EFFECT OF DRIP LATERAL SPACING AND MULCHING ON YIELD, IRRIGATION WATER USE EFFICIENCY AND NET RETURN OF ONION (*Allium cepa L.*) AT AMBO, WESTERN SHOA, ETHIOPIA

MSc THESIS

OLI FIRISSA

AUGUST 2018
HARAMAYA UNIVERSITY, HARAMAY

Effect of Drip Lateral Spacing and Mulching on Yield, Irrigation Water Use Efficiency and Net Return of Onion (*Allium cepa L.*) at Ambo, Western Shoa, Ethiopia

A Thesis Submitted to Postgraduate Program Directorate Through The School of Water Resources and Environmental Engineering
HARAMAYA UNIVERSITY

In Partial Fulfillment of the Requirements for the Degree of
MASTERS OF SCINCE IN IRRIGATION ENGINEERING

Oli Firissa

August 2018
Haramaya University, Haramaya

HARAMAYA UNIVERSITY
SCHOOL OF GRADUATE STUDIES

I hereby certify that I have read and evaluate this Thesis entitled **Effect of Drip Lateral Spacing and Mulching on Yield, Irrigation Water Use Efficiency and Net Return of Onion (*Allium cepa L.*) at Ambo, Western Shoa, Ethiopia** prepared under my guidance by **Oli Firissa.** I recommend that it be submitted as fulfilling the thesis requirement.

Teshome Seyoum (Dr.- Ing.)	____________________	____________________
Major Advisor	Signature	Date
Fentaw Abegaz (PhD)	____________________	____________________
Co-Advisor	Signature	Date

As a member of the Board of Examinations of the MSc. Thesis Open Defense Examination, I certify that I have read and evaluated the Thesis prepared by **Oli Firissa** and examined the candidate. I recommended that the thesis be accepted as fulfilling the Thesis requirements for the degree of Masters of Science in irrigation Engineering.

____________________	____________________	____________________
Name of Chairman	Signature	Date
____________________	____________________	____________________
Name of Internal Examiner	Signature	Date
____________________	____________________	____________________
Name of External Examiner	Signature	Date

Final approval and acceptance of the Thesis is contingent to upon the submission of its final copy to the Council of Graduate Studies (CGS) through the candidate's department or school graduate committee (DGC or SGC).

DEDICATION

I dedicate this thesis manuscript to my mother Tirfe Deressa

STATEMENT OF THE AUTHOR

By my signature below, I declare and affirm that this Thesis is my own work. I have followed all ethical and technical principles of scholarship in the preparation, data collection, data analysis and compilation of this Thesis. Any scholarly matter that is included in the Thesis has been given recognition through citation.

This Thesis is submitted in partial fulfillment of the requirements for a Masters of degree at the Haramaya University. The thesis is deposited in the Haramaya University Library and is made available to borrowers under the rules and of the library. I solemnly declare that this Thesis has not been submitted to any other institution anywhere for the award of any academic degree, diploma or certificate

Brief quotations from this Thesis may be made without special permission provided that accurate and complete acknowledgement of the source is made. Requests for permission for extended quotations from or reproduction of this Thesis in whole or in part may be granted by the Dean of the institute of Technology when in his or her judgment the proposed use of the material is in the interest of scholarship. In all other instances, however, permission must be obtained from the author of the Thesis.

Name: Oli Firissa ________________ Signature:_____________

Date: ________________________________

School/Department: Water Resources and Environmental Engineering

BIOGRAPHICAL SKETCH

The author was born in East Wollega zone, Abay Chomen woreda in 1982 G.C from his father Ato Firissa Kuli and his mother Tirfe Deresa. He attended his primary and secondary education in Imbabo primary and junior secondary school and Shambo senior secondary school. He joined Ambo Agricultural College in 2000 and graduated with Diploma in General Agriculture on July 05, 2001. In 2008 he joined Haramaya University to study BSc degree and graduated with Bachelor of Science Degree in Soil and Water Engineering and Management on September 13, 2013.

He joined Fincha Sugar Factory to work as Formen in Sugar cane plantation section on October 2003. He was transferred to Ambo plant protection Research Center and he has been working in Natural Resource Management Research as junior researcher. He joined the School of Graduate Studies of Haramaya University in 2016 to study MSc in Irrigation Engineering.

ACKNOWLEDGEMENTS

Above all, the author would like to thank the Almighty God, who relieved him in his distress, heard his prayer and did mighty things in his life.

The author would like to express his deepest gratitude to his advisor Dr.-Ing. Teshome Seyoum and Dr. Fentaw Abegaz for their professional guidance, encouragement, heartfelt technical and moral support from planning up to the preparation of this thesis manuscript in this form. The author would also like to thank Ethiopian Agricultural Research Center for providing him academic and research fund.

The author would like to extend his gratitude to Ambo Plant Protection Research Center for their cooperation in meteorological data collection and material support, and to Ambo Plant Protection Research center, Natural Resource Management Research program for material support.

The author gratefully acknowledges the staff members of Natural Resources Department of Ambo Plant Protection Research Center, Dr. Tolera Abera, Mr. Dejene Abebe, Tsige Hunde and Desita Tolesa for their positive cooperation in using different materials and common facilities. He is also indebted to Mr. Niguse Hundesa the Director of Ambo Plant Protection Research Center for his unlimited effort in creating conducive environment to conduct this study.

The author is also grateful to his beloved wife Meseret kitaw, mother Tirfe Deresa, father Firissa Kuli, brother Damesa Firisaa, sister Nache Beyene and his family as a whole for their incontestable support and encouragement throughout the study.

There are a lot of people who directly or indirectly contributed to the study and the preparation of this thesis manuscript. Though they are too many to mention them by name, their contribution is highly appreciated.

LIST OF ABBREVIATIONS AND ACRONYMYS

AE	Application efficiency
ANOVA	Analysis of Variance
CEC	Cation Exchange Capacity
CSA	Central Statistical Agency
CU	Coefficient of Uniformity
CV	Coefficient of Variance
DU	Distribution Uniformity
Ea	Application Efficiency
EC	Electrical Conductivity
EPA	Environmental Protection Authority
Eta	Actual Evapotranspiration
ETB	Ethiopian Birr
ETc	Crop Evapotranspiration
ETFRUIT	Ethiopian Fruit and Vegetable Marketing Enterprise
ETo	Reference Crop Evapotranspiration
EU	European Union
EU	Emission Uniformity
FAO	Food and Agricultural Organization
FC	Field Capacity
FC	Fixed Cost
GDP	Growth Domestic Product
GIR	Gross Irrigation Requirement
ICID	International Commission on Irrigation and Drainage
IDE	International Development Enterprise
IDI	International Development Institute
IWUE	Irrigation Water Use Efficiency
Kc	Crop Coefficient
LSD	Least Significance Difference

Continues…

m.a.s.l	Meter Above Sea Level
MoA	Ministry of Agriculture
MOWR	Ministry of Water Resource
NI	Net Income
NIR	Net Irrigation Requirement
NPC	National Planning Commission
OM	Organic Matter
Pe	Effective Rainfall
PWP	Permanent Wilting Point
RCBD	Randomized Complete Block Design
TAW	Total Available Water
TC	Total Cost
UNEP	United Nations Environment Program
WP	Water Productivity
WUE	Water Use Efficiency
Y	Crop Yield

TABLE OF CONTENT

Continues…

Continues…

Continues…

LIST OF TABLES

Table **Page**

LIST OF FIGURES

LIST OF TABLES IN THE APPENDIXE

Appendix Table **page**

LIST OF FIGURES IN THE APPENDICE

EFFECT OF DRIP LATERAL SPACING AND MULCHING ON YIELD, IRRIGATION WATER USE EFFICIENCY AND NET RETURN OF ONION (*Allium cepa L.*) AT AMBO, WESTERN SHOA, ETHIOPIA

ABSTRACT

Despite the fact that irrigation water and cost of production are the most limiting factor for vegetable production in areas where rainfall is unevenly distributed temporary and spatially, limited information has reported on means of minimizing production cost and improving yield and water productivity using modern irrigation system and water conservation methods. Hence, the field experiment was conducted at Ambo during the dry season of 2017/2018 to investigate effects of drip lateral spacing and mulching on yield, water use efficiency and net return of onion production. In this research 8 treatments with three replications were randomized in complete block design to conduct the experiment. Two levels of drip lateral spacing (drip laterals in every plant rows and drip laterals between two rows) and four levels of mulch (no mulch, wheat straw mulch, white and black plastic mulches) were used to evaluate their effect on onion yield, water use efficiency and net return.100% ETc of irrigation water was applied throughout growing season for all plots. Yield and irrigation water data were subjected to ANOVA using SAS software with significance level $p \leq 0.05$. LSD test was applied for statistically significant parameters to compare means among the treatments. The result showed that both onion yield and water use efficiency was affected by main effects of drip lateral spacing and mulching but not affected by their interaction effect. The maximum bulb yield (34990 kg ha^{-1}) of onion was recorded from onion grown under drip lateral in every row. In case of mulching, the highest mean bulb yield of (35117 kg ha^{-1}) was obtained from white plastic mulch. The highest water use efficiency of 1.14 kg lit^{-1} was recorded from onion grown under drip lateral spacing in every row and 1.15kg lit^{-1} was from white plastic mulch. Even though white plastic mulch scores significantly higher yield and water use efficiency, based on the partial budget analysis highest net return of 246,410ETB ha^{-1} and 284,616ETB ha^{-1} were obtained from drip laterals in every rows and no mulch, respectively. This suggests that drip laterals in every rows and no mulching is economically feasible for drip irrigated onion production at Ambo.

Key words: *Drip irrigation, Drip lateral spacing, mulching, bulb yield, water use efficiency, net return and Ambo woreda.*

1. INTRODUCTION

Ethiopia‘s economy is dependent on agriculture, which contributes 43 percent of the GDP and 90 percent of exports (USAID, 2017). It also employs 83 percent of the active population (MoA, 2011). Agriculture is primarily rain-fed and thus highly dependent on rainfall. But the uneven temporal and spatial distribution of rainfall has significantly affected the agriculture. The challenge of food insecurity due to its dependency on rain–fed and inability to develop the irrigation potential in Ethiopia is a concern and it is also a bottleneck problem in Ethiopia (Mihret *et al*., 2013).

Water is one of our basic resources by which we increase production and productivities of land and crops, but it is often scarce. Ethiopia has 12 river basins, 11 fresh lakes, 9 saline and few ground water potential (Awulachew *et al.,* 2015). Though the country possesses a substantial amount of water resources little has been developed for agriculture (Awulachew *et al*., 2015).

Irrigation is practiced in Ethiopia since ancient times producing subsistence food crops. However, modern irrigation systems were started in the 1960s with the objective of producing industrial crops in Awash Valley. Currently, the government is giving more emphasis to the sub-sector by way of enhancing the food security situation in the country. Irrigation is always required to produce high yielding crops with minimum water consumption and safe guarding the environments. With future water scarcity and climate change, management of water will become an increasingly important issue in intensive vegetable production (Devasirvatham, 2008). Improving water productivity using proper irrigation method will reduce the additional water requirements in agriculture (Nangia *et al*., 2008). In Ethiopia, lack of research topics selected based on farmers true problems or needs, lack of capital to implement modern irrigation methods and lack of integrated soil and water management practices are among major constraints and challenges identified in the area of irrigation water and crop management practices (MOA, 2011).

Drip irrigation is an irrigation method that allows precisely controlled application of water and fertilizer by allowing water to drip slowly near the plant roots through a network of valves, pipes, tubing and emitters (Simonne *et al*., 2009). Drip irrigation, with its ability to provide small and frequent water applications directly in the vicinity of the plant root zone has created interest, because of decreased water requirement and possible increase in production (Jain *et al.*, 2000). Until recently, drip irrigation has been limited to large-scale commercial farming systems. Such systems require high pressure through the use of boosters or pumping systems, making it even more expensive and out of reach for small-scale farmers. However, appropriate, affordable, and accessible irrigation technologies that are within the reach of smallholder farmers can provide a basis for increased agricultural production and income generation. 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 (IDE, 2004).

The development of smallholder drip irrigation system is to bring down the cost (Isaya, 2001). This means still relatively low initial capital investment is required to adopt the technology. It is obvious that efforts should be made to bring down the cost as minimum as possible. Among the various components of drip irrigation, the cost of lateral is the major factor, which influence the total system cost (Aujla *et al.,* 2004). Any effort made to reduce number of lateral required per unit area of the field will result in reduction of the system cost (Aujla *et al.,* 2004). Singh (1978) and Wondatir *et al*. (2013) studied the effect of drip lateral spacing on production cost of drip irrigation system for different onion and tomato crops and found that for all the investment cost reduced by 27% (Wondatir *et al*., 2013).

According to Wondatir *et al*. (2013) currently the drip lateral spacing used is fixed (drip lateral placed in every row). This leads to loss of land, less net return income and un-optimized irrigation production. So it is Vital to investigate whether drip lateral spacing adjustment is effective and economical in terms of initial investment cost and irrigation management efficiency.

Mulching is a promising strategy by which water loss can be minimized with a substantial amount (Fang *et al*., 2007). For instance, plastic mulches consisting of white or black color as observed by Allen *et al*. (1998) directly affect the microclimate around the plant by modifying the radiation budget of the surface and decreasing the soil water loss, resulting in more uniform soil moisture and a reduction in the amount of irrigation water (Geo *et al*., 2007). Similarly, straw mulching has been reported to improve the water use efficiency of crops and thereby yield increments have also been possible. Thus, integrating mulching with other cost-saving irrigation strategy is paramount importance for sustainable crop production particularly in small-scale irrigation and water stress areas where agriculture is hampered by insufficient rainfall (Sharma, 2010).

Vegetable crops play an important role in contributing to the household food security. At present following tomato, onion (*Allium cepa*) is one of the most popular vegetables in the world. The world average yield at present is about 17.3 tones/ha (FAO, 1999). Ethiopia has a great potential to produce onion every year for both local consumption and export with an average yield of 13.3 tones/ha (CSA, 2001/02 as cited in Taha (2007). In view of this onion is one of the most important cash generating crops for farmers especially around the study area .Since it is shallow rooted vegetable, the amount of water that will be applied must be controlled to save the water and to minimize its damage due to excess water application.

Farmers in the study area producing vegetable crops especially onion two times per dry season using traditional furrow irrigation method for their consumption and market sell. But due to shortage of irrigation water its production and land productivity is reduced and there is conflict among irrigators. The main reasons for shortage of water are inefficient use of irrigation water as a result of high percolation loss, runoff loss and high evaporation loss which is caused due to over irrigation resulting low water use efficiency. Shortage of capital and new technologies are the main constraints in the study area to implement and use modern irrigation method (especially, drip irrigation method) with water loss minimizing methods.

A number of researches have been done to evaluate performance of drip irrigation practices in this country (Rahel, 2008 and Aklilu, 2009). However none of these researches have attempted to evaluate the combined effects of drip lateral spacing and mulching in the study area. Therefore the aim of this experiment is to evaluate the combined effect of different drip lateral spacing and mulching to improve water productivity or water use efficiency (WUE) without substantially affecting the yield of the study area.

The general objective of this study was to

Evaluate the feasibility of drip lateral spacing and mulches for onion cultivars in terms of yield, water use efficiency and economics for improving crop and irrigation water productivity in drip irrigated agriculture.

The specific objective of this study were

1. To evaluate the main effects of different drip lateral spacing and mulches on yield and water productivity of onion.
2. To evaluate the interaction effects of different drip lateral spacing‘s and different mulch types on yield and water productivity of onion, and.
3. To evaluate economic advantage of combined use of drip lateral spacing and mulches in drip irrigated onion production.

2. LITERATURE REVIEW

2.1. Water Resource and Irrigation Potential of Ethiopia

2.1.1. Water resource of Ethiopia

Water is a mobile resource; it falls from the clouds, seeps into the soil, flows through aquifers, runs along stream courses, and eventually returns to the clouds. This natural cycle is the basis of all life forms and of the economy of nature.

Ethiopia is endowed with a substantial amount of water resources but very high hydrological variability (Dessalegn, 1999). The surface water resource potential is impressive, but little developed. The country possesses twelve major river basins, which form four major drainage systems. The Nile Basin, The Rift Valley, The Shebelli-Juba basin and The North-East Coast (Awulachew, 2007).

All river basins except the Nile basin face water shortages (EU, 2011). Most of the rivers in Ethiopia are seasonal and there are almost no perennial rivers below 1 500 m altitude. About 70 percent of the total runoff takes place during the period June-September. Dry season flow originates from springs which provide base flows for small-scale irrigation.

The groundwater potential of the country is not known with any certainty, but so far only a small fraction of the groundwater has been developed. It is however more easily available than surface water in the arid areas and supplies about 80 percent of the existing drinking water sources (EPA and UNEP, 2008). Traditional wells are widely used by nomads. Ethiopia has many small, medium and large reservoir dams constructed for hydropower generation, irrigation and drinking water supply (ODI, 2015).

2.1.2. Irrigation potential of Ethiopia

Water resources management for agriculture includes both support for sustainable production in rain-fed agriculture and irrigation (Awulachew *et al.*, 2005). Currently, the MoWR (Ministry of Water Resources) has identified 560 irrigation potential sites on the major river basins. The total potential irrigable land in Ethiopia is estimated to be around 3.7 million hectares. Awulachew *et al*. (2005) noticed that irrigation is one by which agricultural production can be increased to meet the increasing demand in Ethiopia. According to Robel (2005) expanding irrigation development on various scales is one of the best alternatives to consider for reliable and sustainable food security development. Traditional irrigation in Ethiopia dates back several centuries, especially in the highlands for subsistence food crops, while "modern" irrigation was started by the commercial irrigated sugar estate established in the early 1950s by the Imperial Government of Ethiopia. In the 1960s, large-scale irrigation was developed by private companies in the whole Awash basin. Modern small-scale irrigation through communal schemes started only in the 1970s to fight major droughts and famines.

In 2004, the water managed area was estimated at 510, 000 ha, of which 175, 300 ha estimated to be full-control irrigation. However, a research estimated that about 30 percent of the command area was not operating (IWMI, 2010). In 2015, the area equipped for full-control irrigation is estimated at 658 340 ha. The area equipped for community spate irrigation is estimated at around 200 000 ha, giving a total area equipped for irrigation of 858 340 ha. In addition around 1 100 000 ha was estimated to be cultivated by small farmers using temporary structures. Thus, in total around 1 958 000 ha is considered to be water managed in 2014/15 (NPC, 2015). Over 1.2 million private holders practiced irrigated agriculture in 2014/15 in the Meher season–main rainy season and over 0.8 million in the Belg season–small rainy season. In small-scale irrigation schemes, irrigated crops are more diversified, but for the country as a whole the main irrigated crops are cereals–maize, wheat, barley or teff, pulses, vegetables, root crops, fruits and fiber crops (cotton). Smallholder irrigators generally prefer subsistence crops rather than cash crops and use irrigation to complement rainfed agriculture, i.e. supplementary irrigation (MoA, 2011). However, during the dry season they use full irrigation to get additional income (IWMI, 2009).

Irrigation is pouring water to the soil using proper methods and in proper times as required by the plant growth as a result of insufficient rain. The success of irrigation depends on the selection of the most proper irrigation method as per the conditions and planning, projecting, establishing and operating the irrigation system necessary for that method (Ahmet, 2009). According to Ahmet (2009) Irrigation methods are divided into surface irrigation and pressure irrigation methods.

2.2. Pressurized Irrigation Method

In pressurized irrigation systems water is pressurized and precisely applied to the plants under pressure through a system of pipes. Pressurized irrigation systems, as opposed to the surface irrigation systems, are more effective in application of irrigation water to the crops. They provide improved farm distribution, improved control over timing, reduced wastage of land in laying field distribution network, reduced demand for labor and better use of limited water resources (ICID, 2017). In the pressure irrigation method, the water is given to soil by using closed pipe systems with an additional energy or a drawing effect (Ahmet, 2009). As ICID (2017) discussed Pressurized irrigation systems have the potential to avoid the water loss related to surface irrigation increasing the open irrigation application efficiency from 45%-60% to pressurized irrigation with efficiency in the range of 75% 95%. While open canals systems have high labor requirement for maintenance pressurized systems have skilled labor requirements. Pressurized irrigation systems need from one-tenth to one-quarter of the man hours canal systems require. Driven by needs to reduce labor input into agriculture and the love of high technology, pressurized irrigation systems are costly and out of reach of small-holder farmers in developing countries.

According to ICID (2017) there are many variations of pressurized irrigation systems but the two major ones are: drip irrigation systems and sprinkler systems. Among them, there are many variations depending on the type of field, the crop and the kind of water delivery fittings needed, but the components of the basic system remain the same.

Drip irrigation, also known as trickle irrigation or micro irrigation or localized irrigation, is an 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. It is done through narrow tubes that deliver water directly to the base of the plant (ICID, 2017).

2.3. Water Application Principles of Drip Irrigation System

Drip irrigation is sometimes called trickle irrigation and involves dripping water onto the soil at very low rates (2-20 liters/hour) from a system of small diameter plastic pipes fitted with outlets called emitters or drippers. Water is applied close to plants so that only part of the soil in which the roots grow is wetted, unlike surface and sprinkler irrigation, which involves wetting the whole soil profile. With drip irrigation water, applications are more frequent (usually every 1-3 days) than with other methods and this provides a very favorable high moisture level in the soil in which plants can flourish (Isaya, 2001).

Ibragimov *et al*. (2007) compared drip and furrow irrigation methods, obtaining that 18-42% of the irrigation water was saved and the IWUE increased by 35-103% with drip systems. According to Satpute and Pandey (1989) and Pandey *et al*. (2003) drip irrigation saves water to extent of 30 to 70 percent without significantly affecting the crop yield. Same comparisons were made by Maisiri *et al*. (2005) in a semi-arid agro tropical climate of Zimbabwe; in this study, drip irrigation used about 35% of the water used by the surface irrigation systems, providing higher IWUE. The gross margin level for surface irrigation was lower than for drip irrigation.

Sivanapan (2002) mentioned a known fact that the efficiency in the use of water is extremely low in the flood method of irrigation because of evaporation and losses in conveyance and distribution. Camp *et al.* (1989) explained that the potential advantage of drip irrigation system is the ability to maintain the soil at high moisture yet unsaturated condition. In this manner soil remains at a constant phase of exchanging gases with the atmosphere. According to IDI (2002) side by side comparison of drip with flood irrigation, with its ability of small, frequent irrigation applications, has created interest because of decreased water requirements and possible increased production. Small but frequent applications enable the plant to grow well without any ill effect of water-stress periods between consecutive irrigations. Performance assessment of surface drip irrigation for small holder‘s crop production in Ethiopia particularly in conjunction with harvested rainwater has been well established and demonstrated (Adinew, 2005; Moges, 2006).

Drip irrigation is adaptable to any farmable slope. Normally the crop would be planted along contour lines and the water supply pipes (laterals) would be laid along the contour also. This is done to minimize changes in emitter discharge as a result of land elevation changes. Drip irrigation is suitable for most soils. On clay soils water must be applied slowly to avoid surface water ponding and runoff. On sandy soils higher emitter discharge rates will be needed to ensure adequate lateral wetting of the soil (Larry *et al*., 2015). For achieving high effectiveness of water, use drip irrigation is one of the most appropriate technologies in modern irrigated agriculture with great potential. It also leads itself to easy adoption for chemigation and automation. Drip system permits the controlling of discharge and flexibility in time of water application. Drip irrigation systems are widely used for irrigating orchards, vegetables, spices, cash crops like sugarcane and cotton.

One of the main problems with drip irrigation is blockage of the emitters. All emitters have very small waterways ranging from 0.2-2.0 mm in diameter and these can become blocked if the water is not clean. Thus it is essential for irrigation water to be free of sediments. If this is not so then filtration of the irrigation water will be needed. Blockage may also occur if the water contains algae, fertilizer deposits and dissolved chemicals which precipitate such as calcium and iron. Filtration may remove some of the materials but the problem may be complex to solve and requires an experienced engineer or consultation with the equipment dealer. Drip irrigation is particularly suitable for water of poor quality (saline water). Dripping water to individual plants also means that the method can be very efficient in water use (Larry *et al*., 2015).

With water growing scarcer drip irrigation is the gardener‘s choice for making every drop count. Drip irrigation can increase plant performance and water savings, and its easy automation can make irrigation simpler while reducing weed and pest problems. This easy-to-use reference guide answers common questions about components, materials, design, installation, maintenance, and troubleshooting (Larry *et al*., 2015).

2.4. Basic Components of Drip Irrigation System

According to Isaya (2001) a typical drip irrigation system is consists of the following components: Water Sources, Pump unit, Control head, Main and sub main lines, Laterals and Emitters or dripper and Filter.

Pump/Overhead tank

Takes water from the source and provides the right pressure for delivery into the pipe system. It is required to provide sufficient pressure in the system. Centrifugal pumps are generally used for low pressure trickle systems. Overhead tanks can be used for small areas or orchard crops with comparatively lesser water requirements

(www.ag.ndsu.edu/pubs/ageng/irrigate/ae1243w.htm).

Filters

The hazard of blocking or clogging necessitates the use of filters for efficient and trouble free operation of the micro-irrigation system.

Chemical injection equipment

Micro-irrigation‘s high distribution uniformity gives it great potential for uniformly and efficiently applying agricultural chemicals, a process called chemigation. The main components of a chemigation unit are a chemical solution tank, an injection system and chemigation safety devices.

The control head

It consists of valves to control the discharge and pressure in the entire system. It may also have filters to clear the water. Common types of filter include screen filters and graded sand filters which remove fine material suspended in the water. Some control head units contain a fertilizer or nutrient tank. These slowly add a measured dose of fertilizer into the water during irrigation. This is one of the major advantages of drip irrigation over other methods.

Mainlines, sub mains and laterals

Supply water from the control head into the fields. They are usually made from PVC or polyethylene hose and should be buried below ground because they easily degrade when exposed to direct solar radiation. Lateral pipes are usually 13-32 mm diameter.

Emitters

According to Tom Bressan, Emitters are the most important part of any drip irrigation system. They should deliver water at a predictable rate and resist clogging. In a large or hilly system, the emitter should compensate for variations in line pressure. Emitter types are: Simple orifice flow- is limited by a very small hole. Laminar flow- water travels through a long spiral or tube, permitting a larger opening than the simple orifice emitter. Turbulent flow- turbulence reduces water pressure, allowing the flow path of a laminar flow emitter to be widened. This decreases clogging problems and provides partial pressure compensation.

2.5. Hydraulics of Drip Irrigation

2.5.1. Drip lateral hydraulics

Flow in the drip irrigation lines is hydraulically steady, spatially varied pipe flow with lateral out flows. The total discharge in the drip irrigation lines (lateral, manifold, sub-main and/or main) decreases with respect to the length of line. The lateral and sub-main can be considered as having the same hydraulic characteristics and area designed to maintain the smallest pressure, the required pressure and the slope of the energy gradient line, which will give the total energy higher than that required at any sub-main for irrigation (von Bernuth, 1990).

A drip irrigation system is made by a combination of different size of plastic pipes which are usually considered as smooth pipe. One empirically equation frequently used is the Hazen and Williams formula. Also, because of the possibility of laminar, turbulent or fully turbulent flow in trickles the Darcy Weisbach equation can be used to compute the head loss due to pipe friction (von Bernuth, 1990).

$$\mathrm{H}f = \frac{f l v}{2gd} \tag{2.1}$$

where, Hf = head loss in pipe, m

f = coefficient of friction for pipe

l = length of pipe, m

v = velocity of water in pipe, m/sec

g = acceleration due to gravity m/sec^2

d = diameter of pipe, m

In order to find the correct friction factor (f) for the Darcy-Weisbach equation knowing the relative roughness and Reynolds Number, one must refer to the Moody Diagram. If the flow of water is considered laminar, that is, having a uniform velocity profile and a Re < 2,000, then one would use equation (2.2). Or, more commonly for this application, if one is determining the friction factor for a small diameter pipe, this factor varies according to equation (2.3) which is also known as the Blasius equation (Provenzano and Pumo, 2004; Demir, 2007).

$$f = 64Re^{-1} \ (Re<2000) \qquad (2.2)$$

$$f = 0.302Re^{-0.25} \ (2000 \leq Re \leq 100000) \qquad (2.3)$$

Even though the Blasius equation is quite often used in hand calculations, the most common for computer applications is the Fanning equation, shown as equation (2.4), because of its wider range of allowable Reynolds numbers (Burt and Styles, 2011).

$$f = 0.0056 + 0.5Re^{-0.32} \ (2000 \leq Re \leq 100000) \qquad (2.4)$$

$$Re = \frac{DV}{v} \qquad (2.5)$$

where, Re= Reynolds number

D= diameter of pipe, (ft)

V= Average velocity water velocity, (ft/sec.)

v =Kinetic viscosity of fluid, (ft^2/sec.)

2.5.2. Drip emitter hydraulics

Hydraulically, the pressure variation along a sub-main will cause a lateral flow variation along a Sub main and pressure variation along a lateral will cause an emitter flow variation along the lateral through each emitter.

The pressure variation and emitter flow variation are related and can be expressed as,

$$Q_{var} = 1-(1-H_{var})\ 0.5 \qquad (2.6)$$

where, the emitter flow variation, q_{var} is defined as;

$$Q_{var} = q_{max} \frac{q_{min}}{q_{max}} \qquad (2.7)$$

where, q_{max}= is the maximum emitter flow along the line

q_{min} = is the minimum flow along the line

Q_{var} = should be less than 10% (desirable)

The pressure variation, H_{var} is defined as

$$\text{Hvar} = \text{h max} - \frac{\text{h min}}{\text{h max}} \tag{2.8}$$

Where, h max and h min = are the maximum and minimum pressure variation respectively along the line and Hvar should be less than 20 percent.

In drip irrigation systems design, the design criterion is generally based on an emitter flow variation of less than 20 percent and pressure variation less than 10 percent i.e. acceptable limits.

2.6. Performance Indicator of Irrigation System

The ideal irrigation system applies water at a rate that allows all water to infiltrate and the water is distributed both in space and time to match crop water requirements in each section of the field (Hoffman and Martin, 1993). But, this is for an ideal system which is rarely found in practice. Most irrigation systems will require some measure of improvement, in order to get to an ideal irrigation system. In order to quantify any improvements in irrigation performance obtained from either better management or through the application of technology. Lecler (2004) stated that to ensure the long term viability of production, development and adoption of strategies to improve the performance of the various water management and irrigation systems was needed. There are three performance parameters which are important when reporting on the evaluation of an irrigation system; these are adequacy, efficiency and uniformity. All of these parameters are inter-related and will be discussed in the following sections.

2.6.1. Application efficiency

Precise water application in using drip irrigation is possible making irrigation much more efficient, and is an attribute that makes the drip irrigation method especially attractive if water is scarce or expensive. Direct evaporation from the soil surface and water uptake by weeds is reduced by not wetting the entire soil surface between rows. Wolters and Bos (1989) stated that efficiency is generally defined as the dimensionless ratio of output divided by input. Fairweather *et al.*, (2003) agree with this definition. Application efficiency is the ratio, expressed in percent, of the volume of water beneficially used by the crop to the volume of water delivered to the area (James, 1988). It is an important irrigation concept that is very important both in the system selection and design, and in irrigation management. Application efficiencies are affected by cultural practices that water storage in the plant root zone and by irrigation management practices (Haman *et al*., 2002). They mentioned that application efficiency of drip systems is primarily dependent on the hydraulic design of the systems and their maintenance and management. The ability of an irrigation system to apply water uniformly and effectively to the irrigated area is a major factor influencing the agronomic and economic viability of the farming enterprise (Kenneth, 1998). Moreover, Haman *et al*. (2002) indicated that irrigation efficiency deals with the water conservation property of the system. Kenneth (1998) indicated that attainable water application efficiency vary greatly with irrigation system type and management, and suggested that the attainable application efficiency for trickle irrigation are 75-90% and 70-85% under point source and line source emitter respectively. FAO (1998) suggested 90% attainable water application efficiency for drip irrigation. Haman *et al*. (2002) also indicated that drip irrigation can potentially provide high application efficiency because these systems distribute water near or directly into the plant root zone, water losses due to wind drift and evaporation are typically small.

$$AE = \frac{\text{average depth of irrigation water contributed to target}}{\text{average depth of irrigation water applied}} * 100 \quad (2.9)$$

where, AE = Application efficiency

2.6.2. Application uniformity

According to Solomon (1998) the term irrigation uniformity refers to the variation or non-uniformity in spatial distribution of the amounts of water applied to locations within the wetted area. Uniformity influences crop yields through the agronomic effects of under and over watering. Insufficient water leads to high soil moisture tension, plant stress and reduced crop yields. Excess water may reduce crop yields as a result of leaching of plant nutrients, results in an anaerobic rooting environment as well as increased disease or failure to stimulate growth of economically valuable parts of the plant (Griffiths and Lecler, 2001). Heermann *et al*. (1990) notes that irrigation uniformities for drip irrigation systems can be evaluated by the emitter discharge. According to Pereira (1999) several parameters are used as indicators of the uniformity of water application to a field. The most commonly used, which are dependent on the irrigation system, are the emission uniformity (EU), emitter flow variation (qvar), the uniformity coefficients (UC) and coefficient of variation (CV).

The first uniformity parameter used was emission uniformity (EU) which is the most useful system performance indicator for trickle systems. Some times in case of field evaluation it is defined as distributions uniformity (DU) which was calculated using Equation (2.10) (Kruse, 1978).

$$EU = 100 * \frac{q\,min}{qa} \tag{2.10}$$

where, EU = Field emission uniformity (%);

q_{min} = Minimum discharge rate computed from minimum pressure in the system (l/h)

q_a = average of all field data emitter discharge rates (l/h).

The second uniformity parameter used was emitter flow variation (qvar) which was calculated using Equation (2.11) (Wu, 1983).

$$q_{var} = \frac{(qmax - qmin)}{qmax} \tag{2.11}$$

where: qmax = maximum emitter flow rate (l/h)

qmin = minimum emitter flow rate (l/h)

The second uniformity parameter used was emitter flow variation (qvar) which was calculated using Equation (2.12) (Wu, 1983).

$$Cv = \frac{s}{\mathrm{qa}} \tag{2.12}$$

where: S = standard deviation of emitter flow rates (l/h)

qa = average emitter flow rate (l/h)

The fourth uniformity parameter used was uniformity coefficients (UC) which is often described in terms of the coefficient of variation defined as the ratio of the standard deviation to the mean and is calculated using Equation (2.13) (ASAE, 1985) expressed as:

$$Uc = \left(1 - \frac{sq}{qa}\right) * 100 \quad (2.13)$$

where, UC = uniformity coefficient (%)

Sq = average absolute deviation of all emitters flow from the average emitter flow (l/h)

qa = average emitter flow rate (l/h)

2.6.3. Water productivity

Historically, farm productivity was measured in yield per hectare, since land was the constraining resource. However, as the twenty-first century begins, policy makers are beginning to look at water as the limiting factor for food production. "Water productivity" (WP) is defined as crop yield per unit applied irrigation water that is looking into the efficiency of applied irrigation water (Zhang, 2003). Water use efficiency is defined as tones of produce yield per amount of irrigation water used in the production cycle. Even if yield per hectare is high, using excessive amounts of irrigation water to achieve that high yield is not an efficient use of a limited water resource. Water productivity with dimensions of kg m^{-3} is defined as the ratio of the mass of marketable yield (Y) to the volume of water consumed by the crop (ETa).

$$\text{Crop water productivity} = \frac{Crop\ yield}{water\ consumptively\ used\ in\ ET} \quad (2.14)$$

Representative values of WUE for vegetables at field level, expressed with evapo-transpiration in the denominator, can vary between 0.10 and 4 kg/m3 (Zwart *et.al.*, 2004). Crop water productivity (WP) or water use efficiency (WUE), as reviewed by Molden (2003), is a key term in the evaluation of irrigation.

2.7. Crop Water Requirement

Crop water use, consumptive use and evapotranspiration are the terms that are used interchangeably to describe the water consumed by a crop. Water requirement depend mainly on the nature and stage of growth of the crop, soil type and environmental conditions.

Different crops have different water requirements under the same weather conditions. Hence, the crop coefficients appropriate to the specific crops are used along with the values of reference evapotranspiration for computing the consumptive use at different growth stages of the crop by water -balance approach. Crops will transpire water at the maximum rate when soil water is at field capacity. When soil moisture decreases, crops have to exert energy to extract water from soil. Usually, the transpiration rate does not decrease significantly until the soil moisture falls below 50% of field capacity (Sharma, 2006). The evapotranspiration (ETc in mm) of a crop under irrigation is obtained by the following equation (Sijali, 2001).

$$ET_c = K_c * ETo \tag{2.15}$$

where, ET_C = crop evapotranspiration (mm)

ETo = grass reference evapotranspiration (mm)

K_C = crop coefficient.

The ET_O is often determined from meteorological data using the equation developed by FAO Penman Monteith equation (Allen *et al.*, 1998). Historical climatic data including monthly maximum and minimum temperatures, relative humidity, sunshine hours and wind speed are collected for the determination of ETo.

$$E\,To = \frac{0.408\Delta(R_n - G) + \gamma\frac{900U_2}{T+273}(e_s - e_a)}{\Delta + \gamma(1 + 0.34U_2)} \tag{2.16}$$

where, ETo = reference crop evapo-transpiration (mm)

G = Soil heat flux density (MJ/m^2 day)

T = Air temperature at 2 m heat (oc)

U_2 = wind speed at 2 m height (m/s)

e_s = Saturated vapor pressure (Kpa)

e_a = actual vapor pressure (kpa)

Δ = Slope of vapor pressure curve (Kpa/oc)

R_n = net radiation at the crop surface (MJ/m^2-day) and

γ = Psychometric constant (kpa/oc)

2.8. Principles of Mulching

Mulching is a protective covering, as of bark chip, straw, or plastic sheeting placed on the ground around plants (www.thefreedictionary.com/mulching). Mulches are frequently used in vegetable production to reduce evaporation losses from the soil surface, to accelerate crop development in cool climates by increasing soil temperature, to reduce erosion, or to assist in weed control (Allen *et al*., 2006). Use of mulch had resulted in significant onion yield differences (Ramalan1 *et al*., 2010). As discussed above mulches generally of two types. Plant materials (organic) or they may be synthetic (plastic) mulches. One of the best benefits of any mulch is its ability to retain moisture in the soil.

2.8.1. Organic mulch

Wheat straw, grass clippings, and leaf debris are fairly abundant byproducts which can be used as organic mulch (Michael, 2013). There are many advantages of adding organic mulch. These include: Organic mulches break down over time and contribute to soil health. This can be very helpful, especially if the soil fertility is poor, Mulch reduces winter injury and helps with weed control and other mulch benefits include protection from erosion and protection from mechanical injury from weed eaters and lawnmowers. The Use of straw mulch had resulted in significant onion yield and water use efficiency increase (Ramalan *et al*., 2010). If 50% of the soil surface were covered by organic crop residue mulch, then the soil evaporation would be reduced by about 25% (Allen *et al*., 1998). Study shows Onion crop mulched with rice straw and water application depth per irrigation should be kept at 50–75% weekly reference evapotranspiration. This improves crop water productivity in the study area (Igbadun *el al*., 2012). Mulching with plant products such as wheat straw increases water retention and prevents soil evaporation (Steiner, 1989; Li and Xiao, 1992; Baumhardt and Jones, 2002; Kar and Singh, 2004). This also ensures a more even moisture distribution throughout the soil profile, which further improves water use. Organic mulches also improve water use efficiency indirectly. As the mulch decomposes, humus is added to the soil, which increases its water holding capacity (Unger, 1974). According to Michael (2013) all organic mulch types were equally effective in conserving soil moisture.

A mulch layer prevents weed seedling growth by inhibiting light penetration to the soil surface (Ossom *et al*., 2001). Lower weed prevalence significantly improves water use efficiency. Mulching with many types of organic materials, including chopped grass and clover material has been demonstrated to positively contribute to improved plant growth, development and enhanced bulb yield of onions (Russo *et al*., 1997; Hanson *et al*., 2001; Hugh *et al*., 2003; Riley *et al*., 2003). Experiment result showed that, wheat straw, grass clippings, and leaf debris mulch layer of at least 5 cm thick reduced surface evaporation to 40% compared to the water losses from bare soil. Further, earlier researchers have demonstrated that in comparison to not mulched soils, the crop yields of mulched soils depending on factors such as geographic location, soil type and nature of mulch can be enhanced two- or three-folds in vegetables yield (Stephenson and Bergman, 1963; Pollack *et al*., 1969; Bhella, 1986). Experimental plot treated with organic based mulch showed that onion bulb yield increment greater than 230% than no mulch (Baba *et al*., 2013). Onion yield under straw mulch, though at average with the plastic mulches, out-yielded bare soil (no mulch) (Ramalan1 *et al*., 2010). Mulching with rice straw material gave a yield increase of about 12–15% and also significantly improves the crop water productivity of the onion crop compared to a no-mulch condition (Igbadun *et al*., 2012).

The depth of the organic mulch and the fraction of the soil surface covered can vary widely. These two parameters will affect the amount of reduction in evaporation from the soil surface. If 50% of the soil surface were covered by organic crop residue mulch, then the soil evaporation would be reduced by about 25% (Allen *et al*., 1998). According to Michael (2013) a mulch layer of at least 5 cm reduced surface evaporation to 40% compared to the water losses from bare soil. Doubling mulching rate from 5cm to 10cm maintained soil moisture 10% higher throughout most of the experiment. However, increasing the rate further to 15 cm had no significant effect. Wheat straw mulch is used at the rate of 2tons ha^{-1}.

2.8.2. Plastic mulch

Plastic mulches generally consist of thin sheets of polyethylene or a similar material placed over the ground surface. According to (Allen *et al*., 1998) crop growth rates and vegetable yields are increased by the use of plastic mulches. Plastic mulches substantially reduce the evaporation of water from the soil surface, especially under trickle irrigation systems.

Associated with the reduction in evaporation is a general increase in transpiration from vegetation caused by the transfer of both sensible and radioactive heat from the surface of the plastic cover to adjacent vegetation. Even though the transpiration rates under mulch may increase by an average of 10-30% over the season as compared to using no mulch, the Kc values decrease by an average of 10-30% due to the 50-80% reduction in soil evaporation (Allen *et al*., 1998). Mulching with black polyethylene did significantly improve the crop water productivity of the onion crop. No yield advantage was observed using white as against black mulch. Seasonal water uses were significantly reduced under mulches (straw>white plastic>black plastic) than with bare soil which resulted in over 400mm per season (Ramalan *et al*., 2010). Color plastic influences albedo mainly during the early stages of the crop (Allen *et al*., 1998).

Mulching black polyethylene material gave a yield increase of about 12–15% and also significantly improves the crop water productivity of the onion crop compared to a no-mulch condition (Igbadun *et al*., 2012).

2.9. Principles of Drip Lateral Spacing

Drip lateral is water saving irrigation system that delivers water directly to the plant‘s roots through a series of tubes, pipe valves and emitters. The largest expense of a surface drip irrigation system is the cost of drip line system (Mahbub *et al*., 2009). The closer the spacing of the drip line, the more drip lines are needed to irrigate a given area and the higher the cost for the system (Mahbub *et al*., 2009). Currently the drip lateral spacing used is fixed drip lateral placed in every row (Wondatir *et al*., 2013). Therefore, one means of minimizing drip irrigation system cost is to adjust the drip lateral spacing. According to Wondatir *et al*. (2013) research result one lateral design for each two plant rows gave high net income than the one lateral design for each one plant row for drip irrigated fresh marketable yield of onion. Wondatir *et al*. (2013) also discussed that drip irrigation cost of double row lateral spacing was 20.64% less than a single lateral spacing for each crop rows. A maximum marketable yield obtained in treatment of 2 m lateral spacing by 80% pan coefficient contribute for a high economical yearly net return income of ETB 49,175. Similarly 2 m lateral spacing with 80% pan coefficient gave the maximum water use efficiency of 6.13kg m^{-3}. One lateral design for each two plant rows was found to be more economic than one lateral design for each one plant row as its gross return and net return were higher. Also, the cost of production for one lateral design for each two plant rows was lower than that of one lateral design for each one plant row (Himanshu *et al*., 2012).

2.10. Agronomy of Onion

Onion (*Allium cepa L.*) is a popular vegetable grown for its pungent bulbs and flavorful leaves. It is widely grown throughout the world. The bulb is composed of concentric, fleshy, enlarged leaf bases or scales. The outer leaf bases lose moisture and become scaly and the inner leaves generally thicken as bulbs develop. Onions can be grown successfully on any fertile, well-drained, non-crusting soil. The optimum pH range, regardless of soil type, is 6.0 to 6.8, although alkaline soils are also suitable. Onions do not thrive in soils below pH 6.0 because of trace element deficiencies, or occasionally, aluminum or manganese toxicity. Onion is cool-season biennial, and is tolerant of frost. Optimum temperatures for plant development are between 13 and 24°C, although the range for seedling growth is narrow, 20-25°C. High temperatures favor blubbing and curing. Onions are considered as shallow-rooted crop. As sited in Pejic. *et al*.(2010) is that the maximum root penetration of onion was 0.76 m, most of the roots were in the top 0.18 m of soil, whereas only few roots were found below 0.31 m. Irrigation water that moves below 0.76 m is most likely not available to the onion crop. Greenwood *et al*. (1982) showed that 90% of the root system of the onion plant was concentrated at the top 0.4 m of soil and only 2 - 3% of the total root length was recorded below 0.6 m depth, which indicates that very little water could be extracted from soil depths below 0.6 m. Because onions have very strong positive yield and grade responses to wet soil, yet exhibit increased risk of decomposition in overly wet soil, it is indispensable that the drip system be carefully designed to apply water uniformly. Yield is lost in excessively dry areas, while disease and nitrate leaching are promoted in excessively wet areas. The minimum water application uniformity for onion is 90 percent (Shock *et al*., 2013).

3. MATERIALS AND METHODS

3.1. Description of the Study Area

The experiment was conducted at West Shoa Zone, Ambo Woreda in Ambo Plant Protection Research Center Farm site from October 2017 to May 2018 G.C. The geographical location of the site is 037^0 51'35.016'' E longitude and $08^0$58'16.783'' N latitude and at altitude of 2144 m a.s.l. The area is about 115km from Adis Abeba and experienced a bimodal rainfall within a mean annual precipitation of 1029 mm. The mean maximum and minimum temperatures of the area range from 26.4^{o}C and 10.3^{o}C respectively. The soil texture of the study area is clay.

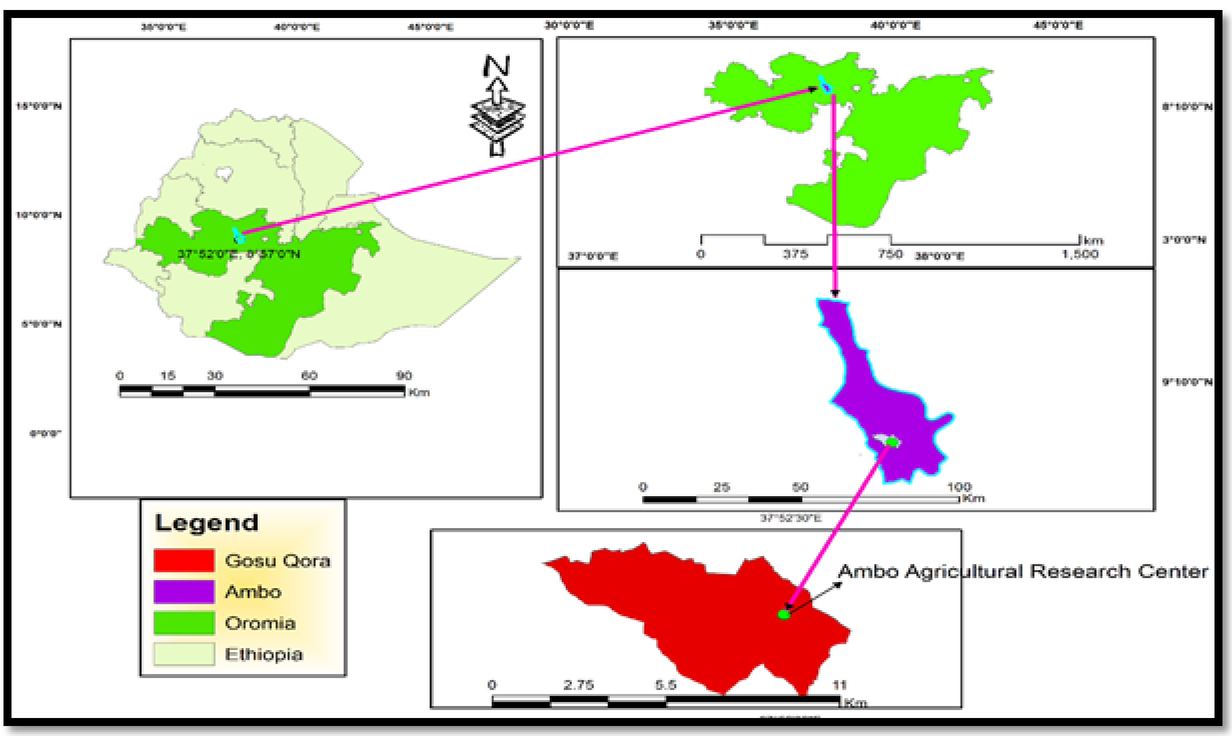


Figure 1. Map of the study area

3.2. Experimental Design of the Study

The experiment was a two factor factorial experiment arranged in Randomized Complete Block Design (RCBD) with three replications. The two factors were drip lateral spacing and mulch types. The drip lateral spacing were two levels (the drip laterals were placed in every plant row and between two rows (at equal distance from the two rows)), whereas mulch type were four levels (white plastic mulch, black plastic mulch, wheat straw mulch and no mulch).

No mulch with drip lateral in every row was considered as a control for this experiment. The sizes of experimental plots were 3 meter by 1.2 meter (3.6 m^2) with 8 plots per each replication. The spacing between blocks and plots were kept 2 meters and 1meter respectively. Inter-row 30cm and intra-row spacing of 10cm with 4 onion plant rows per each plot.

The treatment combinations was

T1=No mulch with drip lateral in every row (control)

T2=No mulch with drip lateral between two rows

T3=Wheat straw mulch with drip lateral in every row

T4=Wheat straw mulch with drip lateral between two rows

T5=White colored plastic mulch with drip lateral in every row

T6=White colored Plastic mulch with drip lateral between two rows

T7=Black colored plastic mulch with drip lateral in every row

T8=Black colored plastic mulch with drip lateral between two rows

3.3. Crop Management

An onion seed of "Adama Red" variety was used as test crop from Melkas Agricultural research Center. The seeds were sown in the well prepared nursery seed bed field on 1st January 2018. The seedlings were transplanted on to the experimental plots on 16th January 2018. The recommended fertilizers rates of 150 kg/ha for urea and 200 kg/ha for TSP were applied during transplanting in this experiment (Getachew *et al*., 2011). The amount of fertilizer applied per each plot was calculated from the recommended fertilizer rate per hectare base. 0.054 kg of urea and 0.075 kg of TSP were applied for the 3.6 m^2 experimental plot at the time of transplanting planting. Hand weeding was used to control weeds. The data of yield and total amounts of water applied were used to evaluate the effects of drip lateral spacing and mulching on onion crop and water use efficiency.

3.4. Field Layout

Prior to sowing, well suited land in terms of slope and land uniformity was selected. Land preparation like plowing and harrowing was done one month prior to planting buy using tractor and the nursery and experimental seed bed preparation was done manually.

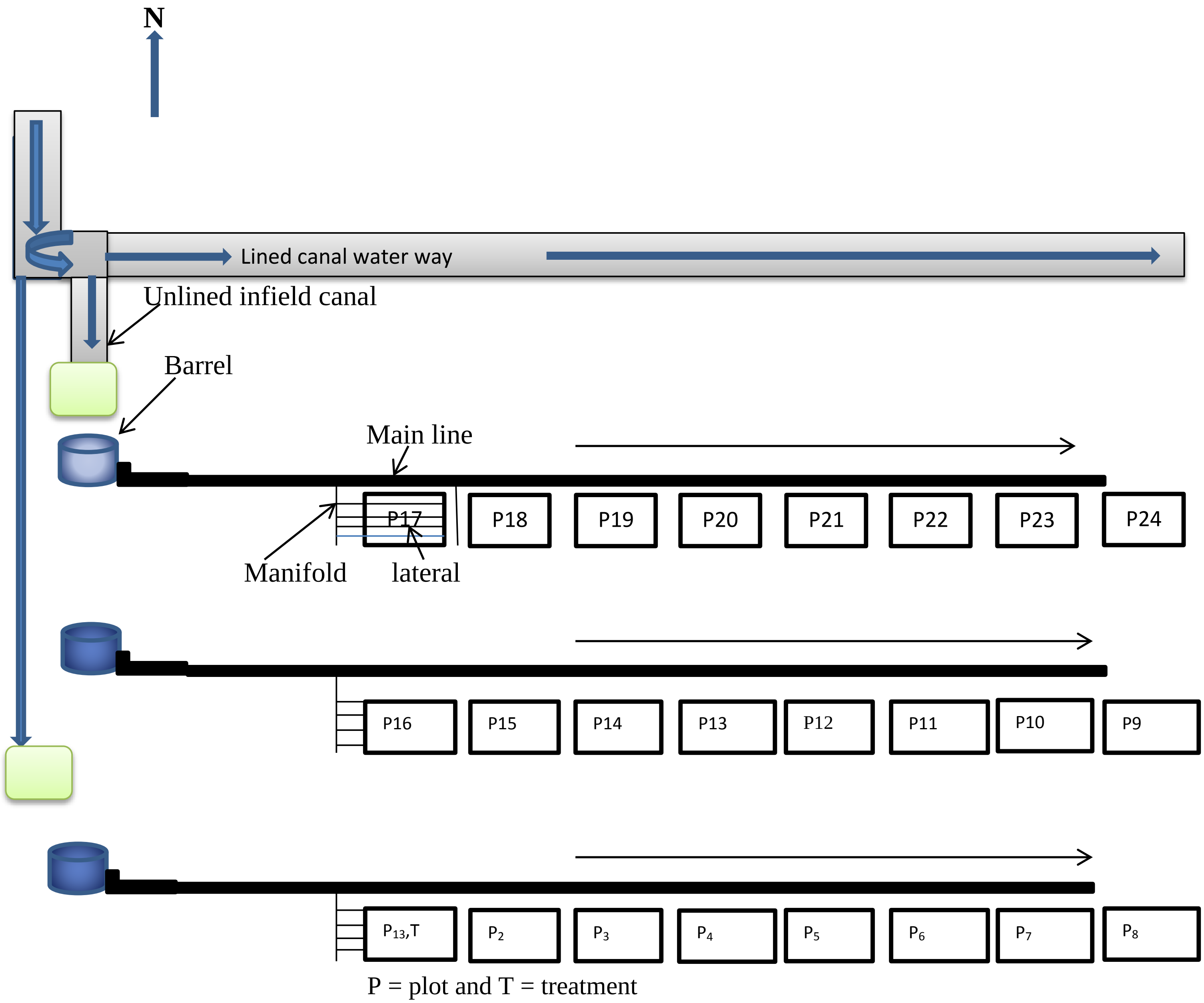


Figure 2. Field Layout

Figure 3. Field layout of the study area

3.5. Drip Installation Procedure

Overhead barrel system (one barrel per each replication) was used to provide the right pressure for the pipe system. The stand for placing water container of 200 litre barrel was constructed 1.5 m (as per recommended by manufacturer) above the ground from locally available wood. The barrel top was covered with sack in order to prevent entrance of trash and it was drilled 5 cm above its bottom and ¾" socket was welded on to it. Drain outlet was fitted to the socket on its upper end. A mainline with a diameter of 25 and 20 mm was connected to the drain outlet. Manifold of 16 mm was connected to main line. The filter was attached to the drain outlet that distributes relatively clean water and for each replication control valves was connected on the drain outlet. The laterals were connected to the manifold at 0.60 m spacing for drip lateral between two rows and at 0.30 m spacing for drip lateral in every row. Control valve was also connected to the manifold to control the water flow to each plot separately. The end of the laterals and the manifold was closed with end caps. The size of main line is 20mm, size of lateral is 16mm, and dripper spacing is 30cm. Two adjacent drippers were available at 30cm dripper spacing.

Figure 4. Overhead tanks (barrel) system

3.6. Application of Mulch

Three types of mulch (no mulch, wheat straw mulch, white plastic mulch and black plastic mulch) were used to conduct the experiment.

3.6.1. Wheat straw mulch

Wheat straw mulch was collected from wheat experimental field of Ambo Plant Protection Research site and applied uniformly to the experimental plots at the layer of 10cm depth and at 15 days after transplanting (Michael, 2013). The cost of wheat straw mulch was 75ETB kg^{-1} of wheat straw. The cost was taken from survey done for three consecutive years.

.

Figure 5. Wheat straw mulch

3.6.2. Plastic mulch

Black and White Plastic mulch treatments were purchased from dealers of Adis Abeba city and applied over the ground surface of experimental plots at 15 days after transplanting as plastic mulch treatment. Plastic mulch 1.5mm thick was used (Charles, 1993). Holes were cut into the plastic film at plant spacing (10cm) to allow the plant vegetation to emerge. The mean cost value of (38ETB 2m^2 and 40ETB per 2m^2 of plastic for white and black plastic mulch respectively) three years consecutive years were used.

Figure 6. Black plastic mulch and white plastic mulch

3.7. Irrigation Water Application Procedure

For the experiment water source was river. Water was conveyed from river to the experimental site by lined canal and diverted to the field by unlined canal and collected in to the overhead tank manually to irrigate the experimental plot

Figure 7. Appling water to barrel manually

3.8. Irrigation Scheduling

Crop water requirement of onion crop during different growing stage was computed by CROPWAT software using climate data (maximum and minimum air temperature, relative humidity, wind speed, sunshine hour and rain fall) (Appendix Table 1), test crop data (plant root depth, crop coefficient, growth stage and length of growth period) and soil data(Appendix Table 3). Crop evapotranspiration (ETc) was calculated using CROPWAT 8.0 soft model (Allen *et al*., 1998) (Appendix Table 9). Irrigation scheduling for 50% of soil water depletion and knowing ETc and soil infiltration rate, the frequency and duration of application was determined as follow (FAO, 1997) (Appendix Table 9).

Fraction of surface area wetted (P)

$$P = \frac{W}{(Lr * Le)} \tag{3.1}$$

where, P = fraction of surface area wetted

W = surface area wetted (m^2)

Lr = plant row spacing (m)

Le = emitter spacing (m)

Surface Area Wetted (w) was taken from FAO (1997) for Different Emitter Flow and Soil Infiltration Rate (Appendix Table 5).

Depth of application

$$d = \frac{(P * Sa)D * P}{(Eu * Ea)} \tag{3.2}$$

where, d = depth of application (mm)

S_a = Total available soil water (mm/m)

D = plant root depth (m)

Ea = field application efficiency (%)

Eu = emission uniformity (%)

Irrigation interval (i)

$$i = \frac{(P * Sa)D * P}{ETc} \tag{3.3}$$

where, *i* = irrigation interval (day)

ET_{crop} = Crop Water Requirements (mm/day)

Flow duration (t) was

$$t = \frac{d * Lr * Le}{qe} \tag{3.4}$$

where, t =flow duration (hr.)

q_e = emitter flow rate (l/hr)

A total of 30650lit of water was applied to the experimental field through drip irrigation system for the cropping season. The Irrigation frequency was 2 days and the set time was 2 hours Appendix Table 9). Irrigation was scheduled based on crop consumptive use rate and the amount of available moisture in the crop root zone.

3.9. Gross Irrigation Water Requirement

Gross irrigation requirement of test crop was determined equation (3.5) FAO (1998) and drip irrigation efficiency was taken 90%.

$$GIR = \frac{NIR}{Ea} 100 \quad (3.5)$$

where, GIR = growth irrigation requirement (mm)

NIR = net irrigation requirement (mm)

Ea = application efficiency (%)

3.10. Net Irrigation Water Requirement

Net irrigation requirement of test crop was computed from equation (3.6).

$$NIR = ETc - P_e \quad (3.6)$$

where, P_e = effective rainfall value (mm)

Effective rainfall was taken from meteorological stations and calculated from equation (3.7)

$$Pe = P-(C*P) \quad (3.7)$$

where, P = total rainfall

C = constant (0.8)

3.11. Bulb Yield of Onion

The test plant was up rooted from two central rows of each plot at its optimum maturity (June 6^{th}) it was field dried for 5 days under sunny conditions (George *et al.*, 2014). After it was dried the bulb yield was cut from its above ground plant part and the weight of its bulb yield was taken and converted to hectare base and bulb yield per hectare (Kg ha^{-1}) was used for the analysis to determine effects of drip lateral spacing and mulching on bulb yield.

3.12. Biomass of Onion

It is the sum of the fresh weight above ground parts and roots. Biomass of onion was recorded as soon as the crop was harvested from two central rows at the time of harvesting.

The sample taken from two central rows was converted to hectare bases and biomass per hectare (kg ha^{-1}) was used to determine effects of drip lateral spacing and mulching on onion biomass.

3.13. Plant Height

The height of above ground onion plant part was measured in cm from five plants of randomly selected from the central two rows. The total measured plant height was summed and divided by the number of plants to get the height of each plant. This average onion plant height was used to determine the effects of drip lateral spacing and mulching on plant height.

3.14. Plant Population

Number of onion plants per plot was recorded three times, first at 15 days, second at 60 days; and third at maturity from the central two rows and the mean was computed and used for analysis.

3.15. Onion Bulb Diameter

Onion bulb diameter was measured in cm from five plants randomly selected from central two rows and the mean was computed and used for the analysis. Onion bulb was measured by diameter, from one side to the other side across the widest point while looking at the bulb from the top (stalk end) by using caliper.

3.16. Harvest Index

It was taken from weight of mean biomass as a percentage of the mean bulb weight of the crop.

3.17. Water Use Efficiency

Onion crop water-use efficiency is in terms of the marketable bulb yield produced per unit volume of water. It was calculated from the ratio of mean weight of bulb yield to that of total volume of water consumed. And the values were used for analysis. Water use efficiency was calculated using (equation 3.8) (Oweis *et al*., 1998; Zhang *et al*., 1998) as:

$$WUE = \frac{Y}{\mathrm{ETa}} \tag{3.8}$$

where, WUE = Water Use efficiency (Kg m^3)

ETa = Actual Evapotranspiration (mm)

3.18. Economic Analysis

Economic analysis of the experiment was analyzed by taking the average of three years cost of drip lateral, mulching cost and manpower cast for weeding, drip lateral installation and mulch installation removal. Each cost was calculated for each treatment separately. The mean bulb yield (kg ha^{-1}) was adjusted for yield losses by subtracting 10% of the bulb yield from total yield. The total net return was calculated by multiplying bulb yield with its production cost separately for each treatment. It was determined using partial budget analysis. Equations (3.9, 3.10 and 3.11) were used. The value with the highest net return was taken as profitable.

$$TR=Y*P \tag{3.9}$$

$$NI=TR-TC \tag{3.10}$$

$$TC=FC+VC \tag{3.11}$$

Where, TR = total return

Y = crop yield

P = unit price

NI = net income

TC = total cost

FC = fixed cost

VC = variable cost

3.19. Data Collection

Primary and secondary data were collected during the experiment.

3.19.1. The primary data

The Physical and chemical properties of soil like Texture, Bulk density, Infiltration rate, FC, PWP, EC, CEC, OM and PH were collected, analyzed and discussed below.

Agronomic parameters like Land preparation date, Seed bed preparation date, Sowing date, transplanting date, Spacing, Fertilizer Application time and rate, wedding and pesticide application, date of planting, emergence, flowering, fruiting, maturity, harvesting date, wetting diameter of drip emitters, emitters discharge rate, growth and yield components were recorded.

3.19.2. Secondary data collection

Location of the study area, rainfall, minimum and maximum air temperature, sunshine hours, wind speeds and relative humidity were collected from Ambo Plant Protection Research Center meteorological stations (Appendix Table 1).

3.19.3. Soil sampling and analysis

The soil was characterized in terms of its physical and chemical properties. The physical and chemical properties of the soil in the study area (organic matter content, pH, texture, bulk density, moisture content at Field Capacity (FC) and Permanent Welting Point (PWP)) was measured to characterize soils of the study site (Appendix Table 2 and Appendix Table 3).

Bulk density

The soil bulk density of the study area was determined from undisturbed soil samples collected by core samplers at three depths of 0-15 cm, 15-30 cm, and 30-45 cm. and analysed by core method i.e., oven dring for 24 hrs at 105^0c and weight for calculating dry density using equation 3.12 given by(Hillel, 2004) (Appendix 3).

$$\rho_b = \frac{M_s}{V_c} \tag{3.12}$$

where:- ρ_b is soil bulk-density (g/ cm^3)

M_s is mass of dry soil (g) and

V_c is volume of soil in the core (cm^3)

That means, a low density indicates a high volume of pore space and a high density shows low volume of pore space in soil.

Soil water content

Moisture content at field capacity and permanent wilting point of the study area was determined from disturbed soil samples collected using core sampler by taking soil sample at a depth of 0-30cm, 30-60cm and 60-90cm. Soil samples were saturated for two to three days and using a pressure plate apparatus at a pressure of 1/3 bar (for field capacity) and 15 bars (for permanent wilting point) was exert until no further change in soil moisture content was observed. After getting soil moisture values corresponding to these constants, available water holding capacity of the soil was calculated. 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 using equation below as proposed by (Allen *et al*., 1998) (Appendix 2).

$$TAW = \sum(\theta_{FC} - \theta_{PWP})Z_r \tag{3.13}$$

where:-TAW is Total available soil water, mm

θ_{FC} is Moisture content of the soil at field capacity (%)

θ_{PWP} is Moisture content of the soil at permanent wilting point (%)

Z_r is depth of the soil layer within the root zone (mm)

Soil Texture

The soil particle size of the study area was determined from distributed soil sample taken at different depth (0-30cm, 30-60cm and 60-90cm) using hydrometer method (Staney and Bernard, 1992) and the soil separate (textural class) of the study area was classified using USDA textural triangle (Appendix 2).

The soil infiltration rate of the study area was determined using double infiltrometer

Organic matter content

Organic carbon content was determined using titration method to determine soil organic matter content of the study area (Staney and Bernard, 1992) (Appendix 3).

Soil pH

The pH of the soil was measured potentiometrically using a pH meter with combined glass electrode at soil water ratio of 1:2.5 as described by Carter (1993) (Appendix 3).

3.19.4. Test for uniformity of drippers

Water application uniformity test of the irrigation system was carried out for drip lateral spacing in every row and drip lateral spacing between two rows at the beginning and end of the experiment. For each treatment the two central lateral and three drippers (head, middle and tail positions) was selected randomly. Uniformity of water application was determined from the dripper outflow collected in cans for a known duration. A measuring can was placed beneath the dripper by excavating the soil and the water coming out of the dripper was collected for 10 minutes. A graduated cylinder was used to measure the volume of water collected in 10 minutes. To determine emitter flow characteristics and uniformity (equation 3.14 and 3.15) were used (Keller and Karmeli, 1974)

$$\mathrm{EU} = (1 - \frac{1.27\mathrm{CV}}{\sqrt{n}})\frac{qn}{qa} \qquad (3.14)$$

$$\mathrm{EUa} = 100(1 - \frac{1.27\mathrm{Cv}}{\sqrt{n}})\frac{1}{2}(\frac{qn}{qa} + \frac{qa}{qx}) \qquad (3.15)$$

where,Cv = manufacturing coefficient of variation of the emitter discharges when tested under the same pressure head,

EU = design emission uniformity of a subunit, percentage,

EUa = design absolute emission uniformity, percentage,

qn= minimum emitter discharge in the subunit, lph,

qa = average emitter discharge in the subunit, lph,

qx = maximum emitter discharge in the subunit, lph,

n = is 1 or the number of emitters per plant (St Sr/Se S1) if more than one,

To evaluate uniformity of water application from drip irrigation systems in the field (equation 3.16) was used (Merriam and Keller, 1978)

$$\mathrm{EUf} = \frac{(\frac{\mathrm{q}1}{4})}{\mathrm{q}a} * 100 \qquad (3.16)$$

where, EUf = field emission uniformity expressed as a percentage

q1/4 = average discharge of the emitters on quarter of the area receiving the least amount in the tested subunit, lph.

3.19. 5. Irrigation application efficiency

The application efficiency (E_a) of drip irrigation was computed using (equation 3.17) as proposed by (Wu, 1983).

$$Ea= \frac{Wz}{Wa} * 100 \qquad (3.17)$$

where, W_Z = water stored in the root zone and

W_A = water applied in mm.

Water stored in the root zone was determined gravimetrically at a depth of 0-30cm, 30-60cm and 60-90cm before and after irrigation and water applied was registered during each irrigation application.

3.20. Data Analysis

In order to evaluate main effects of drip lateral spacing and mulching on onion bulb yield and water use efficiency, interaction effects of drip lateral spacing and mulching on onion bulb yield and water use efficiency, economic advantage of combined use of drip lateral spacing and mulching in drip irrigated onion production and to test difference in application uniformity between drip lateral spacing data on bulb yield, yield components, cost of production and water applied were collected. Dependent variables like onion bulb yield, dry biomass, plant height and plant population, water use efficiency and application uniformity were subjected to ANOVA using SAS software with significance level $p \leq 0.05$. LSD test was applied for statistically significant parameters to compare means among the treatments (Steel and Torrie, 1980).

4. RESULTS AND DISCUSSION

The results of one cropping season experiment (onion bulb yield, dry biomass, plant height, plant population, water use efficiency and application uniformity of irrigation water) were collected from experimental plot. After necessary adjustments and calculation the data were subjected to ANOVA using SAS software with significance level $p \leq 0.05$. LSD test was applied for statistically significant parameters to compare means separation among the treatments. The main effects on mean yields, water use efficiency and net return due to the effects of drip lateral spacing and mulching were analyzed and discussed as follows.

4.1. Effects of Drip Lateral Spacing and Mulching on Onion Yield and Water use efficiency of Onion.

Main effect of drip lateral spacing and mulching had significant ($P \leq 0.05$) effect on marketable yield and water use efficiency of onion (Table 1 and Table 2).

4.1.1. Main effects of drip lateral spacing on onion bulb yield

The summarized mean values of bulb yield of onion are indicated in Table 1. Lateral spacing affected marketable bulb yield of onion. There was significant ($P \leq 0.05$) difference on mean bulb yield of onion due to main effects of drip lateral spacing. Significantly higher bulb yield of (34990 kg ha^{-1}) onion was recorded from onion grown under drip lateral in every row and the lowest bulb yield was recorded from onion grown under drip lateral spacing between two rows (30230 kg ha^{-1}). Bulb yield was reduced by 13.6% when drip lateral between two rows were used. This result is in agreement with finding of (Solomon *et al*., 2013) reporting drip lateral spacing in every row yields more. Similarly, Himanshu *et al*. (2012) reported the highest mean marketable bulb yield of onion was recorded from lateral spacing in every row. In contrary Wondatir *et al*. (2013) discussed that the highest marketable bulb yield was obtained due to the effects of 1m lateral spacing and the lowest were obtained due to the effects of 0.5m lateral spacing. Effects of drip lateral spacing on bulb yield and yield components of onion is discussed in terms of its effect on availability of irrigated water for plant roots. Drip lateral spacing in every row was irrigated near the root zone of onion as compared to that of drip laterals between two onion plant rows. Because drip laterals installed at 0.6meter apart from the plant (drip laterals between two rows) cause onion plant roots unable to extract the water as it drips beyond the root zone. This indicates that installing drip laterals spacing in every row (one drip lateral for one onion plant row) is more efficient in terms of water use than drip lateral spacing between two rows. So drip lateral spacing influenced the mean bulb yield of onion. Which means bulb yield was increased as one drip lateral is installed for one onion plant row. This result indicates that as we put drip laterals far from plant root zone water losses increase resulting in reduced yield. Therefore, drip lateral in every row performed best in reducing soil-water losses and increasing onion bulb yield.

Table 1. Main effects of drip lateral spacing on bulb yield

Treatment	YD (kg ha^{-1})	WUE (kg lit^{-1})	BM(kg ha^{-1})	PH(cm)	PP	BD (cm)	HI (%)
DLER	34990^{a}	1.14^{a}	37769	57.97^{a}	119	7.99^{a}	92.63^{a}
DLBTR	30230^{b}	0.99^{b}	35277	50.32^{b}	119	6.24^{b}	85.80^{b}
LSD (%)	2437.1	0.079	ns	1.96	ns	0.9	1.37
CV (%)	8.54	8.49	8.35	4.13	1.41	6.22	1.75

YD = Bulb Yield, WUE = Water Use Efficiency, BM = Biomass, PH = Plant Height, pp = Plant Population, BD = Bulb Diameter, HI = Harvest Index, DLER = Drip Lateral in every row, DLBTR = Drip Lateral between Two Rows, LSD (%) = Least Significant Difference at 5% of Significance, CV (%) = Coefficient of Variation and ns = no significant difference.

4.1.2. Main effects of mulching on onion yield

Bulb yield of onion has shown significant ($P \leq 0.05$) difference due to the main effects of mulching (Table 2). The highest mean bulb yield of (35117 kg ha^{-1}) was obtained from white plastic mulch and the lowest (31795 kg ha^{-1}) was from no mulch. But there is no significant ($P \leq 0.05$) difference in bulb yield between no mulch, wheat straw mulch and black plastic mulch. This result indicates that white plastic mulch has 9.5% more yield advantage than no much, wheat straw mulch and black plastic mulch (Table 2). Researchers have demonstrated that in comparison to not mulched soil, the crop yields of mulched soils (depending on factors such as geographic location, soil type and nature of mulch) can be enhanced two or three folds in vegetables (Stephenson and Bergman 1963; Pollack *et al*., 1969; Bhella, 1986). Bulb size under white plastic mulch treatment was significantly larger than in the other treatments. It is apparent that the large size of bulbs translated into heavy bulbs and enhanced bulb yield. White plastic mulch affects not only bulb size, but bulbs under the treatment also attractive in color and shape. There are many reports confirming the stimulation of growth and consequent yield increases by the use of plastic mulches. Plastic mulches substantially reduce evaporation of water from the soil surface especially under trickle/drip irrigation (Anusuya, 2001). Among its advantages in use is increase in soil temperature, reduced fertilizer leaching, reduced evaporation, cleaner product and reduced weed problems. Vavrina and Roka (2000) also reported that the benefits associated with the use of plastic mulches for vegetable production include higher yields, earlier harvests, improved weed control, cleaner fruit and increased efficiency in the use of water and fertilizers. Mulches may increase or decrease root zone temperature, depending on how the mulch affects the energy balance of the soil (Liakatas *et al*., 1986). Black plastic mulch resulted in the highest root zone temperature, which is consistent with numerous reports that show root zone temperature under black plastic mulch may be at least 2 °C higher compared to bare soil (Diaz- Perez and Batal, 2002; Lamont, 1993). No consistent differences in root zone temperature between bare soil and straw mulch. Total yield, marketable yield, total number of bulbs and weight of individual bulbs increased with increasing seasonal root zone temperature up to an optimum at 15.8 °C, followed by reductions in yields and individual bulb weight at >15.8 °C (Juan *et.al*., 2004).

The extent of the increase in soil temperature depends on the color of the film and the intensity of solar radiation. The other advantage associated with plastic mulch is that, the movement of water is directed upwards in soil under plastic mulch. So, the moisture content of soil under plastic mulch becomes lower in the long term. Plastic mulching prevents the leaching of fertilizer, because it acts as a physical barrier to irrigation water and/or rainfall and prevent leaching of nutrients. Plastic mulch reduces the splattering of soil on onion leaves during rains or sprinkling. This can reduce losses due to soil-borne diseases (Steiner *et al*., 1998; Derpsch, 2001; Westerfield, 2013). Similarly, Hamma (2013) reported that the highest bulb yield was observed from white plastic mulch than no mulch and other treatments. Igbadum *et al*. (2012) also reported that mulching with plastic materials gave significant yield increment. Anusuya (2001) found that vegetable yields were significantly higher, heads larger, and harvest earlier for plants grown under white plastic mulch compared to the control and other mulch treatments. Allen *et al*. (1998) reported that mulching with polyethylene did significantly improve bulb yield of onion than straw mulch. But Allen *et al*. (1998) indicated that no yield advantage was observed using white as against black plastic mulch. In contrary, Ramalan (2010) also reported that onion yields more under straw mulch but straw type and rate of straw mulch used was not specified. The practice of plastic mulching also shortened the growth period (Nishitani, 1979). From field observation of this experiment almost no onion flower was observed from onion grown under white plastic mulch and the growth of above ground plant parts was shorter in height. Onion grown under white plastic mulch was matured earlier than others. But onion grown under wheat straw mulch, black plastic mulch and no mulch were almost all flowered. The effect of flower was reduced bulb yield. The observation indicates that white plastic mulch conserved moisture and is transparent thereby allowing the penetration of light through it which enhanced the photosynthetic activities of plants resulting in the production of higher treatment means than the rest of the treatments. Field observations during the trial indicated that there is high weed germination under wheat straw mulch treatment resulting high labor consumption for weeding operation, relatively high moisture competition and crop-damage as a result of soil disturbance during hand weeding. These contribute to lower treatment mean of bulb yield. In the control treatment, there was no moisture conservation in which the plants under this treatment were denied adequate moisture for normal growth and developmental processes due to excessive evaporation thus resulting in the production of lower treatment means as earlier reported by (Baten *et al*., 1995; Duranti and Cuocolo, 1989). It is observed that weed germination under no mulch was almost less than that of wheat straw mulch due to moisture stress.

Table 2. Main effects of mulching on bulb yield

Treatments	YD(kg ha^{-1})	WUE(kg lit^{-1})	BM(kg ha^{-1})	PH(cm)	PP	BD(cm)	HI (%)
NM	31795^{bc}	1.04^{c}	37119	53^{bc}	119	6.22^{b}	85.66^{c}
WSM	32498^{b}	1.06^{b}	35352	55^{b}	119	6.00^{b}	91.82^{b}
WPM	35117^{a}	1.15^{a}	36949	51^{c}	118	7.18^{a}	95.04^{a}
BPM	32030^{b}	1.05^{c}	36672	57^{a}	119	6.16^{b}	87.33^{c}
LSD (%)	2520	0.08	ns	1.77	ns	0.8	1.94
CV (%)	8.54	8.49	8.35	4.13	1.41	4.13	1.75

YD = bulb yield, WUE = water use efficiency, BM = biomass, PH = plant height, PP = plant population, BD = bulb diameter, HI = harvest index, NM = no mulch, WSM=wheat straw mulch, WPM=white plastic mulch, BPM=black plastic mulch, ns = non-significant at 5 % probability level, LSD (%) = least significant Difference at 5% of significance, and CV (%) = Coefficient of variation.

4.1.3. Biomass and plant population

The mean value of biomass and plant population were showed non-significant ($p \leq 0.05$) difference due to main effect of drip lateral spacing and mulching (Table 3).

Table 3. Main effects of drip lateral spacing and mulching on biomass and plant population

Treatments	YD(kg ha^{-1})	BM(kg ha^{-1})	PP
NM	31795^{bc}	37119	119
WSM	32498^{b}	35352	119
WPM	35117^{a}	36949	118
BPM	32030^{b}	36672	119
LSD (%)	2520	ns	ns
CV (%)	8.54	8.49	1.41
DLER	34990^{a}	37769	119
DLBTR	30230^{b}	35277	119
LSD (%)	2437.1	ns	ns
CV (%)	8.54	8.35	1.41

YD = bulb yield, BM = biomass, PP = plant population, NM = no mulch, WSM=wheat straw mulch, WPM=white plastic mulch, BPM=black plastic mulch, DLER = drip lateral in every row, DLBTR = drip lateral between two rows, LSD (%) = least significant Difference at 5% of significance, CV (%) = Coefficient of variation and ns = no significant difference.

4.1.4. Main effects of drip lateral spacing on plant height

The mean value of plant height has showed significant ($P \leq 0.05$) difference due to main effect of drip lateral spacing (Table 4). The highest mean value of plant height of (57.97 cm) onion was recorded from onion grown under drip lateral spacing in every row and the lowest mean value of plant height (50.32 cm) was recorded from onion grown under drip lateral between two rows. The lowest mean value of plant height was observed due the effect of reduce availability of irrigation water applied by drip lateral between two rows.

Table 4. Effects of drip lateral spacing and mulching on plant height

Treatment	YD(kg ha^{-1})	BM(kg ha^{-1})	PH(cm)
DLER	34990^{a}	37769	57.97^{a}
DLBTR	30230^{b}	35277	50.32^{b}
LSD (%)	2437.1	ns	1.96
CV (%)	8.54	8.35	4.13

YD = bulb yield, BM = biomass, PH = plant height, DLER = drip lateral in every row, DLBTR = drip lateral between two rows, LSD (%) = least significant Difference at 5% of significance, CV (%) = Coefficient of variation and ns = no significant difference.

4.1.5. Main effects of mulching on plant height

The mean values of plant height showed significant ($P \leq 0.05$) difference due to the main effects mulching (Table 5). The highest mean value of plant height of (57cm) was recorded from black plastic mulch and the lowest (51cm) was from white plastic mulch. This result is in contrary with the result Hamma (2013) who reported that white polythene significantly produced a higher mean over other treatments and the lowest mean was produced by the control. There was no significant difference observed among no mulch and wheat straw mulch treatments. In view of this experiment increase in plant height under black plastic mulch is due to effect of flower observed on onion grown under black plastic mulching. Flowered onion plant showed higher plant height, reduced number of plant leave and reduced bulb size and weight.

Table 5. Effects of mulching on plant height

Treatment	YD(kg ha^{-1})	BM(kg ha^{-1})	PH(cm)
NM	31795^{bc}	37119	53^{bc}
WSM	32498^{b}	35352	55^{b}
WPM	35117^{a}	36949	51^{c}
BPM	32030^{b}	36672	57^{a}
LSD (%)	2520	ns	1.77
CV (%)	8.54	8.35	4.13

YD = bulb yield, BM = biomass, PH = plant height, DLER=drip line in every roe, DLBTR=drip line between two rows, NM = no mulch, WSM=wheat straw mulch, WPM=white plastic mulch, BPM=black plastic mulch, LSD (%) = least significant Difference at 5% of significance, CV (%) = Coefficient of variation and ns=non-significant at 5 % probability level

4.1.6. Main effects of drip lateral spacing on bulb diameter

The mean values of bulb diameter showed significant ($P \leq 0.05$) difference due to the main effects lateral spacing (Table 6). The highest mean value of onion bulb diameter (7.99 cm) was recorded from onion grown under drip lateral spacing in every row and the lowest mean value of bulb diameter (6.24 cm) was recorded from onion grown under drip lateral between two rows. This result is observed due to relatively efficient irrigation water consumption by the crop from water applied by drip laterals in every row than water applied through drip lateral between two rows. High onion bulb yield is expressed in terms of larger bulb size.

Table 6. Main effects of drip lateral spacing on bulb diameter

Treatments	YD(kg ha^{-1})	WUE(kg lit^{-1})	PH(cm)	BD(cm)	HI (%)
DLER	34990^{a}	1.14^{a}	57.97^{a}	7.99^{a}	92.63^{a}
DLBTR	30230^{b}	0.99^{b}	50.32^{b}	6.24^{b}	85.80^{b}
LSD (%)	2437.1	0.079	1.96	0.9	1.37
CV (%)	8.54	8.49	4.13	6.22	1.75

YD = bulb yield, WUE = water use efficiency, PH = plant height, BD = bulb diameter, HI = harvest index, DLER = drip lateral in every row, DLBTR = drip lateral between two rows, LSD (%) = least significant Difference at 5% of significance, and CV (%) = Coefficient of variation.

4.1.7. Main effects of mulching on bulb diameter

The mean values of bulb diameter showed significant ($P \leq 0.05$) difference due to the main effects mulching (Table 7). The highest mean value of bulb diameter of (7.18 cm) onion was recorded from onion grown under white plastic mulch and the lowest mean values of bulb diameters (6, 6.16 and 6.22 cm) was recorded from onion grown under wheat straw, black plastic and no mulches respectively. Bulb diameter results from no mulch, wheat straw mulch and black plastic mulch were showed non-significant ($P \leq 0.05$) difference due to the main effects of mulching. The biggest bulbs were obtained when the onions were mulched with white plastic and bulb size under this treatment was significantly larger than in the other treatments. It is apparent that the large size of bulbs translated into heavy bulbs and enhanced yield.

Field observations during the trials indicated that onion grown under white plastic mulch was not flowered on onion beds which resulted in shorter above ground plant parts, bigger bulb size and color full bulb than other three treatments and was thus more effective mulch in this regard. Inhibited flowering of the white plastic mulch threatened onions, in comparison to the other treatments may have led to enhanced bulb size and weight as more assimilates were translocate into bulb formation than in the other treatments. Anisuzzaman *et al.* (2009) demonstrated that mulching enhances the development and size of bulb than other agronomic parameters of onion.

Table 7. Main effects of mulching on bulb diameter

Treatments	YD(kg ha^{-1})	WUE(kg 1it^{-1})	PH(cm)	BD(cm)	HI (%)
NM	31795^{bc}	1.04^{c}	53^{bc}	6.22^{b}	85.66^{c}
WSM	32498^{b}	1.06^{b}	55^{b}	6.00^{b}	91.82^{b}
WPM	35117^{a}	1.15^{a}	51^{c}	7.18^{a}	95.04^{a}
BPM	32030^{b}	1.05^{c}	57^{a}	6.16^{b}	87.33^{c}
LSD (%)	2520	0.08	1.77	0.8	1.94
CV (%)	8.54	8.49	8.35	4.13	1.41

YD = bulb yield, WUE = water use efficiency, PH = plant height, BD = Bulb Diameter, HI = harvest Index, NM = no mulch, WSM=wheat straw mulch, WPM=white plastic mulch, BPM=black plastic mulch, LSD (%) = least significant Difference at 5% of significance, CV (%) = Coefficient of variation and ns=non-significant at 5 % probability level.

4.1.8. Harvest index

Harvest index describes plant capacity to allocate biomass into the formed reproductive parts; hence it is an important trait. Harvest index and its associations with bulb and biomass yields is important parameter. The mean values of harvest index were significantly ($P \leq 0.05$) different due to the main effects of drip lateral spacing (Table 8). The highest mean value of (92.63%) harvest index was recorded from onion grown under drip laterals in every row and the lowest mean value of (85.80 %) harvest index was obtained from drip lateral between two rows. So onion production under drip line installed in every row yields more.

The mean values of harvest index showed significant ($P \leq 0.05$) difference due to the main effects of mulching (Table 8). The highest mean value of (95.04 %) harvest index was recorded from white plastic mulch and the lowest (85.66%) score was from no mulch. This is due to highest mean bulb yield obtained from white mulch.

Table 8. Effects of drip lateral spacing and mulching on harvest Index of onion

Treatment	YD(kg ha^{-1})	BM(kg ha^{-1})	HI (%)
DLER	34990^{a}	37769	92.63^{a}
DLBTR	30230^{b}	35277	85.80^{b}
LSD (%)	2437.1	ns	1.37
CV (%)	8.54	8.35	1.75
NM	31795^{bc}	37119	85.66^{c}
WSM	32498^{b}	35352	91.82^{b}
WPM	35117^{a}	36949	95.04^{a}
BPM	32030^{b}	36672	87.33^{c}
LSD (%)	2520	ns	1.94
CV (%)	8.54	8.35	1.75

YD = bulb yield, BM = biomass, HI = harvest index, DLER = drip lateral in every row, DLBTR = drip lateral between two rows, NM = no mulch, WSM=wheat straw mulch, WPM=white plastic mulch, BPM=black plastic mulch LSD (%) = least significant Difference at 5% of significance, CV (%) = Coefficient of variation and ns = no significant difference.

4.1.9. Correlation of onion yield and yield parameters and water use efficiency

The results of correlation between each pair of the characters studied are presented in a Table 9. The correlation matrixes were showed that biomass, bulb diameter, harvest index and water use efficiency were correlated positively and significantly ($p \leq 0.05$) with onion bulb yield. Onion bulb yield (kg ha^{-1}) positively and significantly associated with bulb diameter (r = 0.74**), biomass (r = 0.89**), harvest index (r = 0.58*) and water use efficiency (r = 0.99**). This indicates that as bulb size increase bulb yield also increases which intern increase water use efficiency and harvest index. In another case bulb yield was negatively and significantly ($p \leq 0.05$) correlated with onion plant height (r = -0.56*). As observed from trial, onion with highest plant height was recorded form treatments with flower. Flowering of onion affected bulb size negatively. In this way bulb yield and plant height associated negatively. Onion bulb yield was positively and non-significantly correlate with plant population. Biomass was positively and significantly ($p \leq 0.05$) correlated with water use efficiency(r = 0.89**) and it was positively and significantly ($p \leq 0.05$) correlated with bulb diameter (r = 0.70**). Biomass also correlated with plant population positively and non- significantly (r = 0.05) and harvest index (r = 0.16). Bulb diameter correlated with plant population (r = -0.02) negatively and non-significantly ($p \leq 0.05$) and correlated with harvest index ($r = 0.35$) positively and non-significantly ($p \leq 0.05$).

Table 9. The correlation matrix of onion yields and water use efficiency

	YD	WUE	BM	PH	PP	BD	HI
YD	1.00						
WUE	0.99**	1.00					
BM	0.89**	0.89**	1.00				
PH	-0.56*	-0.57*	-0.27 ns	1.00			
PP	0.15 ns	0.15 ns	0.05 ns	0.02 ns	1.00		
BD	0.74**	0.74**	0.70**	-0.25 ns	-0.02 ns	1.00	
HI	0.58*	0.57*	0.16 ns	-0.74**	0.20 ns	0.35 ns	1.00

YD = bulb yield, WUE = water use efficiency, BM = biomass, PH = plant height, PP = plant population, BD = bulb diameter, HI = harvest index and * = significant difference

4.1.10. Water use efficiency

Water productivity or water use efficiency (WP) is a measure of crop yield per unit applied irrigation water that is looking into the efficiency of applied irrigation water (Zhang, 2003). Since it is affected by water losses, irrigation system used and place of irrigation water applied in terms of root zone it is main concern of this thesis. Irrigation water use efficiency is an important factor when considering irrigation systems and water management and probably will become more important as access to water becomes more limited. The mean values of water use efficiency are revealed that there was significant ($p \leq 0.05$) difference on water use efficiency of onion due to main effect of drip lateral spacing (Table 10). The highest water use efficiency of (1.14 kg lit^{-1}) was recorded from onion grown under drip lateral spacing in every row and the lowest water use efficiency (0.99kg lit^{-1}) was recorded from onion grown under drip lateral spacing between two rows. Higher water use efficiency occurred in drip lateral spacing in every row as compare to drip lateral spacing between two rows. Irrigation water use efficiency tends to increase with deceased drip lateral spacing under the same plant spacing. Similarly, Wondatir *et al*. (2013) reported drip lateral spacing in every row gave the maximum water use efficiency. Himanshu *et al*. (2012) also stated that the maximum irrigation water efficiency was recorded under drip lateral spacing in every row. This is because water use efficiency increases as bulb yield increase with the same amounts of irrigation water applied. As drip lateral in every row used we irrigate near the plant root zone and plants easily utilize applied water before it percolated deep beyond root zone. This means irrigation water loss is minimized; yield increased and score high water use efficiency. In contrary, when one drip lateral was use for two onion plant rows there were competition for water among two onion rows. Weed growth also high along drip laterals installed between two onion rows because that area is free of onion plant and wet.

Table 10. Effects of drip lateral spacing on water use efficiency of onion

Treatment	YD(kg ha^{-1})	BM(kg ha^{-1})	WUE(kg lit^{-1})
DLER	34990^{a}	37769	1.14^{a}
DLBTR	30230^{b}	35277	0.99^{b}
LSD (%)	2437.1	ns	0.079
CV (%)	8.54	8.35	8.49

YD = bulb yield, BM = biomass, WUE = Water use efficiency, DLER = drip lateral in every row, DLBTR = drip lateral between two rows, LSD (%) = least significant Difference at 5% of significance, CV (%) = Coefficient of variation and ns = no significant difference.

The mean values of water use efficiency showed significant ($P \leq 0.05$) difference due to the main effects of mulching (Table 11). The highest mean value of water use efficiency of (1.15kg lit^{-1}) was recorded from white plastic mulch and the lowest score of (1.04kg lit^{-1}) was from no mulch. This means that white plastic mulch reduce irrigation water losses and weed growth which in turn increase yield and water use efficiency than other treatments. This finding confirms of Igbadum *et al*. (2012) who reported, plastic mulch significantly improve the crop water productivity of onion compared to no mulch. Similarly Biswas (2015) reported that the highest water use efficiency was obtained under plastic mulch.

This is because onion requires frequent irrigation as the crop extract very little water from depths below 5cm. Most of the water is within the depth of 30 cm of the soil (Ali *et al*., 2007). Thus upper soil areas must be kept moist to stimulate root growth and provide adequate water for the plant. Mulching with plastic materials is a well-established technique for conserving soil moisture in the soil for plant growth and development (Rhu *et al*., 1990; Kashi *et al*., 2004).

In view of this experiment soil under plastic mulch was kept moist until next irrigation. This is because soil temperature under plastic mulch is high at day time and this high soil temperature causes to evaporate soil water from deeper soil but did not escape to the environment beyond plastic mulch. The evaporated soil water becomes condensed and drops as rain to the root zone at night time. These processes keep the soil around plant root zone moist to stimulate root growth and provide adequate water for the plant. Especially white plastic mulch and black plastic mulches are the most effective means of moisture conservation practice through its effect on soil water losses and weed growth. In another case soil temperature under white plastic mulch is more favorable than black plastic mulch for soil as black plastic absorbed most solar heat (Hanada, 1991). This high soil temperature under black plastic mulch affects plant growth and reduce yield. As a result water use efficiency reduced as yield decrease for the same amount of applied irrigation water. White plastic mulching reduced evaporation rate from the soil surface and the reduced water is utilized by plants, consequently, increased water use efficiency of onion. Therefore, the white plastic mulch performed best in reducing irrigation-water consumption and increasing water use efficiency.

Table 11. Effects mulching on water use efficiency of onion

Treatment	YD(kg ha^{-1})	BM(kg ha^{-1})	WUE(kg lit^{-1})
NM	31795^{bc}	37119	1.04^{c}
WSM	32498^{b}	35352	1.06^{b}
WPM	35117^{a}	36949	1.15^{a}
BPM	32030^{b}	36672	1.05^{c}
LSD (%)	2520	ns	0.08
CV (%)	8.54	8.35	8.49

YD = bulb yield, BM = biomass, WUE = Water Use efficiency, NM = no mulch, WSM=wheat straw mulch, WPM=white plastic mulch, BPM=black plastic mulch LSD (%) = least significant Difference at 5% of significance, CV (%) = Coefficient of variation and ns = no significant difference.

4.2. Interaction Effects of Different Drip Lateral Spacing and Mulch Types on Onion Yield and Water use efficiency

The summarized mean values of onion yield and water use efficiency showed that there were non-significant ($P \leq 0.05$) difference due interaction effects of lateral spacing and mulch types. Therefore no need to discuss about interaction effects of lateral spacing and mulching.

Table 12. Interaction effects of drip lateral spacing and mulching on onion yield and water use efficiency of onion

Sources of Variation	DF	Mean Square						
		Bulb yield (kg ha^{-1})	WUE (kg lit^{-1})	Biomass (kg ha^{-1})	Plant Height (cm)	Plant population	Bulb diameter(cm)	HI (%)
Replication	2	33181552.2	0.0351125	50598550.7	12.6467	1.04167	0.13013	5.90975
Drip lateral spacing	1	135929733.8*	0.14726667*	37250416.7	351.135*	0.375	0.38506667*	280.059467*
Mulching	3	6566.12.9*	0.00664444*	3862280.5	33.521666*	2.04167	0.05246111*	55.6753425*
Drip lateral spacing x Mulching	3	4347333.2	0.00446667	5849658.8	10.5928	2.375	0.02324	3.00633

DF = Degree Freedom, WUE = Water Use efficiency, HI = Harvest Index and * = Significantly Different

4.3. Economic Analysis and Evaluation

4. 3.1. Effect of drip lateral spacing on benefit to cost ratio (B/C) and marginal rate of return of onion production

In implementing modern irrigation system the most challenging one is material cost like drip accessories and materials used for water conservation measure (mulches). Drip laterals and mulches need means to offer them with affordable cost for farmers. So, to identify the most affordable system economic analysis and evaluation were computed based on investment, operation and production costs.

Economic analysis of this study was computed by using the results of the study based on the mean cost of materials taken from three consecutive years (2016, 2017 and 2018). Production costs and net return was calculated as Ethiopian birr (ETB ha^{-1}). The production costs were computed by considering drip lateral cost, labor cost for drip lateral installation and removal, cost for mulches, labor cost for mulch application and removal, labor cost for weeding and costs of additional bags purchased for added yield. Production costs like cost for seed, man power, land and land preparation, water, fertilizer, guarding and transportation were not included, because these costs were the same for each treatment in the production season.

Thus, based on drip lateral spacing, the cost of treatment in which the drip lateral between two onion plant rows was 50.34% less than the treatment in the drip lateral in every onion plant rows (Table 13). Even though the total variable cost of implementing drip lateral in every row greater than that of drip laterals between two rows, drip lateral in every row gave the maximum net income of 246,410ETB ha^{-1}. On the other hand, less net income of 238,070ETB ha^{-1} was obtained from drip lateral between two rows. This means farmers installing drip laterals in between two onion plant rows for production of onion under drip irrigation losses 8,340ETB per hectare under Ambo climate condition. The net benefit value to cost ratio for drip lateral in every row is 3.6 and for that of drip lateral between two rows is 7. This result generally revealed that drip lateral in every row gave high net income than the drip lateral between two rows for drip irrigated fresh marketable bulb yield of onion under Ambo condition. The result is due to significantly higher bulb yield obtained from onion grown under drip laterals in every row. Similarly Himanshu *et al*. (2012) reported that drip lateral in every row resulted in higher gross return, net return and benefit cost ratio. In spite of high initial investment, drip irrigation method is profitable for onion production with drip lateral in every row for the study area.

Table 13. Effect of drip lateral spacing on cost of production and net return of onion

Treatment	Mean Bulb yield (kg ha^{-1})	Adjusted Bulb yield (kg ha^{-1})	Gross field benefit (ETB ha^{-1})	TVC (ETB ha^{-1})	Net benefit (ETB ha^{-1})	Value to cost ratio	MRR (%)
Drip lateral between two rows	30230	27207	272070	34000	238070	7.00	
Drip lateral in every row	34990	31491	314910	68500	246410	3.60	24.17

TVC = Total Variable Cost and ETB = Ethiopian Birr and MRR = Marginal Ret of Return.
Note: - the price of onion is taken was 10ETB Kg^{-1}.

4.3.2. Effect of mulching on B/C ration of onion

The mean values of marginal ret of return (MRR) was revealed that no mulching gave the higher value than the control treatment (no mulch). Thus, the highest net benefit of 284,616ETB ha^{-1} was recorded from no mulch and followed by 280,329ETB ha^{-1} with wheat straw mulch for onion production (Table 14). The lowest net benefit 239,474 ETB ha^{-1} was obtained from black plastic mulch. The value to cost ratio for no mulch was 184.89 and for that of black plastic mulch is 4.91. This result confirms the farmer’s production practices (drip lateral in every row and no mulch) are economically feasible for onion production in sub humid areas of Ambo. This result shows that onion production under mulches is highly dependent on cost of mulch. Among the list of cost items for the onion production technology total variable costs of wheat straw, white straw and black straw mulches accounts about 87%, 96% and 97% respectively regardless of the technology. The remaining percentage of the cost is distributed among other costs. The cost structure of the trials indicates that a potential user of the mulching technology requires additional investment of 10,613.45, 43,497.65 and 47,256.91ETB per hectare for wheat straw, white plastic and black plastic mulch, respectively. The extra cost is associated with two main reasons. First, the farmer will have to pay for the cost of mulch materials used on the field. Due to the recorded increase in yield, the farmer will have to procure more bags for packaging.

Further research is required to investigate the over year effects of mulching on soil fertility and economic benefits of onion. This is because it takes time to observe the effects of mulching on soil fertility. And the reuse of drip laterals and mulching reduce costs of production.

Table 14. Effect of mulching on Benefit / cost ratio of onion production at Ambo

Treatments	Mean bulb yield (kg ha^{-1})	Adjusted bulb yield (kg ha^{-1})	Gross field benefit (ETB ha^{-1})	TVC (ETB ha^{-1})	Net benefit (ETB ha^{-1})	Value to cost ratio	MRR (%)
No mulch	31795	28615.5	286155	1539.35	284616	184.89	
Wheat straw mulch	32498	29248.2	292482	12152.8	280329	23.07	-0.40
White plastic mulch	35117	31605.3	316053	45037	271016	6.02	-0.28
Black plastic mulch	32030	28827	288270	48796.3	239474	4.96	-8.39

TVC = Total Variable Cost and ETB = Ethiopian Birr and MRR = Marginal Ret of Return.
Note: - the price of onion is taken was 10 ETB Kg^{-1}.

4.4. Test for Uniformity of Drippers

Field evaluations of systems under operation can play a fundamental role in improving performance and reveal often performances well below potential. Proper design and management of water are essential conditions to ensure uniformity of application. Performance of irrigation system can be evaluated in terms of application efficiency and uniformity.

4.4.1. Application uniformity

According to Solomon (1998), the term irrigation uniformity refers to the variation or non-uniformity in spatial distribution of the amounts of water applied to locations within the wetted area. The special uniformity of irrigation water application ensures the application of the same volume of water to all plants. Uniformity influences crop yields through the agronomic effects of under and over watering. Insufficient water leads to high soil moisture tension, plant stress and reduced crop yields. Excess water may reduce crop yields as a result of leaching of plant nutrients, results in an anaerobic rooting environment as well as increased disease or failure to stimulate growth of economically valuable parts of the plant (Griffiths and Lecler, 2001). Heermann *et al*. (1990), note that irrigation uniformities for drip irrigation systems can be evaluated by the emitter discharge. According to Pereira (1999) several parameters are used as indicators of the uniformity of water application to a field. The uniformity parameters used to test the uniformity of applied irrigation water for this experiment was emission uniformity (EU), emitter flow variation (q_{var}), the uniformity coefficients (UC) and coefficient of variation (CV).

Irrigation water application uniformity test of the irrigation system of the study area was carried out at the beginning and end of the treatments. For each treatment the two central lateral and three drippers (at head, at middle and at tail) positions was selected randomly for the two lateral spacing types. Uniformity of water application was determined from the dripper outflow collected in cans for 10 minutes. The obtained data was subjected to ANOVA using SAS software with significance level $p \leq 0.05$. LSD test was applied for statistically significant parameters to compare means among the treatments. The mean values showed no-significant ($P \leq 0.05$) difference in emission uniformity between emitter position and drip lateral spacing (Table 15).

Table 15. The emission uniformity (%) of the system during the experiment

Lateral spacing	Head	Middle	Tail
Lateral in every row	93.42	91.83	90.83
Lateral between two row	93.50	91.50	90.75
LSD (%)	ns	ns	ns
CV (%)	0.39	0.8	0.45

LSD (%) = least significant Difference at 5% of significance, CV (%) = Coefficient of variation and ns = non-significant difference.

Table 16 shows the emission uniformity expressed as distribution uniformity, emitter flow variation, coefficient of variation and uniformity coefficient under field condition. The average emission uniformity of the system was 92.39%. According to ASABE (1999), standard criteria for emission uniformity, 90% was categorized as excellent (Appendix Table 19). Therefore, the result on this experiment for emission uniformity was classified as excellent with values of under Table 16.

ASABE (1999), states that uniformity coefficient value greater than 90% classified as excellent and the results obtained on uniformity coefficient under the experiment in three places were classified as excellent (Appendix Table 19).

Generally the overall results obtained on application uniformity parameters had excellent performance. This could be due to proper pressure head, good water quality, good installation and follow-up

Table 16. Uniformity measures for the drip system

Parameter	Unit	Replication 1			Replication 2			Replication 3			Average
		Head	Middle	Tail	Head	Middle	Tail	Head	Middle	Tail	
Emission Uniformity	%	93.2	92.8	91.3	92.9	92.1	91.7	93	92.5	92	92.39
Emitter flow variation	%	14	15	15.2	14.3	14.8	15	13.9	14	14.8	14.55
Coefficient of variation	%	0.4	0.6	0.7	0.45	0.6	0.7	0.35	0.5	0.6	0.54
Uniformity coefficient	%	93	92.5	92.8	94	93	93.5	93.4	91	92	92.8

5. SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Summary

An experiment on effects of drip lateral spacing and mulching on yield, irrigation water use efficiency and net return of onion was conducted on clay soil of Ambo in 2017/2018 cropping season. The experiment was a two factor factorial experiment arranged in Randomized Complete Block Design (RCBD) with three replications. The two factors were drip lateral spacing and mulch types. The drip lateral spacing were two levels (the drip laterals was placed in every row and between two rows (at equal distance from the two rows)), whereas mulch type were four levels (white plastic mulch, black plastic mulch, wheat straw mulch and no mulch). No mulch with drip lateral in every row was considered as a control for this experiment.

The results of this experiment indicated that interaction effect of drip lateral spacing and mulching on onion yield and water use efficiency was showed non-significant difference ($P \leq 0.05$). But the main effects of both drip lateral spacing and mulching was showed significant difference ($P \leq 0.05$) on bulb yield, water use efficiency, plant height, bulb diameter and harvest Index. On the other side the mean value of biomass and plant population were showed non-significant ($p \leq 0.05$) difference due to main effect of drip lateral spacing and mulching. The highest bulb yields of 34990 kg ha^{-1} and 35177kg ha^{-1} were recorded from drip lateral spaced in every row and white plastic mulching respectively. The highest irrigation water use efficiency was 1.14ha lt^{-1} recorded from drip lateral in every row and 1.15kg lt^{-1} from white plastic mulching. Even though white plastic mulch yields more, the economic analysis result showed that no economic advantage was obtained by the use of wheat straw, white and black plastic mulches when compared with that of control (no mulch) for drip irrigated fresh marketable bulb yield of onion at Ambo. Drip irrigation method is also profitable for onion production with drip lateral spacing in every row with net benefit of 24640ETB ha^{-1} and its marginal ret of return is 24.17%. But

It was observed that reducing drip laterals from one drip lateral for each onion plant row to one drip lateral for two onion plant row caused significant yield reduction which resulted in reduced net benefit in the study area. The use of white plastic mulch, black plastic mulch and wheat straw mulch for the production of drip irrigated onion have no net benefit than producing onion without mulching around Ambo.

Drip lateral spacing in every row and no mulch mulching is profitable for smallholder farmers' by providing different biological and economic advantages that enhance sustainable onion production.

To validate the results the experiment should be repeated at least for two years under different agro-climatic and soil conditions so that appropriate packages for drip irrigated onion production could be developed. In addition, it is necessary to have multidisciplinary approach for the production of onion under suitable drip lateral spacing and mulching in the study area.

5.2. Conclusions

The conclusions drawn from this research are

- The maximum bulb yield of (34990 kg ha^{-1}) was obtained from drip lateral spacing in every row.
- In case of mulching the highest bulb yield of (35117kg ha^{-1}) was recorded from white plastic mulching.
- Highest result of (1.14kg lt^{-1}) water use efficiency was obtained from drip laterals in every row.
- White plastic mulching was resulted highest score (1.15kg lt^{-1}) of water use efficiency.
- Even though the highest bulb yield and water use efficiency was obtained from drip lateral in every row and white plastic mulch during growing season. The highest net benefit of 246410ETB ha^{-1} and 284616ETB ha^{-1} were obtained from drip lateral in every row and no mulching respectively.
- The analysis of drip irrigation uniformity test showed that there is no significant uniformity variation between drip lateral in every rows and drip lateral between two rows.

In conclusion, this study point out that drip lateral in every onion plant row and no mulching is economically profitable than the other treatments for the production of onion under drip irrigation around Ambo areas. But, it is subjected to future investigation to evaluate the over year and over location effects of mulching and drip lateral spacing on soil fertility and cost of production respectively.

5.3. Recommendations

Although, the experiment should be repeated for the second season before reaching to the final recommendations, the following recommendations have been made based on the findings from one cropping season:

- Drip lateral in every row is economical for onion producers under drip irrigated at Ambo area of clay soil.
- Onion production under wheat straw, white plastic and black plastic mulching is not economical at Ambo. So, production of onion under drip irrigation is more profitable with no mulch for Ambo farmers and other onion producers.
- Drip lateral spacing and mulching have no interaction effects on onion yield and water use efficiency at Ambo.
- However further work is required because the effects of mulch on soil has been seen over years and no costs of drip lateral in the next cropping season as they are reused.

6. REFERENCE

Adinew, M. 2005. Technical and economic feasibility of smallholder drip irrigation using harvested rain water for onion production at Dire Dawa. M.Sc. Thesis, Alemaya University, Alemaya, Ethiopia. African Sugar Technologists Association, 75:58-67.

Agetachew T., Ishetu D. and Tebikew D. 2011. Onion and garlic production manual. Ethiopian Agricultural Research Center, Debere Zeit.

Ahmet, K. 2009. A Guide to Irrigation Methods. A Featured Article.

Ali, M. Alam, M., Islam, M. and Khandaker, S. 2007. Effect of Nitrogen and Potassium level on yield and quality of seed production of onion. *Journal of Applied. Science Res*, 3:1889-1899.

Allen, R.G., Pereira, L.S., Raes D. and Smith, M. 1998. Crop evapotranspiration. Guidelines for computing crop water requirements. FAO Irrig. Drain, Paper No. 56. FAO. Rome, Italy.

Allen, R.G., Pereira, L.S., Raes, D. and Smith, M. 2006. Crop Evapotranspiration. Guidelines for computing crop water requirements. FAO Irrigation and Drainage Paper No. 56. FAO. Rome, Italy.

Anisuzzaman, M., Asrafuzzaman, M., Mohd, R., Ismail, U. M. K. and Rahim, M. A. 2009. Planting time and mulching effect on onion development and seed production. *Africn Journal of Biotechnology*. 8(3):412–416.

Anusuya, R. and Betsy, I. 2001. Mulch Color Affects Radicchio Quality. Department of Horticulture, Cornell University, 134 Plant Science Building, Ithaca, NY 14853. 36(7):1240–1243.

ASABE (American Society of Agricultural and Biological Engineers), 1999. Field evaluation of micro irrigation system. ASAE *stan-dards*. 46th Ed EP 458.

ASABE (American Society of Agricultural and Biological Engineers), 2008 Design and installation of microirrigation. ASABE *stan-dards*. 50th Ed. EP 405.

Aujla, M.S., Thind, H.S., and Buttar, G.S. 2004. Cotton yield and water use efficiency.

Awulachew, B., Merrey D.J., Kamara, A. B., Van Koopen, B., De Vries, F. Penning, and Boelle, E. 2005. Experiencesand Opportunities for Promoting Small-Scale/Micro

Irrigation and Rainwater Harvesting for Food Security in Ethiopia. IWMI Working Paper 98.

Awulachew, B., Yilma, D., Loulseged, M., Loiskand, W., Ayana, M. and Alamirew, T. 2007.Water Resources and Irrigation Development in Ethiopia. Colombo, Sri Lanka: International Water Management Institute. (Working Paper 123).

Baba, I., Alexander, W., Julius, Y., Michael, M. and Mohammed. 2013. Effects of different mulches on the yield and productivity of drip irrigated onions under tropical conditions. Council for Scientific and Industrial Research-Savannah Agricultural Research Institute (CSIR-SARI), Nyankpala,Tamale, Ghana.

Baten, M., Nahar, B., Sarker, S. and Khan, M. 1995. Effect of different mulches on the growth and yield of late planted garlic. 38:138-141.

Baumhardt, L. and Jones, R. 2002. Residue Management and Tillage Effects on Soil Water Storage and Grain Yield of Dry land Wheat and Sorghum for a Clay Loam Soil in Texas. Soil and Tillage Research. 68(2): 71–82.

Bhella, H. S. 1986. Effect of plastic mulch and trickle irrigation on tomato growth, yield and nutrition. Proc. 19th Notational Agricultural Plastics Congress. Pp. 80–86.

Biswas, S., Akanda, A., Rahsman, M. and Hossain, M. 2015. Effect of drip irrigation and mulching on yield, water-use efficiency and economics of tomato. Irrigation and Water Management Division, Bangladesh Agricultural Research Institute, Gazipur, Bangladesh. 61(3): 97–102.

Bralts, V. F. 1986. Operational principles-Field performance and evaluation. *In:* trickle irrigation for Crop Production, Amsterdam, Elsevier. pp216-240.

Camp, R., Sadler, J. and Busscher, J. 1989. Subsurface and alternate middle micro irrigation for the southern coastal plains. Transactions of the ASAE. 32(2): 451-456.

Charles, M. 1993. Plastic Mulches for Vegetables, Kansas State University.

CSA(Central Statistical Agency). 2015. Agricultural sample survey. Report on farm management practice of Meher season crops for private peasant holdings. Central Statistical Agency, Addis Ababa.

Demir, V., Yurdem, H. and Degirmencioglu, A.2007. "Development of Prediction Models for Friction Losses in Drip Irrigation Laterals Equipped with Integrated In-lineand On-line Emitters Using Dimensional Analysis." Bio systems Engineering 96(4): 617.

Derpsch, R. (2001). Conservation tillage, no-tillage and related technologies. In: Garcia Torres L., Benites J. and Martinez Viela A.,1st Edition World Congress on Conservation Agriculture. Springer, Madrid, Spain. Pp. 181-190.

Dessalegn, R. 1999. Water resource development in Africa, Ethiopia.

Devasirvatham, V. 2008. Improved lettuce establishment by subsurface drip irrigation. A thesis submitted for the Degree of Master of Science –Agriculture, University of Western Sydney School of Natural Sciences.

Díaz-Pérez, J.C. and Batal, K.D. 2002. Colored plastic film mulches affect tomato growth and yield via changes in root-zone temperature. *Journal of the American Society for Horticultural Science*. 127:127–136.

Duranti, A. and Cuocolo, L. 1989. Chemical weed control and mulching in onion and garlic.

EPA(Environmental Protection Authority) and UNEP(United Nation Environmental Program). 2008. Ethiopia environment outlook. Environment for development, Environmental Protection Authority. United Nations Environment Program. Addis Ababa.

ETFRUIT(Ethiopian Fruit and Vegetable Marketing Enterprise). 1992. Annual Report for the period 1987-1992., Addis Abeba.46-58.

EU(European Union). 2011. Managing water for inclusive and sustainable growth in Ethiopia: key challenges and priorities. European Report on Development. European Union.

Fairweather, H., Austin, N and Hope, M. 2003. Water Use Efficiency, an Information Package. Irrigation Insights: Land and Water Australia. Canberra, Australia 5:1-67.

Fang, Q.X., Chen, Y.H., Yu Q., Ouyang, Z., Li, Q.Q. and Yu, S.Z. 2007. Much improved irrigation use efficiency in an intensive wheat-maize double cropping system in the north China Plain. *Journal of Integrative Plant Biology*, 49: 1517–1526.

FAO(Food and Agricultural Organization). 1999. Production Year Book, *Food and Agricultural Organization of the United Nation*. Rome. 53.78-80.

FAO(Food and Agricultural Organization). 2002. Localized Irrigation systems planning, design, Operation and maintenance, Irrigation Manual. Sub-Regional Office for East and Central Africa (SAFR), Harare.4.PP 26-35.

FAO(Food and Agricultural Organization). 2006. Irrigation and Drainage Paper, No. 56, Crop Evapotranspiration, guidelines for computing crop water requirements. Rome, Italy.

FAO(Food and Agricultural Organization). 2015. State of food security. Food and Agriculture Organization of the United Nations, Rome.

FAO(Food and Agricultural Organization).1998. Institute and technical Operations in the development and Management of small-scale irrigation. Proceedings of the third session of the multilateral cooperation workshops for sustainable agriculture, Forest and Fisheries Development, Tokyo Japan, Water paper, No.17. 21-38.

George, E. and Kelley, W. 2014. Onion Production Guide (B 1198-2), *3rd Edition*. The University of Georgia.

Griffiths, B and Lecler, NL. 2001. Irrigation system evaluation. Procedures of the South Africa.

Haise, H.R., Donnan, W.W., Phelan, J.T., Lawhon, L.F. and Shockley, D.G. 1956. The use of cylinder infiltrometers to determine the intake characteristics of irrigated soils. Publ. ARS, Agricultural Research Service and Soil Conservation Service, USDA, Washington DC. 41-7.

Haman, D.Z., Snajstrla, A.G. and Pitts, D.J. 2002. Efficiencies of irrigation systems used in Florida nurseries. BUL312, Agricultural and Biological Engineering Department, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida.(http://edis.ifas.ufl.edu.

Hamma, I. 2013. Growth and yield of onion as influenced by planting dates and mulching types, *International Jornal of Agricultural Research Center*. in Samaru, Zaria.

Hanada, T.1991. The Effect of Mulching and Row Covers on Vegetable Production Chugoku Agr. Exp. Stn. Ueno 200, Ayabe city.

Hanson, O., Lienhard, P., Seguy, L., Tuan, H. D. and Duanh, L. Q. 2001. Development of direct sowing and mulching techniques as alternative to slash-and-burn systems in northern Vietnam. Conservation agriculture: A worldwide challenge. First World Congress on conservation agriculture. Madrid, Spain. 2: 29–33.

Heerman, D., Wallender, W.W. and Bos, M.G. 1990. Irrigation Efficiency and Uniformity. ASAE,

Hillel, D. 2004. Introduction to Soil Environmental Physics. University of Massachusetts, ELESIVIER Academic Press. New York.

Himanshu, S., Kumar, S., Kumar, D. and Mokhtar, A. 2012. Effects of Lateral Spacing and Irrigation Scheduling on Drip Irrigated Cabbage (Brassica Oleracea) in a Semi-Arid Region of India. Department of Civil Engineering, Graphic Era University, Dehradun, Uttarakhand, INDIA , Department of Civil Engineering, G. B. Pant Engineering College, Pauri Grahwal, INDIA, TAFE, Muzaffarpur, INDIA.1(5): 1-6.

Hoffman, G. and Martin, D.L. 1993. Engineering systems to enhance irrigation performance.

Hugh R., Anne-Kristin L., Sissel H. and Steinar D. 2003. Yield responses and nutrient utilization with the use of chopped grass and clover material as surface mulches in an organic vegetable growing system. *Journal of Sustainable Production system*. 21(1),63–90.

Ibragimov, N., Evett, S.R., Esanbekov, Y., Kamilov, B.S., Mirzaev, L. and Lamers, J.P.A. 2007. Water use efficiency of irrigated cotton in Uzbekistan under drip and furrow irrigation. Agric. Water Manage. 90:112-120.

ICID(International commission on Irrigation and Drainage).2017. Maneging awater for Sustainable Development.

IDE (International Development Enterprise). 2004. Affordable Small-Scale irrigation

IDI (International Development Institute). 2002. Micro-irrigation for income generation in Asia. A case study prepared by International Development Enterprise for the Asia-Pacific regional consultation workshop on water & poverty, Asian Development Bank.

Igbadun,N. 2012. Effects of regulated deficit irrigation and mulch on yield, water use and crop water productivity of onion in Samaru, Nigeria. 109,169. Irrigation Science 14, 53-63.

Isaya, V.S. 2001. Drip irrigation: options for smallholder farmers in Eastern and Southern Africa. Published by Sida‗s Regional Land Management unit, Nairobi, Kenya.

IWMI (International Water Management Institute). 2009. Importance of irrigated agriculture to the Ethiopian economy: capturing the direct net benefits of irrigation. Research Report 128. International Water Management Institute.

IWMI (International Water Management Institute). 2010. Irrigation potential in Ethiopia. Constraints and opportunities for enhancing the system. International Water Management Institute.

Jain, N., Chauhan, H.S., Singh, P.K. and Shukla, K.N. 2000. Response of tomato under drip irrigation and plastic mulching. In: Proceeding of the *6th* International Micro-irrigation Congress, Micro-irrigation Technology for Developing Agriculture, South Africa.

James, L.G. 1988. Principles of Farm Irrigation System Design. Washington State University, New York.

Juan, C. Díaz-Pérez, Ron W, William M, Randle.and Ronald G. 2004. Effects of Mulch and Irrigation System on Sweet Onion: I. Bolting, Plant Growth, and Bulb Yield and Quality. *Journal of the American Society for Horticultural Science*. 129(2):218–224

Kar, G. and Singh, R. 2004. Soil Water Retention-Transmission Studies and Enhancing Water Use Efficiency of Winter Crops through Soil Surface Modification. Indian *Journal of Soil Conservation*. 8, 18–23.

Kashi, A., Hosseinzadeh, S., Babalar, M. and Lessani, H. 2004. Effect of black polythene mulch and calcium nitrate application on growth and yield of water melon (Citrullus lanatus). *Journal of Science; Technical agriculture and Natural resources*. 7:1-10.

Kenneth, H.S. 1998. Irrigation Systems and Water Application Efficiencies. California State University, Fresno, California 93740-0018.

Kruse, E.G. 1978. Describing irrigation efficiency and uniformity. *Journal of Irrigation and Drainage Division, ASCE 104 (IR1).*

Krystal, A and Zanker, K. 1974. "Hydraulic and mechanical properties of drippers", In Proc. of the 2nd Int. Drip irrigation Congress. San Diego, CA.

Larry, S. and Terry, P. 2015. Drip Irrigation in the Home Landscape Paperback.

Lecler, N.L. 2004. Performance of irrigation and water management systems in the lowveld of Levels of water and N through drip irrigation under two methods of planting.

Li, S. and Xiao, L. 1992. Distribution and management of dry lands in the people's republic of china. Advances in Soil Sciences, 18, 147-302.

Mahbub, A., Danny, H. R and Troy, J. D.2009. Subsurface Drip Irrigation for Alfalfa. Kansas State University Agricultural Experiment Station and Cooperative Extension Service Manhattan, Kansas.Pp3.

Maisiri, N. Sanzanje, A. Rockstrom, J. and Twomlow, S.J. 2005. On farm evaluation of the effect of low cost drip irrigation on water and crop productivity compared to conventional surface irrigation system. Phys. Chem.Earth, 30, 783-791.

Merriam, J. and Keller, J. 1978. Farm Irrigation System Evaluation. A Guide for Management, Agriculture and Irrigation Engineering Department, Utah State University.

Michael McMillen. 2013. The effect of mulch type and thickness on the soil surface evaporation rate. Horticulture and Crop Science Department California Polytechnic State University San Luis Obispo, Michigan, USA.

Mihret, D. Ermias, A. Mekonen, A. and Adugna, B. 2013. Environmental Impacts of Small Scale Irrigation Scheme,Evidence from Ethiopian Rift Valley Lake Basins. School of Bio-systems and Environmental Engineering, Hawasa University, Ethiopia.pp.17.

MoA (Ministry of Agriculture). 2011. Small-scale irrigation situation analysis and capacity needs assessment. Ministry of Agriculture,Ethiopia.

Moges, F. 2006. Evaluating small-scale drip irrigation system: An option for water harvesting-based smallholder farmers' vegetable production in Amhara region. M.Sc. Thesis, Alemaya University, Alemaya, Ethiopia.

Nangia, V. Fraiture, C.D. Turral, H. 2008. Water quality implications of raising crop water productivity. Agric. Water. Manage. 95: 825-835.

Nishitani, K. 1979. Adaptability of silver polyethylene mulching for vegetable production in the open fields. Agriculture and Horticulture Japanese, 54(5): 657-662.

NPC (National Planning Commission). 2015. The second growth and transformation plan (GTP II) (2015/16-2019/20).

Ossom, E.M., Pace, P.F., Rhykerd, R.L. and Rhykerd, C.L. 2001. Effect of Mulch on Weed Infestation, Soil temperature, Nutrient Concentration, and Tuber Yield in Ipomoeabatatus (L.)Lam.in Papua New Guinea. Tropical Agriculture, Trinidad. 78, 144–151.

Oweis, T. and Zhanga, H. 1983. Water-use efficiency: Index for Optimizing Supplemental Irrigation of Wheat in Water Scarce Areas. Zeitchrift, F. Bewaesserung swirts chaft, 33(2), 321-336.

Patel, N. and Rajput, T.B. 2009. Effect of subsurface drip irrigation on onion yield. Irrig Sci 27:97–108.

Pereira, L. 1999. Higher performance through combined improvements in irrigation methods.

Pollack, G. L., Smith, N. J. and Cialone, J. C. 1969. Summary of crop responses to various agricultural film mulches. Proc. 9th Natl. Agri. Plastics Congr. Pp. 17–25.

Provenzano, G. and Domenico, P. 2004. "Experimental Analysis of Local Pressure Losses for Microirrigation Laterals." *Journal of Irrigation and Drainage Engineering* 130 (4): 318-24.

Ramalan, H. N. and Oyebode, M.A. 2010. Effect of deficit irrigation and mulch on water use and yield of drip irrigated onions. Department of Agricultural Engineering, Federal Ministry of Agriculture and Rural Development, Ethiopia, 134, 47-49.

Rhu, A. Mushi, A. and Khan, M. 1990. Effect of different mulches on the growth of Irish potato (Solanum tuberosum L.). Bangladesh J. Bot.19:41–46.

Russo, V. M., Cartwrught, B. and Webebber III, C. I. 1997. Mulching effects on erosion of soil beds and on yield of autumn and spring planted vegetables. *J. Biol. Agric. Hortic.* 14(2):85–93.

Satpute, G.V and Pandey, N.N. 1988. Effect of drip layout and planting geometry of tomato and cost of drip system. Proc. Agri.Engg. Conference Bangkok, Thailand, AIT. (1992),773-781.

Schales, F.D. and Sheldrake, R. 1965. Mulch Effects on Soil Conditions and Muskmelon response. Proceedings, American Society for Horticultural Science. 88, 425-430. 45

Sharma, A.R., Singh, R., Dhyani, S.K. and Dube, R.K., 2010. Moisture conservation and nitrogen recycling through legume mulching in rain fed maize (Zea mays)-wheat (Triticum aestivum) cropping system. Nutrient Cycling in Agro ecosystems, 87: 187–197.

Sharma, B.R. 2006. Crop water Requirements and water productivity: Concepts and Practices, International water Management Institute, Asia Regional Office, New Delhi, India: (http://www.waterandfood.org/gga/)Lecture%20Material/BRSharma.

Shock, C.C., Flock, R., Feibert E., Shock, C.A. and Klauzer, J. 2013. Drip Irrigation Guide for Onion Growers. Oregon State University.

Sijali, I.V. 2001. Drip irrigation option for smallholder farmers in Eastern and Southern Africa. Handbook No. 24. Regional Land Management. Sida's Regional Land Management unit.

Simonne, E., Hochmuth, R., Breman, J., Lamont, W., Treadwell, D. and Gazula, A. 2009. Drip-irrigation systems for small conventional vegetable farms and organic vegetable farms, University of Florida IFAS Extension.

Sivanapan, R. K. 2002. Technologies for water harvesting and soil moisture conservation in small watershed for small scale irrigation. Saivy Pumps Ltd. Coimbatore, India.

Staney, W. C. and Yerima, B. 1992. Improvement of soil service for agricultural development: guideline for soil sampling and fertility evaluation. Ministry of Natural Resources development and Environmental protection, Adis Abeba, Ethiopia.

Steel, R.G. and Torrie, J.H. 1980. Principles and procedures of statistics: a biometrical approach. 2nd edition, McGraw-Hill. New York.

Steiner, K. G., Derpsch, R. and Koller, K. H. (1998). Sustainable Management of Soil Resources through Zero Tillage. Agricultural Rural Development. 5:64–66.

Stephenson, K. Q. and Bergman, E. L. 1963. Some mechanical and cultural developments on the Penn State transplanter mulcher. Proc. 4th Natl. Agr. Plastics Congr. Pp. 58–64.

Taha, M. 2007. Determinants of the adoption of improved onion production package in Dugda Bora district, East Shoa, Ethiopia. M.Sc. Thesis (Unpublished) Presented To School of Graduate Studies of Haramaya University.

Tom Bressan. The Urban Farmer Store® Drip Irrigation Handbook. The Catalog for Getting Started, 25th Anniversary Edition.

Unger, P. 1974. Crop residue management. Proceedings. 15, 45-56.

USAID,.2017. Agriculture and Food Security in Ethiopia.

Vavrina, C.S. and Roka, F.M. 2000. Comparison of plastic mulch and bare-ground production and economics for short-day onions in a semitropical environment. Hort. Technology 10:326–330.

von Bernuth, R. D. 1990. Simple and accurate friction loss equation for plastic pipe. Irrigation and Drainage Engineering, ASCE, 116(2), 294-298.

WRIDE(Water Resources and Irrigation Development in Ethiopia). International Water Management Institute. Colombo, Sri Lanka (Working Paper 123). pp.4.

Westerfield, R. R. 2013. Mulching vegetables. The University of Georgia, College of Agriculture and Environmental Sciences (CAES). Cooperative Extension. Available on line: http://www.caes.uga.edu/applications/publications/files/pdf/C%20984_2.PDF.

Wolters, W and Bos, M.G. 1989. Irrigation Performance Assessment and Irrigation Efficiency.

Wondatir, S., Belay and Desta, G. 2013. Effect of drip lateral spacing and irrigation regime on yield, irrigation water use efficiency and net return of tomato and onion production in the Kobo Girrana valley of Ethiopia, Rainwater management for resilient livelihoods in

Ethiopia: Proceedings of the Nile Basin, Development Challenge science meeting, Addis Ababa.204-203.

Wu,I.P. 1983. A unit-plot for drip irrigation lateral and sub-main design. ASAE paper, St. Joseph, MI 49085. No. 83-1595.

Zhang, H. 2003. Improving water productivity through deficit irrigation. Water Productivity in Agriculture Limits and Opportunities for Improvement. Examples from Syria, the north ChinaPlain and Oregon, USA.

Zwart, S.J.and Bastiaanssen, G.M. 2004. Review of measured crop water productivity values for irrigated wheat, rice, cotton and maize. Agricultural Water Manage. Pp. 69.

7. APPENDICES

Appendix Table 1. Weather data of the study area (1987-2017)

Month	Minimum Temp.(ºc)	Maximum Temp.(ºc)	Relative humidity (RH%)	Wind speed (km hr^{-1}) 1m	Sun shine hours/day	Av.Rainfall(mm)
Jan.	8.99	27.1	57.55	2.39	4.09	14.9
Feb.	10.23	28.2	49.02	2.6	4.5	15.08
Mar.	11.45	29.2	49.85	2.58	3.99	53.72
Apr.	11.46	28.5	53.91	2.39	3.6	56.9
Nov.	8.67	25.9	57.73	1.88	4.63	18.3
Dec.	8.34	25.9	58.04	2.18	3.98	8.94
Mean	9.86	27.47	54.35	2.34	4.13	27.97

Appendix Table 2. Soil moisture content and soil texture of the study area

No	Depth (cm)	FC(0.33)	PWP (15bar)	TAWC	Bulk Density (g cm^{-3})	Particles size			Class
						%sand	%silt	%clay	
1	0-30	68.31	45.44	22.87	1.09	16	18	66	Clay
2	30-60	44.18	35.27	8.91	1.12	16	18	66	Clay
3	60-90	40.33	31.12	9.21	1.13	18	14	68	Clay

Appendix Table 3. Soil data of the study area

No	Depth(cm)	pH(1:25)	%OC	%OM	%TN	Avail.P(ppm)
1	0-30	7.83	2.13	3.66	0.13	5.9
2	30-60	8.13	1.2	2.06	0.1	4.3
3	60-90	8.01	1.22	2.09	0.07	3.6

Appendix Table 4. Flow rate per tree, continuous flow, for different ETc and tree spacing, 1/hr

Tree spacing	ETo mm day^{-1}		
	5	6.25	7
6 * 6	7.5	9.5	11
9 * 9	17	21	25
12 * 12	30	37	45
15 * 15	47	59	70
18 * 18	67	84	101

Source (FAO, 1997)

Appendix Table 5. Surface area wetted (w) in m^2 for different emitter flow and soil infiltration rate

Emitter flow $l\ hr^{-1}$	Soil infiltration rate $mm\ hr^{-1}$		
	2.5	5	7.5
2	0.8	0.4	0.25
4	1.6	0.8	0.5
6	2.4	1.2	0.75
8	3.2	1.6	1.00

Source (FAO, 1997)

Appendix Table 6. Average intake rates of water in $mm\ hr^{-1}$ for different soils and corresponding stream size $1 sec^{-1}\ ha^{-1}$

Soil texture	Intake rate $mm\ hr^{-1}$	Stream size (q) $l\ sec^{-1}\ ha^{-1}$
Sand	50 (25 to 250)	140
Sandy loam	25(15 to 75)	70
Loam	12.5 (8 to 20)	35
Clay loam	8 (2.5 to 15)	22
Silty loam	2.5 (0.03 to 5)	7
Clay	5 (1 to 15)	14

Source (FAO, 1997)

Appendix Table 7. Generalized data on rooting depth of full grown crops, fraction of available soil water (p) and readily available soil water (p. Sa) for different soil types (mm m^{-1} soil depth) when ETcrop is 5 - 6 min day^{-1}

Crop	Root Depth(m)	Fraction (p) of available soil water	Really available Soil Water(p.Sa) (mm m^{-1})		
			Fine	Medium	Coarse
Onion	0.3-0.5	0.25	50	35	15

Source (FAO, 1997)

Appendix Table 8. Soil infiltration rate of the study area

Elapsed time(min)	Cumulative Time(min)	Reading(cm)	Difference(cm)	Infiltration rate (mm/hr.)
0	0	24	-	-
5	5	17.62	6.38	645.60
5	10	15.12	2.50	419.41
5	15	13.39	1.73	207.82
5	20	12.28	1.11	132.85
5	25	11.49	0.80	95.43
5	30	10.88	0.61	73.37
15	45	9.63	1.25	49.82
20	65	8.62	1.01	30.17
20	85	7.96	0.67	20.01
20	105	7.47	0.49	14.66
20	125	7.09	0.38	11.42
20	155	6.64	0.44	8.86
30	185	6.30	0.34	6.89
30	215	5.96	0.34	6.80

Appendix Table 9. Irrigation scheduling

Month	Date of irrigation	Growth stage	Time of application (hr.)	Irrg. interval (day)	NIR (mm)	ETc (mm/day)	Remark
Jan. (21-31),2018	21,24,27 and 30	Init	1:15	4	12.9	1.77	
Feb. (1-10),2018	3,6 and 9	Deve	1:30	4	13.8	1.93	
Feb. (11-20),2018	12,15 and 19	Deve	1:30	4	14.00	2.43	
Feb. (21-28),2018	22,25 and 28	Mi	2:00	4	16.4	2.85	
March (1-10),2018	1,4,7 and 10	Mid	2:00	4	18.1	2.95	
March (11-20),2018	13,16 and 19	Mid	2:00	4	18.3	3.01	
March (21-31),2018	22,25,28 and 31	Mid	2:00	4	17.8	3.01	
April (1-10),2018	3,6 and 9	Mid	2:00	4	19.1	3.01	
April (11-20),2018	12,15 and 18	Mid	2:00	4	17.1	3.00	
April (21-30),2018	21,24,27 and 30	Late	1:30	4	19.1	3.05	
May (1-10),2018	3, 6,and 9	Late	1:30	4	18.0	2.98	
May (11-20),2018	12,15,17 and 20	Late	1:30	4	19.0	2.83	
May (21-31),2018	23,26 and 29	Late	1:30	4	17.7	2.38	

Appendix Table 10. Analysis of variance for bulb yield (kg ha^{-1})

Source	DF	Sum of square	Mean sum of square	F value	Pr > F
Replication	2	66363104.4	33181552.2	4.28	0.1354
Treatments	7	168669772.4	24095681.8	3.11	0.0336*
Error	14	108457245.4	7746946.1		
Total	23	343490122.2			

Appendix Table 11. Analysis of variance for biomass (kg ha^{-1})

Source	DF	Sum of square	Mean sum of square	F value	Pr > F
Replication	2	101197101.3	50598550.7	5.45	0.1178
Treatments	7	66386234.6	9483747.8	1.02	0.4585
Error	14	130082569.4	9291612.1		
Total	23	297665905.3			

Appendix Table 12. Analysis of variance for water use efficiency (kg lit^{-1})

Source	DF	Sum of square	Mean sum of square	F value	Pr > F
Replication	2	0.07022500	0.03511250	4.29	0.1352
Treatments	7	0.18060000	0.02580000	3.15	0.0321*
Error	14	0.11457500	0.00818393		
Total	23	0.36540000			

Appendix Table 13. Analysis of variance for plant height (cm)

Source	DF	Sum of square	Mean sum of square	F value	Pr > F
Replication	2	25.2933333	12.6466667	2.53	0.1154
Treatments	7	483.4783333	69.0683333	13.82	<.0001**
Error	14	69.9866667	4.9990476		
Total	23	578.7583333			

Appendix Table 14. Analysis of variance for plant population

Source	DF	Sum of square	Mean sum of square	F value	Pr > F
Replication	2	2.08333333	1.04166667	0.37	0.6963
Treatments	7	13.62500000	1.94642857	0.69	0.6765
Error	14	39.25000000	2.80357143		
Total	23	54.95833333			

Appendix Table 15. Analysis of variance for bulb diameter (cm)

Source	DF	Sum of square	Mean sum of square	F value	Pr > F
Replication	2	0.26025833	0.13012917	0.90	0.4286
Treatments	7	0.61218333	0.08745476	0.61	0.0425*
Error	14	2.02254167	0.14446726		
Total	23	2.89498333			

Appendix Table 16. Analysis of variance for harvest index

Source	DF	Sum of square	Mean sum of square	F value	Pr > F
Replication	2	11.8195070	5.9097535	2.42	0.1253
Treatments	7	456.1044830	65.1577833	26.67	<.0001**
Error	14	34.2096496	2.4435464		
Total	23	502.1336397			

Appendix Table 17. Drip system uniformity classification based on uniformity coefficient

Uniformity coefficient (%)	Classification
Above 90	Excellent
90 – 80	Good
80 – 70	Fair
70 – 60	Poor
Below 60	Unacceptable

Adopted from ASABE standards EP 458, 1999

Appendix Table 18. Drip system uniformity classification based on the coefficient of variation for point source emitter type

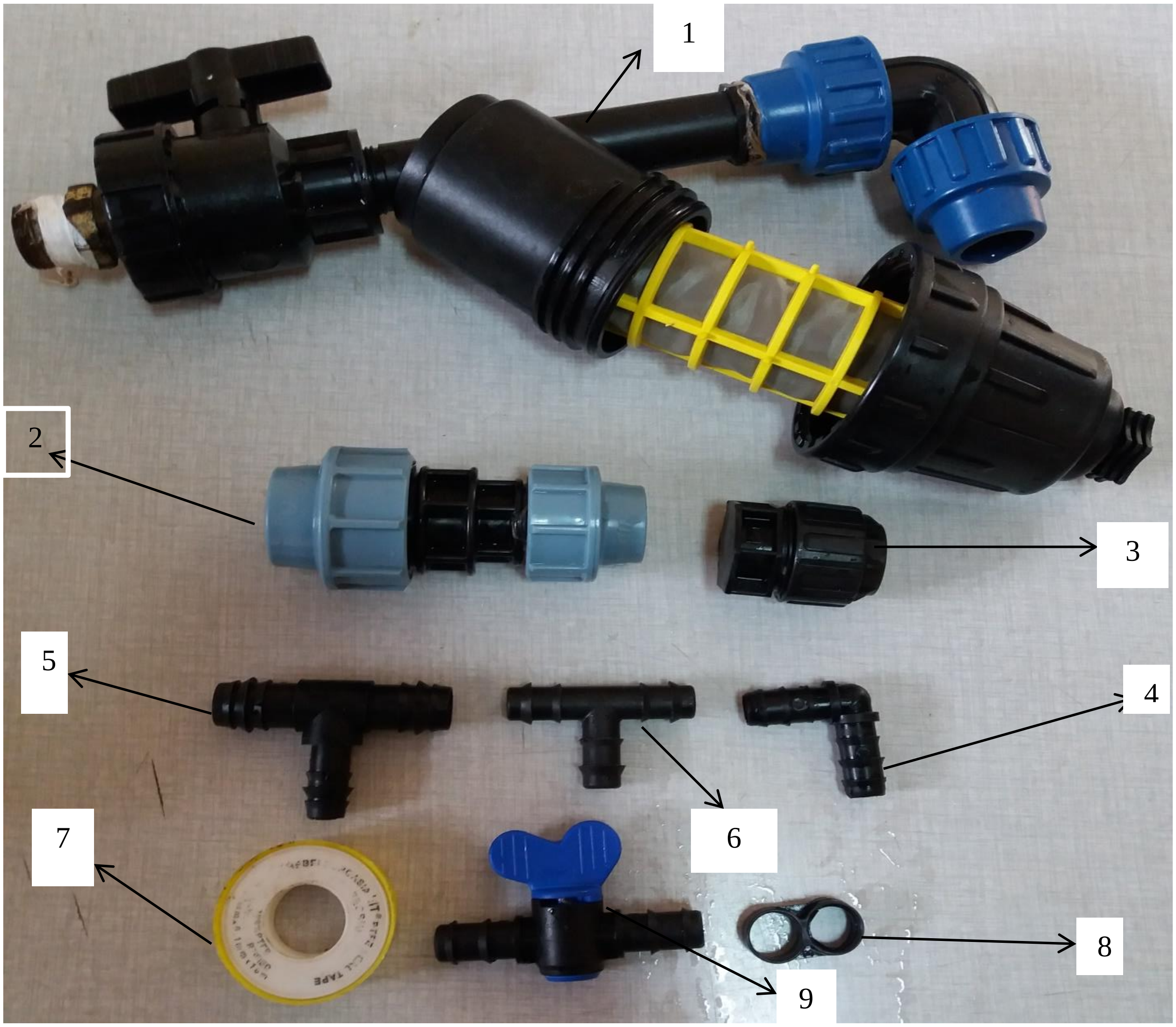
Cv range (%)	Classification
< 5	Excellent
5 -7	Good
7 – 11	Fair
11 – 15	Poor
>15	Unacceptable

Adopted from ASABE standards EP405.1, 2008

Appendix Table 19. General criteria for emitter flow variation

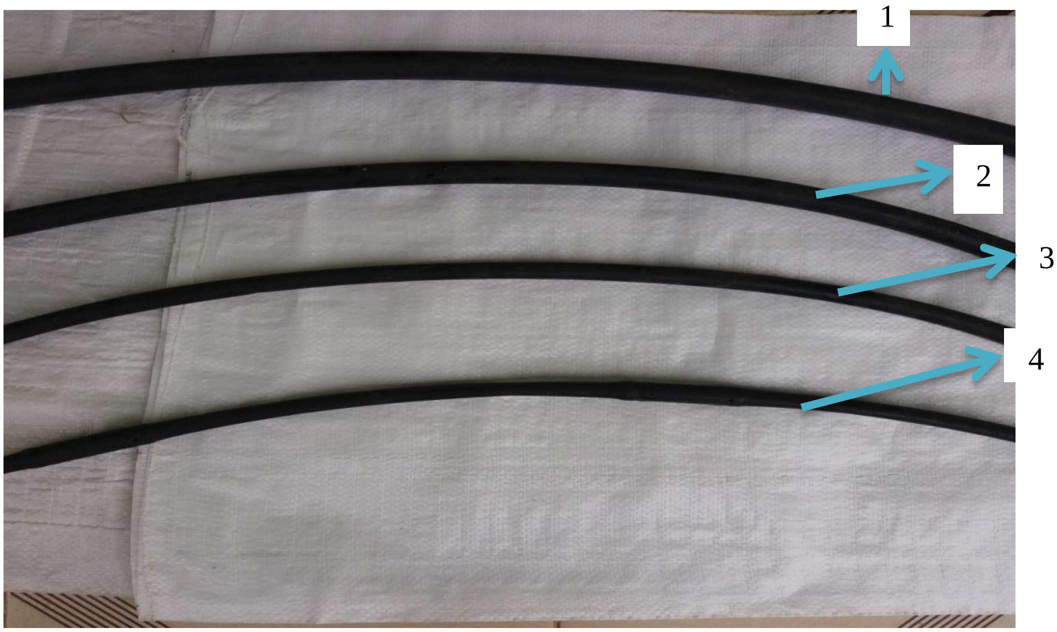
Emitter flow variation	Recommendation
< 10	Desirable
10 -20	Acceptable
>20	Unacceptable

Source: Brats, 1986



1. Drain outlet, 2. Reducer (25” by 20”), 3. End cup (20”), 4. Bend (16”), 5. 20” by 16” T, 6. 16” T, 7. Plaster 8. End cup and 9. 16” Valve

Appendix Figure 1. Drip irrigation system accessories



1. 25" main line, 2. 20" main line, 3. 16" manifold 4. 1" lateral

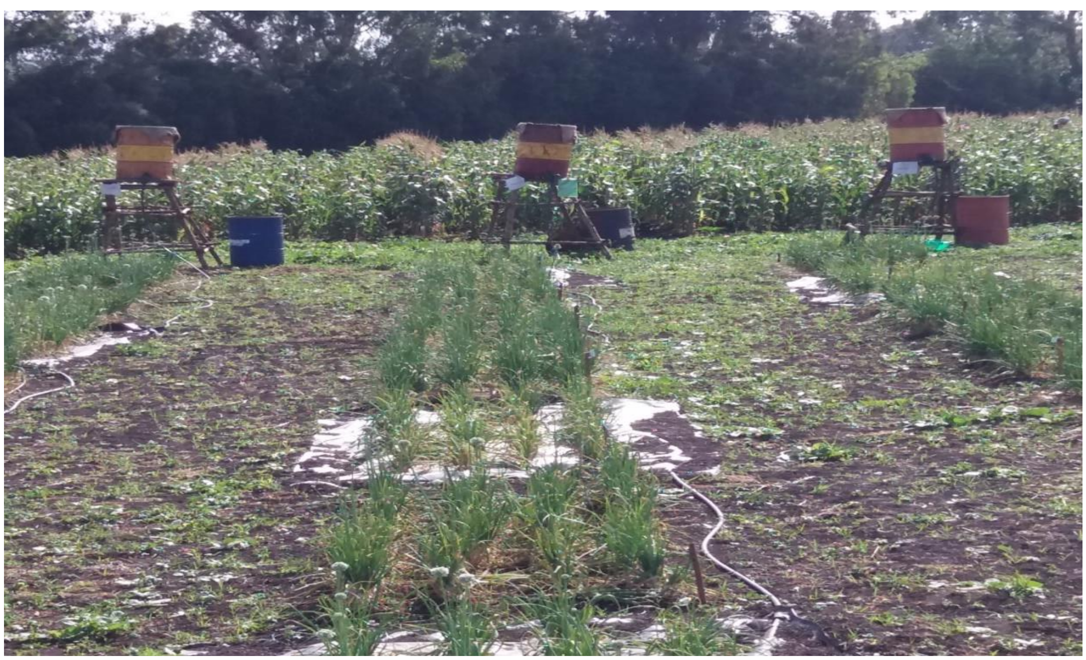
Appendix Figure 2. Pipes used for drip irrigation

Appendix Figure 3. Field visit

Appendix Figure 4. Drip lateral in every row

Appendix Figure 5. Drip lateral between two rows

Appendix Figure 6. Training for Agricultural experts, Development agents and Farmers

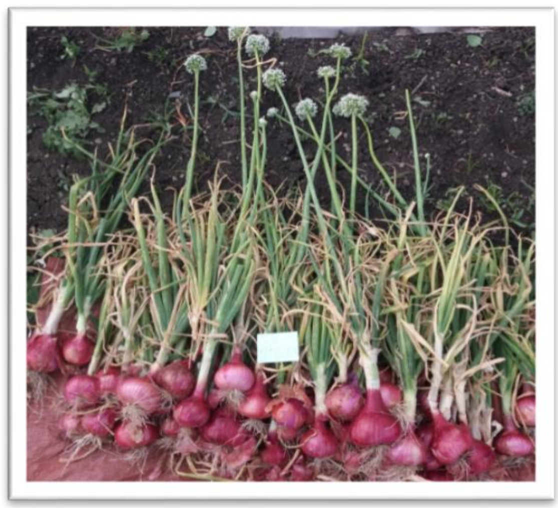


Appendix Figure 7. Observed variations between treatments

Appendix Figure 8. Yield under white plastic mulch

Appendix Figure 9. Yield under wheat straw mulch

Appendix Figure 10. Yield under No mulch



Appendix Figure 11. Yield under black plastic mulch