technology, and high accuracy with low difficulty (FAO, 2020). Soil moisture content of the experimental site was determined using gravimetric method. Therefore, for determining the soil moisture on a weight basis, the samples of field soil were collected and oven dried, and then calculated based equation as stated by Michael (1997).

3.4.2. Crop water requirement and irrigation scheduling

Crop data

The data collected for the test crop in the experiment includes length of growing stages (days), crop coefficients (Kc), rooting depth (RD), moisture depletion level (P), which were obtained from FAO guidelines (Doorenbos and Kassam, 1992; Allen et al., 1998) and other published materials as well as agronomic information data.

Reference crop evapotranspiration

The required data such as location i.e., altitude, latitude and longitude of the meteorological station, average daily values of maximum and minimum air temperatures (o_c), air humidity, sunshine duration (hours) and wind speed at 2-meter height were collected from the Fogera rice research Centre and metrological station. Monthly and annual reference evapotranspiration (ETo) for each year of climatic record (1990-2017) were calculated based on the modified FAO Penman-Montheith equation (Allen et al., 1998) using FAO CROPWAT software.

Crop water requirement

The crop water requirements (ET_C) over the growing season were determined by multiplying the ET_o values with the onion crop coefficients (Kc) given by Allen et al. (1998) as 0.7 for the 1st, 0.90 for the 2nd, 1.05 for the 3rd and 0.75 for the 4th growth stages. The gross irrigation water requirement was computed by adopting a field application efficiency of 90% for drip irrigation system. The application depth of water was done based on daily water deficit of soil moisture.

After determination of the application depth of irrigation water, the irrigation interval was determined using tensiometer. The tensiometer was installed at 100%ET_C of drip irrigation treatment plot and at required depth according to growth stage of onion. When the tension meter reads 25 cent bars, irrigation was applied. It implies 30% of the available water is depleted or the available water reaches70% of field capacity. It was taken from moisture calibration curve done in the college by collaboration with experts coming from Canada and work on Agricultural transformation through strong vocational education (ATTSVE) project. Tensiometer helped to determine water requirement and irrigation interval indirectly.

Water deficit (WD)

Water deficiency was calculated based on the equation stated by (Garg and Dadhich, 2014).

$$\text{Water deficit (WD)} = TAW * \rho \qquad (3.5)$$

Where, ρ = Fraction for allowable soil moisture depletion

TAW = Total available water

This is only for 100%ETc. For the other treatments, 80% and 60% of the full irrigation treatment was taken as water deficit respectively.

3.4.3. Infiltration rate determination

The soil infiltration capacity was measured using the double ring infiltrometer. The double ring infiltrometer test can be used to determine the infiltration rate based on small in situ field measurement (SFPW, 2017). Infiltration measurement was made at three randomly selected spots and the average value was made to represent the infiltration rate of the experimental site. Before land preparation for the experiment, Infiltration characteristics of the soil were determined by ponding water in to the double ring infiltrometer that installed with 15 cm depth into the soil in order to prevent lateral flows.

Stopwatch used to record time and the reading was continued until infiltration becomes constant. The procedures were repeated until at least three consecutive uniform infiltration depths were observed and the steps outlined by Walker (2003) was observed to install and recording the parameters. Based on this the average infiltration rate of the study area was 5mm/h.

3.5. Phenological and growth parameters

Phenological and growth parameters data such as, day to maturity, Plant height, leaf number per plant, leaf length and neck diameter were collected from 10 randomly selected and pre-tagged sample plants from four central rows of each plot. Ruler was applied to measure height and length of onion. Neck diameter of onions was measured using caliper.

3.6. Yield and yield components parameters

Bulb diameter (cm), Bulb height (cm), Mean bulb weigh (g/plant), fresh biomass yield (g/plant), and dry biomass yield (g/plant) data were collected from 10 randomly selected and pre-tagged sample plants from four central rows of each plot and were measured using calipers and sensitive balance.

Total bulb yield (t ha^{-1}): marketable and unmarketable bulb yields were recorded from bulbs produced by all plants from the central four rows per net plot. Bulbs were weighed after curing and expressed as kg /plot and then converted into t ha^{-1}.

Marketable bulb yield (t ha^{-1}):- Marketable bulb yield was determined after discarding bulbs smaller than 3 cm in diameter, smaller than or equal to 20 g in weight, splitted, thick necked, rotten and discolored after topping and curing of onion crop (Lemma and Shemels, 2003). The yield was recorded from all plants in the central six rows per plot and was converted to t ha^{-1}.

Unmarketable bulb yield (t ha^{-1}):- was recorded as the total weight of damaged, physiological disordered, discolored, pest damaged, splitted, thick necked, rotten and small bulbs (below 20 g in weight, and less than 3 cm in diameter) after curing. (Lemma and Shemels, 2003).

3.7. Statistical Data Analysis

The collected data were analyzed using statistical analysis system (SAS) software. Mean separation was carried out using least significance difference (LSD) 5% level of significance (Gomez and Gomez, 1984).

Analysis of variance (ANOVA) was computed for data obtained from crop and from the soil using general linear model of the statistical analysis system (SAS 9.4) version and treatments means were compared using Fisher's protected least significant difference (LSD) at 5% probability level. The analysis of variance indicated the presence of significant treatment differences.

4. RESULTS AND DISCUSSION

4.1. Soil Physical and chemical properties

4.1.1. Soil physical properties

The laboratory analysis for particle size classification showed that the particle size distribution in the soil was average value of 43% clay, 26% sand and 31% silt at experimental site. Therefore, based on soil textural triangle of international soil society (ISSS) system (Rowell, 1994) the soil of experimental site was clay in texture. The bulk density of the soil of the experimental site showed a slight variation with soil depth and varied from 1.37 to 1.39g/cm^3. This might be due slight decrease of organic matter with depth and compaction due to the weight of the overlying soil layer (Brady and Weil, 2008). A normal range of bulk densities for clay is 1.0 to 1.6 g/cm^3 with potential root restriction occurring at ≥ 1.4 g/cm^3 for clay (G.M *et al.*, 1965).

As indicated in table 4.1 Soil moisture content determinations at field capacity at the study area changed with soil depth between 26.3% and 25.4%. The soil at the top depth (0- 30 cm) had a field capacity of 26.3% while the subsurface soil (30-60 cm) had a field capacity of 25.4%. The moisture content at the permanent wilting point also indicated variation with soil depth between 16.6% and 15.71%. The topsoil at 0-30 cm had a permanent wilting point value of 16.6% and in the subsurface 30-60 cm was 15.71%.

Table 4.1: Physical properties of soil layers determined from the study

Soil sampling depth(cm)	Particle size distribution (%)			Textural class	Bulk density (g/cm^3)	FC (%)		PWP (%)		TAW (mm/m)
	% sand	% Silt	% Clay			W/W	V/V	W/W	V/V	
0-30	25.5	32	42.5	Clay	1.37	26.3	36.03	16.60	22.74	132.90
30-60	26.5	30	43.5	Clay	1.39	25.4	35.31	15.71	21.84	135.00
Average	26	31	43	Clay	1.38	25.85	35.67	16.16	22.29	133.95

Note: FC-field capacity, PWP-permanent wilting point, W/W-soil moisture content in weight, V/V- soil moisture content in volume and TAW-total available water

The total available water (TAW) that is the amount of water that a crop can extract from its root zone is directly related to variation in FC and PWP. The values of TAW in the experimental site soil were found to be 132.90 mm/m depth at the top, 135.00 mm/m depth in the lower layer (30-60cm) and the average is 133.95mm/m.

4.1.2. Soil chemical properties

Soil PH is an important parameter which measures hydrogen ion concentration in the soil to indicate its acidic and alkaline nature of the soil. The pH value of the current experimental site soils showed slightly acidic (pH 6.08). Onion can grow well in soil pH range from 6.0 to 8.0. The soil had average electrical conductivity of (0.174ds/m) which is below the threshold value for onion yield reduction, i.e. 1.2 dS/m (Setia *et al*., 2011). Organic Matter content (OM) is considered to improve water-holding capacity, nutrient release and soil structure. The average OM content and OC content of experimental site was 2.93 and 2.28 respectively. The OM content and OC content of the soil had average values of 1.80% and 1.05%, respectively which is rated as low. The findings of Tekalign (1991) who reported that soils having OM value in the range of 0.86-2.59% are considered low.

Table 4.2: Chemical properties of soil layers determined from the study area

Sampling Depth (cm)	pH	OC (%)	OM (%)	EC (ds/m)
0- 30	6.02	2.52	3.35	0.188
30-60	6.14	2.04	2.51	0.159
Average	6.08	2.28	2.93	0.174

4.2. Crop water requirement and Irrigation water management

The minimum ETo value of the experimental site was 4.1mm/day in June and the maximum value was 4.9mm/day in April. The minimum K_c value at initial growth stage was 0.7 and the maximum K_c value at mid-season growth stage was 1.05. Based on the reference evapotranspiration (ET_o) and crop coefficient value, The net and gross irrigation depth for full drip irrigation level treatments (100%ET_c) was found to be 405.3mm and 449.8mm respectively. The Crop water requirement values were low at the beginning of the initial growing season, increased gradually to attain a maximum during development and mid-season stage and subsequently decreased based on crop growth stages. The crop water requirement for each growth stage and the total gross irrigation requirement for onion crop were indicated in table 4.3 and 4.4.below.

Table 4.3: Irrigation water requirement of onion for drip irrigation methods (100%ETc)

Crop water requirement Parameters	Initial stage	Development stage		Mid-season stage		Late season stage	
	Month and Number of days	Month and Number of days		Month and Number of days		Month and Number of days	
	March (15 days)	March (15 days)	April (15 days)	April (15day)	May (25day)	May (5days)	June (5days)
ET_o (mm/d)	4.6	4.6	4.9	4.9	4.6	4.6	4.1
K_c	0.7	0.9	0.9	1.05	1.05	0.75	0.75
ET_c (mm/d)	3.2	4.1	4.4	5.1	4.8	3.5	3.1
NIR (mm)	48.0	61.5	66.0	76.5	120.0	17.5	15.5
GIR (mm) for drip 100%ET_c	53.3	68.3	73.3	85.0	133.3	19.4	17.2

Table 4.4: Analysis of Variance (ANOVA) for Gross irrigation requirement

Treatment	GIR(mm)
Drip 100%ET_C	449.80a
Drip 80%ET_C	359.80b
Drip 60%ET_C	269.90c
LSD (5%)	12.91
CV	1.58

Key; GIR = Gross irrigation requirement; LSD= Least significance difference; CV= Coefficient of variation.

4.3.Hydraulic evaluation of drip irrigation

In this study, four parameters were used to evaluate irrigation uniformity: emission uniformity (EU), coefficient of variation (CV), flow variation (q_{var}) and uniformity coefficient (UC).

Uniformity coefficient (UC) expresses the uniformity distribution of water from the system devices. In the experiment the uniformity coefficient for 100%ET_c, 80%ET_c and 60%ET_c for drip irrigation were 94.8%, 94.8% and 94.6% respectively.

Emission uniformity (EU) is a major parameter for evaluation of drip irrigation system performance. In the study the emission uniformity was determined in growing season to study the performance of the system.

Coefficient of variation (CV)

No two emitters are identically manufactured; there would be a little variation between them. Consequently, coefficient of variation is used to evaluate the flow rate uniformity of the emitters (ASAE, 2002). During the experiment the hydrostatic pressure has been kept at 1.5 m (15 kpa). As indicated in table 4.5 the Calculated value of hydraulic evaluation parameters are within the recommended standards.

Table 4.5: Hydraulic evaluation of drip irrigation

No	Hydraulic Parameter	Calculated value (%)		
		100%ETc	80%ETc	60%ETc
1	Emission Uniformity	93.4	94.1	93.9
2	uniformity Coefficient	94.7	94.8	94.6
3	Coefficient of variation	5.3	5.2	5.4
4	Flow variation	16.1	16.3	14.6

4.4. Yield of onion

4.4.1. Marketable bulb Yield

The statistical analysis revealed that there was very significant difference of onion bulb yield among the different drip deficit irrigation level treatments ($p < 0.001$). The highest marketable bulb yield of 25.93 t ha^{-1} was obtained at 100%ET_c with drip irrigation technique and followed by 80% ET_c of drip irrigation. The lowest marketable bulb yield of onion was recorded from drip irrigation with 60%ET_c of deficit irrigation (15.39 t ha^{-1}). The yield reductions were increased as deficit irrigation levels increased from 100%ET_c to 60%ET_c of deficit irrigation.

4.4.2. Unmarketable bulb yield

Significant unmarketable onion bulb yield differences were recorded at drip irrigation technique with 60%ET_c water applied (1.01 t $ha\text{-}^{1}$) and followed by 80%ET_c while the lowest unmarketable bulb yield of 0.83 t ha^{-1} was observed when drip irrigation with 100%ET_c. The result revealed that, yield of very small bulbs increased with deficit irrigation. This could be due to low rate of transpiration caused by stomata closer under moisture stress condition which brought about reduced photosynthesis and poor bulb growth and developments.

4.4.3. Total bulb yield

The total bulb yield which is the sum of unmarketable and marketable bulb yield showed a very highly significance effect ($P<0.001$) by the treatments. Higher total onion bulb yield was recorded when drip irrigation system with 100%ET_c that gave 26.8 t h^{-1} and followed by drip irrigation with 80%ETc. On the other hand, the lowest total bulb yield of 16.4 t h^{-1} was recorded when drip irrigation system was applied with 60%ET_c of deficit irrigation.

Decreasing the applied water by 20% and 40% of ET_c led to higher yield reduction of onion

16.8% and 38.8% respectively as compared to full irrigation under drip method. As indicated in table 4.6 the irrigation level increased from 60%ET_c to 100%ETc, the total bulb yields increased. This result was also in agreement with the findings of (Ferreira et al., 2002).

Table 4.6: Effects of deficit irrigation under drip irrigation method on the yield of onion (*Allium cepa L.*)

Treatment	MBY	UMBY	TBY
Drip 100%ET_c	25.93a	0.83b	26.80a
Drip 80%ET_c	21.33b	0.93a	22.30b
Drip 60%ET_c	15.39c	1.01a	16.40c
LSD (5%)	0.93	0.08	0.97
CV	1.96	3.61	1.96

Key; MBY= Marketable bulb yield; NMBY= Unmarketable bulb yield; TBY=Total bulb yield; LSD= Least significance difference; CV= Coefficient of variation.

4.5. Irrigation water saved and irrigation water use efficiency

Water use efficiency was significantly influenced by irrigation levels. Drip irrigation with 100%ET_c gave highest yield and low water use efficiency followed by drip irrigation of 60%ET_c. Drip irrigation with 80%ET_c gave highest water use efficiency. Considering full irrigation application, lowest value of irrigation water use efficiency was observed under drip method with mean value of 5.96 kg m^{-3}. Applying 80%ET_c under drip irrigation method improved IWUE by water saving of 90.mm which is used to irrigate additional area of onion crop. Similarly, drip irrigation at 60%ET_c water application level saved 179.9mm (40%) water, as compared to drip irrigation with 100%ET_c. As shown in table 4.7 below, in drip irrigation as the amount of water applied increased, the water productivity decreased. Water productivity depends on total applied water and yield obtained.

Table 4.7: Effects of drip at different irrigation level on water productivity

Treatment	WP(kg/M^3)
Drip 100%ET$_c$	5.96b
Drip 80%ET$_c$	6.20a
Drip 60%ET$_c$	6.08ba
LSD (5%)	0.16
CV	1.16

Key; WP =Water productivity; LSD= Least significance difference; CV= Coefficient of variation.

4.6. Onion bulb yield response to deficit irrigation

The response of onion yield to water supply as quantified through yield response factor (Ky) was given in Table 4.8. The crop yield response factor (Ky) captures the essence of the complex linkages between production and water use by a crop. Crop yield response factor indicates a linear relationship between the decrease in relative water consumption and the decrease in relative yield. The ky values greater than unity indicates the relative yield decrease is higher than the water deficit as stated by Smith and Kivumb (2002). Under conditions of limited water distributed equally over the total growing season, involving crops with different Ky values, the crop with the higher Ky value will suffer a greater yield loss than the crop with a lower Ky value.

The result showed that only those treatments with a lower crop yield response factor (Ky< 1.0) can generate significant savings in irrigation water through deficit irrigation (Kirda, 2002).

Table 4.8: The yield response factor values for irrigation treatments

Irrigation method and deficit level	Yield (kg ha^{-1})	ET_a (mm)	$\frac{ET_a}{ET_m}$	$\frac{Y_a}{Y_m}$	$1 - \frac{ET_a}{ET_m}$	$1 - \frac{Y_a}{Y_m}$	K_y
Drip 100%ET_C	26800	449.8	1	1	0.00	0.00	-
Drip 80%ET_C	22300	359.8	0.8	0.83	0.20	0.17	0.85
Drip 60%ET_C	16400	259.9	0.58	0.61	0.42	0.39	0.93

Key; Y_a = actual yield (kg/ha); Y_m = maximum yield (kg/ha); ET_a = actual evapotranspiration (mm); ET_m = maximum evapotranspiration (mm), and K_y = yield response factor.

5. SUMMARY, CONCLUSION AND RECOMMENDATION

5.1. Summary

In the study area, there is a shortage of water but high demands of expanding irrigation lands. So, to alleviate this challenge adaptation of economically sound and scientifically proven techniques is a reasonable tool for improving water use efficiency. Drip irrigation with different irrigation level could be the most required management practices to meeting water scarcity and its consequences. In view of this the current study was conducted to investigate the effects of drip irrigation at different application levels on yield and water use efficiency of onion in Fogera district.

The 100%ET_c irrigation implies the amount of irrigation water applied in accordance with the estimated crop reference evapotranspiration with the aid of CROPWAT (8.0 Version) software on daily climatic data basis. The 80 % and 60%ET_c irrigation depths meant 80% and 60%ET_c applied of full irrigation requirement.

Analysis of variance showed that drip irrigation at different application levels had a significant ($p<0.05$) effect on onion bulb yield and water use efficiency. From this study, the maximum water productivity was observed from the experimental plots that received 100%ETc, Likewise, maximum yield (26.8 t/ha), were obtained from the experimental plots that received 100%ETc with drip irrigation system treatments.

5.2. Conclusion

Increasing water efficiency is crucial in areas where water scarcity is critical. Introduction of new methods for reducing water loss in irrigated agriculture can mitigate the water scarcity. Drip irrigation system at different water application level could be used in irrigated areas with limited water resource.

The results of the study revealed that, the deficit irrigation can improve the water productivity without significantly reducing the bulb yield. The main objective of the study was to find the best deficit irrigation level for onion production with higher water use efficiency with possibility of lower bulb yield reduction of onion production in limited irrigation water areas.

In this study, the field experiment on deficit irrigation under drip system was compared in terms of yield, yield parameter and water use efficiency and the finding indicated that applying deficit under drip irrigation improves water use efficiency with minimum yield reduction.

5.3. Recommendation

Based these experiment findings the following recommendation can be made for further consideration and improvement of onion production and water use efficiency in the study area in particular and water stressed area in general.

1. Deficit irrigation practice under drip irrigation is a suitable and most efficient practice for sustainable production in water scarce area by improving water productivity and maintaining soil moisture content below optimum level throughout growth stage.
2. Based on the objective, among the treatments used in this experiment, drip irrigation with 80%ETc was the best treatment selected for the local farmers in the study area who have limited amount of water.
3. However, this experiment was conducted in one location for one season using one onion variety (Bombay red), conducting similar researches over sites (under different agro climatic and soil conditions) and seasons including new onion varieties would be important to get convincing results for best recommendation.

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7. APPENDICES

Appendix Table 1: Total crop water requirement in mm and irrigation level

Irrigation method	Treatments	TBY tha-1	NIR	GIR	WP	Amount of water saved
Drip irrigation	100%ETc	26.8	405.0	449.8	5.96	0.0
	80%ETc	22.3	324.0	359.8	6.20	90.0
	60% ETc	17.4	243.0	269.9	6.45	179.9

Appendix Table 2: Monthly reference evapotranspiration (ET_o) (mm/day)

MONTH	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	average
1990	3.6	3.9	4.2	4.7	4.8	4.4	3.3	3.5	3.4	4.1	3.8	3.6	3.9
1991	3.6	4.1	4.3	4.6	4.8	4.0	3.2	3.2	3.7	3.9	3.6	3.4	3.9
1992	3.3	3.8	4.4	4.7	4.7	4.4	3.4	3.7	3.6	3.6	3.4	3.4	3.9
1993	3.5	3.8	4.5	4.6	4.5	3.9	3.2	3.4	3.4	3.7	3.7	3.5	3.8
1994	3.5	4.0	4.5	5.0	4.6	3.8	3.0	3.1	3.8	4.0	3.7	3.6	3.9
1995	3.6	3.9	4.5	4.8	4.5	4.1	3.2	3.2	3.7	4.2	3.7	3.5	3.9
1996	3.5	4.2	4.4	5.0	4.0	3.9	3.5	3.2	3.8	4.2	3.6	3.5	3.9
1997	3.5	4.1	4.4	4.5	4.3	3.7	3.4	3.4	4.1	3.9	3.7	3.6	3.9
1998	3.5	3.9	4.4	4.9	4.6	4.3	2.9	2.9	3.6	3.9	3.7	3.4	3.8

1999	3.5	4.2	4.4	5.0	4.5	4.0	3.2	3.3	3.5	3.6	3.8	3.4	3.9
2000	3.5	4.0	4.7	4.2	4.6	4.1	3.3	3.0	3.7	3.6	3.6	3.3	3.8
2001	3.5	3.9	4.1	4.7	4.7	3.5	3.1	3.0	3.7	3.8	3.6	3.5	3.8
2002	3.2	3.9	4.2	5.0	4.7	4.1	3.6	3.3	3.7	3.9	3.6	3.4	3.9
2003	3.3	3.8	4.4	4.6	4.4	3.9	3.0	2.9	3.4	4.2	3.7	3.5	3.8
2004	3.5	3.9	4.4	4.3	4.8	3.9	3.5	3.3	3.6	3.9	3.6	3.4	3.8
2005	3.7	4.6	4.9	5.3	5.0	4.3	3.0	3.4	3.6	4.1	4.1	3.9	4.1
2006	4.0	4.1	5.1	5.4	4.9	4.2	3.4	3.1	3.6	4.2	4.1	3.8	4.1
2007	3.6	4.1	5.1	5.3	5.0	4.0	3.0	3.2	3.5	4.1	3.9	3.8	4.1
2008	3.8	4.4	5.1	5.4	4.6	4.4	3.4	3.2	3.5	4.0	3.8	3.5	4.1
2009	3.5	4.3	5.1	5.3	5.1	4.9	2.6	4.4	4.0	3.9	3.8	3.5	4.2
2010	3.6	3.9	4.9	5.4	4.8	4.2	3.2	3.0	3.6	4.1	3.8	3.4	4.0
2011	3.5	4.5	4.5	5.5	4.7	4.1	3.4	3.1	3.5	4.1	3.7	3.6	4.0
2012	3.9	4.5	5.0	5.1	4.9	4.1	3.3	3.1	3.5	4.2	3.7	3.7	4.1
2013	3.8	4.3	5.0	5.4	5.0	4.6	3.2	2.8	3.8	4.0	3.9	3.6	4.1
2014	3.7	4.2	4.7	4.6	4.4	4.0	3.4	3.3	3.6	4.0	3.9	3.6	4.0
2015	3.6	4.3	5.0	5.2	4.7	4.1	4.0	3.9	4.1	4.1	3.9	3.7	4.2
2016	3.60	4.20	4.80	5.10	4.30	4.10	3.20	3.30	3.70	4.10	3.80	3.60	4.0
2017	3.72	3.94	4.62	4.99	4.31	4.10	3.51	3.16	3.80	3.80	3.88	3.54	3.9
Mean	3.6	4.1	4.6	4.9	4.6	4.1	3.3	3.3	3.7	4.0	3.8	3.5	

Appendix Table 3: Emitter flow rate in ml/minute and standard deviation for each replication and application level

		Irrigation Application level								
		100%ETc			80%ETc			60%ETc		
Laterals	Emitters	Replication 1	Replication 2	Replication 3	Replication 1	Replication 2	Replication 3	Replication 1	Replication 2	Replication 3
Lateral 1	1	12.5	13.0	14.5	12.0	14.0	13.0	11.5	12.0	13.5
	2	12.0	14.0	14.0	12.5	12.5	13.5	12.0	12.5	12.0
	3	13.0	13.0	13.0	13.0	13.0	12.5	13.0	13.0	13.0
	4	12.0	12.5	14.5	12.0	12.5	14.0	12.0	12.0	12.5
	5	12.5	13.5	14.0	12.5	12.0	13.0	12.0	12.0	13.5
Lateral 2	6	13.0	14.0	13.5	13.0	13.0	14.0	13.0	12.5	13.0
	7	12.5	13.5	13.0	12.5	14.5	13.0	12.0	13.0	13.5
	8	12.0	13.0	12.0	12.0	13.0	14.5	11.5	12.0	13.0
	9	13.0	13.5	14.0	13.0	13.0	12.5	13.5	13.0	13.5
	10	14.0	12.5	14.0	14.0	12.0	13.0	13.0	14.0	12.0
Lateral 3	11	13.0	12.5	14.5	12.5	13.0	14.0	13.5	13.0	13.5
	12	13.0	14.0	12.0	12.0	12.5	12.0	13.0	14.0	11.5
	13	12.5	13.0	12.5	13.0	12.5	13.0	11.5	12.5	13.0
	14	12.0	15.0	13.0	13.0	13.0	12.0	12.0	12.0	12.5
	15	12.5	13.0	13.0	13.0	14.0	12.5	12.0	12.5	13.0
Lateral 4	16	13.0	12.5	12.5	12.5	13.0	12.0	13.5	12.0	12.0
	17	13.0	13.0	13.0	12.0	12.0	13.0	12.0	12.0	13.0
	18	12.5	13.0	12.0	12.5	12.0	12.0	11.5	12.0	12.0
	19	13.0	14.0	14.5	13.0	12.0	12.5	13.0	13.0	13.5
	20	12.0	12.5	14.5	12.5	13.0	12.0	11.5	12.0	12.5
	Sum	253	265	268	252.5	255	258	247	251	256
	Ave.	12.65	13.25	13.40	12.60	12.75	12.90	12.35	12.55	12.80
	SDEV	0.52	0.68	0.91	0.51	0.71	0.77	0.75	0.65	0.64

Appendix Table 4: Average emitter flow rate in ml/minute and standard deviation for each application level

Replication	Irrigation Application level					
	100%ETc		80%ETc		60%ETc	
	Average flow rate	Average standard deviation	Average flow rate	Average standard deviation	Average flow rate	Average standard deviation
1	12.65	0.52	12.60	0.51	12.35	0.75
2	13.25	0.68	12.75	0.71	12.55	0.65
3	13.40	0.91	12.90	0.77	12.80	0.64
Average	13.10	0.70	12.75	0.66	12.57	0.68

Appendix Table 5: Mean squares of analysis of variance for Marketable bulb yield (MBY), Unmarketable bulb yield (UMBY), Total bulb yield (TBY), Gross irrigation requirement (GIR) and Water productivity (WP)

Source of variation	DF	Mean square values					
		MBY	UMBY	TBY	GRI	WP	DM
Replication	2	1.203	0.008	1.368	7023.643	0.005	1.333
Irr	3	83.768	0.023	81.114	24273.010	0. 044	28.000
Error	6	0.168	0.001	0.183	32.433	0.005	7.833
CV (%)		1.964	3.606	1.959	1.583	1.162	2.608

8. BIOGRAPHICAL SKETCH

The author, Misganaw Yimer was born in Amhara National Regional State, South Wollo Zone, Borena district at Tewa- Millo kebele in September 1976 G.C. He attended at Tewa Elementary and secondary Schools and then Borena high school. He then joined Jima University in 1998 to study for his Diploma and graduated in general agriculture. After graduation, the author was employed by Borena agriculture and rural development office and served as Irrigation agronomist until 2007G.C. Then he joined Haromaya University in 2007 to study soil and water engineering. In 2017 G.C he joined the Graduate School of Hawassa University as a candidate for Master of Science Degree in Irrigation and drainage engineering in the school of water resources engineering.