Universal Journal of Agricultural Research 2(6): 203-210, 2014 http://www.hrpub.org
DOI: 10.13189/ujar.2014.020604

Yield and Water Use Efficiency of Mulched Drip-Irrigated Onion in Low Land Region of Amhara, North Central Ethiopia

Walle Jemberu Lakew[1,*], Belayneh Ayele Anteneh[2], Lewoye Tsegaye Ayalew[2]

[1]Wageningen University and Research, Soil physics and land management group, 6700, The Netherlands
[2]College of Agriculture and Environmental Science, Bahir Dar University, Amhara National Regional State, 5501, Bahir Dar, Ethiopia
*Corresponding Author: walle.lakew@wur.nl

Abstract The use of available water by reducing all forms of losses is a key to maximize crop yield per unit supplied in dry areas. In this study an attempt was made to investigate the influence of drip irrigation and mulching material on the yield and water use efficiency of onion in low land region of north central Ethiopia. The experimental design was split plot embedded in randomized complete block design, replicated three times with three irrigation levels as main plot and three mulching rates as sub plot. The drip irrigation level consisted of full irrigation (FIL), mid irrigation (MIL) and half irrigation (HIL) levels determined using CROPWAT model. A control plot and mulching material of dry *teff* (*Eragrostics abyssinica*) straw with 0.3kg/m^2, 0.5kg/m^2 rates were applied to reduce surface evaporation loss. Total marketable onions were significantly affected by both irrigation level and mulching rate. MIL performs best in yield and this is especially effective for mulching rate of 0.3 kg/m^2. With all forms used to avoid irrigation water losses from the farm (drip irrigation in combination with surface mulching), it was found that on average 1000 litres of water was used to produce 4.56 kg of marketable onion.

Keywords Drip irrigation, Water Use Efficiency, Mulch, Productivity

1. Introduction

Farmers in dry lands of Ethiopia depend on erratic, unrealistic and low rainfall to produce staple food crops for their livelihoods. Crop production is limited by water shortage which is caused low storage, insufficient utilization; inter annual and annual fluctuation in precipitation and high evaporation demand. Competition among various sectors also deprives agriculture of substantial amount water every year (Awulachew, et al., 2009; Paul et al, 1996; Walker, 1989). Thus there is a growing interest in complementing this risky rain fed staple food production with cultivation of high value vegetable crops and fruits using drip irrigation that can save water and reduce crop failure (Pala, 1990; Smith, 1994; Sivanappan, 1994).

To increase agricultural production and living standards in dry lands of Ethiopia, greater priority must be given to enhancing efficiency of water collection and utilization (Hillel, 2001; Sandra, et al, 2001; Hune and Paul, 2002). There are different methods that have been attempted to conserve water and use it efficiently. Technologies such as drip irrigation and other micro-irrigation techniques have been developed to precisely meter and apply water to plant roots so that more crops can be grown for a given volume of water (Michael, 1997; Jensen, 1983; Frederick and Troeh, 1980; Hacham, 2001; Isaya, 2001).

Reducing non-productive loss of irrigation water is best achieved through the integrated use of mulching material and drip irrigation for maximum water use efficiency (WUE) in arid and semi-arid lands (Hacham, 2001; Hanson, 1994). WUE is referred to the crop dry matter or yield per unit of water used whereas water application efficiency (WAE) is the ratio between water stored in root zone and water applied from source during irrigation (Ayesrs, 1996; Doorenbos, 1986; Adams, 1998; Allen, 1998).

Drip irrigation can achieve 90-95% efficiency by reducing evaporation and deep percolation (Baker, et al, 1993; Bresler, 1990; Brouwer, 1990). In addition to this desirable feature of drip irrigation, uniform distribution of water is possible and it is one of the most important parameters in design, management and adoption of this system. Ideally, well designed system applies nearly equal amount of water to each plant, meets its water requirement and is economically feasible (Mizyed and Kruse, 2008; Clark, 1990; Fekadu and Teshome, 1997). This method is profitability used in arid and semiarid areas (ASAL) where water is scarce and often poor in quality in respect of salt concentration and labor is expensive (Crithchely, 1991; Dasten, 1998; Hillel, 2001).

Drip irrigation ensures optimum growth, better fruiting and early maturity of crops by assuring soil, water, air and nutrients throughout the crop growing period (Donald, 1998; Charry, 1997; Dastan, 1998; Hillel, 2001). Until recently drip irrigation technology has been associated with large investments available to commercial farms. This is now changing and many efforts are being made around the world to develop low cost and simple drip systems for small scale farmers (Isaya, 2001; Hune and Paul, 2002).

The development of new small scale drip irrigation types that are appropriate for small scale farms are getting emphasize. But information and data values on applying water under farm conditions were insufficient and no reliable results were found (Allen, 1998; Hacham, 2001; Hune and Paul, 2002). This experiment is, there for proposed and executed with the assumption that drip irrigation and mulching material could save water thereby increase water use efficiency (WUE) and increase yields of vegetables and/or cash crops in arid and semi-arid lands of Ethiopia.

Mulching of the soil surface with crop residue, forest litter, sawdust and woodchips greatly reduce evaporation losses from the land surface (Ester, 1984; Donald, 1998; Charry, 1997). In this experiment *teff* (*Eragrostics abyssinica*) straw mulching, which is assumed to reduce evaporation loss and weed infestation, is used as simple soil surface cover.

1.1. Hypothesis

This experiment is proposed and executed with the hypothesis that drip irrigation combined with mulching material could save water by reducing all forms of water losses thereby increase water use efficiency (WUE) and increase yields of vegetables in arid and semi-arid lands of Ethiopia.

1.2. Objectives

The general objective of the research was to determine the yield and water use efficiency of mulched drip-irrigated onion in semi-arid areas of Ethiopia.

Specific objectives:

a. To evaluate WUE in drip irrigation system,
b. To assess the impact of surface mulching on WAE under drip irrigation system,
c. To determine water productivity of drip irrigation taking onion as indicator crop, and
d. To determine the effects of surface mulching on yield and yield components.

2. Materials and Methods

2.1. Site Description

The field experiment was conducted in North Gondar administrative zone of Amhara National Regional State, at East Belessa district. It is located at Hamusit village about 18 kilometers north east of *woreda* /district/ capital town, Gohala and 186 kilometer East of capital city of North Gondar administrative zone of Amhara Region (Gondar).The attitude of the area is about 1800m above mean sea level which is characterized by hot and dry climate with an average monthly temperature of 29°C. The area can be categorized as arid to semi-arid having with annual rainfall 500 to 850 mm (Hune and Paul, 1997). The experiment was conducted in research site that has water harvesting scheme (farm reservoir).The reservoir has been used to collect run off for small scale irrigation and domestic use (Hune and Paul, 1997).

The soil is silt loam which has medium to high infiltration rate. The landform comprises undulating hills, rugged and dissected land features. The crops grown in the area includes cereals, vegetables and tubers. The experimental site is one of the most degraded and driest lands in Amhara National Regional State of North Central Ethiopia (Hune and Paul, 1997).

2.2. Experimental Design

A farm field with 66m width and 72m long was utilised to install a gravity drip irrigation system. The field was equally divided in to 9 subunits (plots) each 18m width and 24m long with 3 laterals. The laterals as well as each subunit were spaced 6m wide to avoid the interference of treatments. The laterals were connected to sub-main lines having 2.5 cm diameter using nipples. The sub-mains were connected to 8 m long main line with internal 5 cm internal diameter. The water supply was taken from a low pressure three overhead tanks (1.2m x1.2m x1.2m). At the head of each sub-main, a control valve was installed to control the flow of water.

The experiment included three levels of irrigation and three degrees of mulching making a total of nine treatment combinations. Irrigation amount or depth is the amount of water given to a plot at specific irrigation level and the levels were full irrigation level (FIL) equal to average potential Evapotranspiration (Eton), mid irrigation level (MIL) that is75% of the Eton and half irrigation level (HIL) equal to half of the average potential Evapotranspiration calculated by CROP WAT model (Dastan, 1998; Phocaides, 2000; FAO, 2002).

Three mulching levels were no mulch (control), 0.3 kg/m^2 and 0.5 kg/m^2 used for the experimental plots by considering the optimum dry surface mulching rate which is 0.5 ton/ha (Donald, 1998). The treatments were replicated three times to have total of 27 experimental units. The design was two-factor split plot experiment, irrigation level as main plot and level of mulching as sub plots with each the whole plots were assigned at random.

2.3. Data Collection and Analysis

2.3.1. General

The experiment was carried out during the months November to March 2010. The crop was onion (*Allium cepa)* with135 days of growing period. Different direct and indirect measurements and analysis had been made to determine water productivity using small scale drip irrigation system. Parameters like moisture content and water movement uniformity of the soil were measured using gravimetric method. The seasonal potential Evapotranspiration (ETo) for the experimental site was determined from the nearby measurement station (Gohala) and found to be 720 mm for the time of experimentation. This amount irrigation was supplied to full irrigation treatments and an amount that is half to full irrigation level (360) mm was supplied to HIL treatments. 75% of the seasonal potential Evapotranspiration (540mm) was the MIL irrigation treatment level (Dastan, 1998; Phocaides, 2000; FAO, 2002). There was little rain fall event (18mm) during the crop development stage while the experiment was being executed. This amount was deducted uniformly from both three crop water requirement levels during its occurrence for net irrigation need or application.

The irrigation amount was taken from the discharge of the emitters and duration of irrigation. The eventual datum, yield (biomass production), was taken on harvest day. Three onion bulbs were taken at random from each treatment for quality analysis using size and soluble solid calculation. The percentage dry matter content was determined on laboratory using gravimetric method and qualities of onion product were tested (Charry, 1997; Clark, 1991).

2.3.2. Soil Moisture Determination

Soil samples were collected from each plot at different depths based on wetting front (0-5cm, 5-15cm and 15-25 cm) before and after each irrigation to determine the moisture. The samples were taken 10 cm away from emitters.

The depth of available soil moisture was finally determined by using Equation (1).

$$W\_s = P_{\_b}\theta_{\_m}Z \quad (1)$$

Where:
$W_{\_s}$= available soil moisture (mm)
$P_{\_b}$ = bulk density (gm/cm^3)
Z = wetted soil depth (mm)

2.3.3. Depth, Discharge and Time of irrigation

The amount of water trickles out of the emitters was measured using measuring gauge (Phocaides, 2000). The effective circular wetted area of each emitter was measured. The time of application was intensively monitored using stopwatch during each irrigation. The duration of time for the emitters to deliver the desired depth was calculated using the following relationship (Phocaides, 2000).

$$t = \frac{0.8Dr^2}{360q} \quad (2)$$

Where:
D = depth of water applied (cm)
t = application time (hour)
q = emitters discharge rate (1/sec)
r = radius of effective wetted area (m)

2.3.4. Application Efficiency

Normally application efficiency is defined as the ratio between water stored in the root zone and water applied to the farm during irrigation (Jensen, 1983; Phocaid, 2000).

$$E_{-A} = \frac{w_{-s}}{W_{-f}} \quad (3)$$

Where:
E_{-A} = application efficiency (%)
w_{-s} = Water stored in the root zone (mm)
W_{-f}= Water applied to the field (mm)

2.3.5. Water Use Efficiency

The irrigation levels were analysed for the total water use efficiency (TWUE) and net water use efficiency (NWUE). Total water use efficiency is the yield per each mm of total water applied and net water use efficiency is the yield produced per each mm of water consumed (Jensen, 1983; Smith, 1993; Phocaid, 2000; Walker, 1989).

2.3.6. Water Distribution Unformi1y

Comparison between irrigation levels was also made on the infiltration distribution uniformity. The moisture contents at different depths were taken for gravimetric moisture determination. The tool used to evaluate irrigation water distribution uniformity was the Christiansen uniformity coefficient (Mosh, 2006; Sandra, et al, 2001; Phocaides, 2000).

$$C_{\_u} = \left[1 - \left(\sum_{n=i}^{n}(\theta i - \theta)/(n\theta)\right)\right]100\% \quad (4)$$

Where:
C_u = Christiansen uniformity coefficient (%)
θ_i= observed water content for 1th point (from gravimetric moisture determination)
N = Number of points where sample were taken.
θ = the mean water content

2.3.7. Yield Assessments

The crop selected this experiment was a vegetable cash crop, onion. Specifically a local *Aliumcepa* (shallot) variety *aggregatum A. ascalonicum* with a growing period of 135 days was used. Literature values of crop such as rooting depth, stages of growth, and crop coefficients were used (Allen, 1998; FAO, 2002; Phocaides, 2000). In order to assess the overall impact or effect of treatments, crop data i.e. total biomass production for all treatments were collected and weighted. The results then converted on hectare basis.

pulp height

The average heights of pulps were measured for all treatments at maturity stage in centimetres by taking six onion stands for each treatment.

Dry Matter Content

By taking three onion pulps, harvested at random from each treatment, the leaves roots and pulps were separated. The roots and leaves were sun dried for about seven days.

The pulps were oven dried at 105°C and dry matter content on onion products was determined in laboratory as:

$$d_{\_s} = \frac{(M_{\_\theta} - M_{\_s})}{M_{\_\theta}} 100\% \quad (5)$$

Where:
$d_{\_s}$ = dry matter content of onion (%)
$M_{\_\theta}$= the harvest weight of onion (gm)
$M_{\_s}$ = dried weight of onion (gm)

2.4. Data Analysis

In order to make statistical analysis of the date obtained the ANOVA technique was used to evaluate the overall variability in the data, and the LSD and New Duncan's multiple range tests were used for mean separation.

3. Results and Discussions

Water use efficiency, water distribution uniformity, yield and yield components were the important parameters considered to measure the effects of treatments in the experiment (Mosh, 2006; Phocaides, 2000).

3.1. Soil Characterization

The result of the sieve analysis of the soil from the experimental site showed that the composition of clay, silt and sand percentages of 15%, 55% and 30% respectively. Thus using the United States soil textural classification, the soil is categorized as silt loam. From the laboratory analysis the moisture content at field capacity and permanent wilting point were 41% and 29% by volume respectively. The bulk density was determined to be 1.16g/cm^3 (Hacham, 2001; Michael, 1997). The results of the laboratory analysis of soil data are given in Table 1.

Table 1. Physical soil characteristics

Soil type	Texture	Silt loam
Total available soil moisture	mm/m	120
Bulk density	g/cm3	1.16
Moisture content at FC	% vol.	41
Moisture content at PWP	% vol.	29

FC = field capacity PWP = permanent wilting point

3.2. Water Application Efficiency

Using Equation (3) water application efficiency was calculated from the amount of water applied by the drip system and water stored in the root zone. The gross and net irrigation water applied to the treatments given in Table (2) had showed pronounced difference in yield and yield components.

Table 2. Gross and net irrigation application for all treatments

Treatments	Gross gift	Net received	WAE (%)
FIL-1	720	655	91.00
FIL-2	720	660	91.67
FIL-2	720	665	92.33
MIL-1	540	497	92.00
MIL-2	540	500	92.50
MIL-3	540	500	92.66
HIL-1	360	332	93.67
HIL-2	360	344	95.00
HIL-3	360	340	94.33

Note FIL= full irrigation level, MIL= mid irrigation level, HIL = half irrigation level

Table 3. The relationship between irrigation levels and application efficiency

Irrigation Level	Application efficiencies %*
FIL	91.67
MIL	92.39
HIL	94.33
LSD	4.610
CV	1.42%

* Mean of nine observations

Table 4. The relation mulching rates and application efficiency

Mulching rates (kg/m^2)	Application efficiencies(%)*
0	92.333
0.3	93.333
0.5	93.333
LSD	1.762
CV	1.42%

* Mean of nine observations

Water application efficiency is one of the most important parameters for determining efficiency of drip irrigation (FAO, 2002). From the results it was observed that even though there was different in irrigation time between the three irrigation levels, there was no significant different between both irrigation levels in water application efficiency. The irrigation durations for FIL, MIL and HIL were 105, 78 and 53.2 minutes respectively Equation (2). Drip irrigation is generally characterized by frequent applications, low depletion level, little evaporation loss and no percolation loss (Doorenbos, 1986; Mosh, 2006; Mizyed and Kruse, 2008). As result more uniform and high available water is maintained in both treatments.

Even though it is not significant, there is slightly higher application efficiencies for half irrigation level than other levels. This is partially due to higher application time in MIL and FIL irrigation levels leads to higher application losses (Mosh, 2006; Mizyed and Kruse, 2008). From two-way table of means of application efficiency, there was no interaction effect between irrigation levels and mulching rates.

3.3. Distribution Uniformity

Soil moisture content was computed from Equation (1) and the Christiansen uniformity coefficient (Cu) was used to evaluate irrigation water distribution uniformity in the soil (Mosh, 2006; Doorenbos, 1986; FAO, 202). From the statistical analysis, it can be pointed out that there was no significant difference between irrigation levels in water movement uniformity.

Even though it is not significant, full and mid irrigation levels had slightly better water distribution uniformity. In general, it can be concluded that, irrigation water movement uniformity maintains higher and the same for all surface mulching rates.

3.4. Yield and Yield Components

The whole purpose of doing the experiment was to see the yield and effectiveness of drip irrigation in saving water in association with simple dry surface mulching at different irrigation levels. The final output used to evaluate the performance of gravity drip irrigation was yield and yield components. Crop height (related with size of pulp), dry matter content and amount of yields are important parameters of evaluation (Hillel, 1998; Pala, 1990).

3.4.1. Pulp Height

The growth of the crop and final yield depend on genetic characteristics, climatic conditions and the management of the crop (Donald, 1998). For this analysis, the heights of selected pulps were measured during the end of late development stage (after75 days) and analysed for each treatment. The average pulp height during late maturity stage was 26.89 to 34.33 cm. The gross height of onions for full and mid irrigation levels were higher than half irrigation level.

The statistical output also reveals that there was a significant difference between mulching rates in plant gross pulp height of onion. This may be due to optimum moisture content retained in half irrigation level might increase the crop Evapotranspiration but may not be in balance with the rate of photosynthesis and air movement at moderate temperature (Donald, 1989; Mosh, 2006; FAO, 2002). Mulching partially increases the availability and up take of nutrients and increase the plant performance height (Donald, 1989; Hillel, 1998).

3.4.2. Yield

With the intention of comparing the yield of all treatments, the harvested yield from all the treatments was measured and yields per hectare were extrapolated.

From the statistical analysis Table (5) there was a significant difference in yield between irrigation levels. The mid irrigation level performs best for all mulching rates. Both shortage and excess water affect the growth and development of onion directly and consequently its yields and quality (Smith, 1994). Excess irrigation water affects crop growth by influencing availability of nutrients. Water and other inputs interact with each other and improper combination retards growth and yield (Donald, 1998; Hillel, 1998; Awulachew et al, 2009). The excessive application in full irrigation coupled with mulching might have caused poor aeration and nutrient availability.

Table 5. The effect of irrigation level on onion yield

Irrigation level	Yield (kg/ha) *
FIL	10178
MIL	13200
HIL	12100
LSD	1480
CV	18.06%

*Mean of nine observations

There was significant difference observed in performance of yields among mulching rates. This is due to the mulches maintain optimum soil temperature, improve soil structure, increase aeration and moisture condition. These conditions encourage additional root development and biological activity (Donald 1989; Mosh, 2006). The statistical data analysis of variance showed that no interaction effects between mulching rates. The summary of mean values of data analysed generals should that mid irrigation level (MIL) performs best in yield and this is especially rewarding for mulching rate of 0.3 kg/m^2.

Table 6. The effects of mulching on onion yield

Mulching rate (kg/m2)	Yield (kg/ha) *
0	10600
0.3	13125
0.5	11753
LSD	587
CV	18.06%

* Mean of nine observations

Table 7. Two-way Table of means of yield

Irrigation level	Mulching rates kg/m^2 0	0.3	0.5	Mean
FIL	9667	11104	9763	10178
MIL	12100	14405	13095	13200
HIL	10033	13867	12400	12100
Mean	10600	13125	11753	11826

3.4.3. Dry Matter Content

The quality of onion was tested by observing the average size, shape and analysing the dry matter content of the products. The dry matter content was determined using Equation (5). The statistical analysis revealed that there is a significant difference between the three irrigation levels. Half irrigation level (HIL) and MIL had relatively better quality of yields (high dry matter content). It was found that the size of the onions was on average relatively higher for

MIL than other irrigation levels for both mulching rates. The interaction between irrigation levels and mulching rates showed significant difference.

3.5. Total and Net Water Use Efficiency

Both total water use efficiency (TWUE) and net water use efficiency (NWUE) were analysed for performance evaluation. Total water use efficiency is the amount of onion yield per gross water supplied whereas net water use efficiency is the amount of onion yield per net water consumed by the crop (Phocaides, 2000; FAO, 2002; Mosh, 2006).

Table 8. Water use efficiency

Irrigation Treatments	Gross Gift (mm)	Net Gift(mm)	Yield (kg/ha)	Dry matter Content (%)	TWUE (kg/mm)	NWUE (kg/mm)
FIL-1	720	655	9657	13.27	13.41	14.74
F1L-2	720	660	11123	13.90	15.45	16.85
FIL-3	720	665	9763	13.31	13.56	14.68
MIL-1	540	497	12100	15.15	22.41	24.35
MIL-2	540	500	14405	14.68	26.68	28.81
MIL-3	540	500	13095	13.22	24.25	26.19
HIL-1	360	332	10033	15.37	27.87	30.22
HIL-2	360	344	13767	14.20	38.24	40.02
H1L-3	360	340	12500	13.90	34.72	36.76

From these results of Table (8 and 9), it can perceived that there is significant difference between irrigation levels. Higher WUE were observed at minimum water applications. However, for the mulching rates there was no significant different. 0.3 kg/rn^2 mulching rate and 0.5 kg/m^2 mulching rate were similar in total water use efficiency.

Table 9. Irrigation level and total water use efficiency

Irrigation level	TWUE (kg/mm) *
FIL	14.14
MIL	24.45
HIL	34.61
LSD	4.677
CV	15%

* Mean of nine observations

Interaction between irrigation levels and mulching rates were to the point of significant probability. Half irrigation level was best in total water use efficiencies at all mulching rate combination.

Table 10. Two-way Table of means of total water use efficiency

	Mulching rates: kg/m^2			
Irrigation level	0	0.3	0.5	Mean
FIL	13.41	15.45	13.55	14.14
MIL	22.41	26.68	24.25	24.45
HIL	27.87	38.24	37.72	34.61
Mean	21.23	26.79	25.17	24.40

The productivity of water from farm size reservoirs was improved by avoiding all forms of irrigation water losses in the farm right from the source to the root of the crops (Doorenbos, 1986; Donald 1989; Mosh, 2006). Evaporation loss from the scarce water sources like harvested water sources were also reduced by covering the surface with available materials (Donald, 1989; Isaya, 2001). Lower irrigation depth of HIL and MIL in drip irrigation maintained and saved significant amount of water with higher onion yields (Mosh, 2006).

With all forms used to avoid irrigation water loses from the farm in semiarid areas i.e. using drip irrigation and surface mulching, it was found that about one cubic meter of water was used to produce 4.5 kilogram of marketable onion.

4. Conclusions and Recommendations

4.1. Conclusions

The results of the field experiment found at the end of the experiment were the following.

1) Gravity drip irrigation had similar WAE at different irrigation levels with possible reason of lower application losses of whole drip irrigation system. The same results were found when selected mulching rates were analyzed for application efficiency at three irrigation levels (FIL, MIL and HIL).

2) There was no significant difference in infiltration distribution uniformity between irrigation levels. Water application rate in HIL didn't make any spatial difference in soil moisture distribution at different points. Time of irrigation in HIL was as much as half of the duration of irrigation to FIL. But soil moisture determination at different depth shows the same result.

3) Both irrigation levels and mulching rates were significantly different in onion yield. MIL was better than other irrigation levels in yield. The obvious reason for significant difference in yield among irrigation level is degree of deviation from optimum crop water requirement. Higher water application in FIL didn't produce as high yield as lower water application in MIL and HIL.

4) Irrigation levels were significantly different for both TWUE and NWUE. HIL was better in WUE to produce onion yield. Both mulching rates were better in WUE at HIL. Water use efficiencies were not significantly different when irrigation levels and mulching rates were interacted.

5) The higher water application depth in in FIL showed much higher gross height of onions than other irrigation levels. But from statistical analysis of dissolved solids of onion products, higher water application depth in FIL revealed relatively poor onion yield qualities. MIL had showed higher dry matter content in addition to highest yields.

4.2. Recommendations

Dry *teff* (*Eragrostics abyssinica*) straw mulch and FIL significantly produced the least vegetable dry weight. Total marketable onion were significantly affected by both irrigation level and mulching rate. Higher mulch rate produced lowest total soluble solids. But MIL increased the quality and quantity of onion yields. Under these conditions dry *teff* straw mulch at a rate of 0.3 kg/m^2 and MIL should be adopted for onion production in dry land areas of Ethiopia. *Teff* (*Eragrostics abyssinica*) straw is cheap, suitable and readily available for mulching whereas MIL saves water. Further research should be conducted to incorporate different irrigation levels that consider optimum water application taking in to account crop water requirements, growth stages and variations in potential evapotranspiration in crop growing period.

REFERENCES

[1] Adams, E. D., 1998. Bucket kit watering versus hand watering. New York, Chapin third world projects, USA.

[2] Allen, R. G., 1998. Crop evapotranspiration: guidelines for computation crop water requirement. Irrigation and drainage paper no. 56. Rome, Italy.

[3] Awulachew, S.B., Philippe Lemperiere, Tulu Taffa, 2009. Irrigation methods: Drip irrigation-Options for smallholders. *International Livestock Research Institute*, Addis Ababa, Ethiopia.

[4] Awulachew, S.B., Merrey, D.J., Kamara, A.B., Koppen, B. van, de Vries, F.P., and Boelee, E, 2005. Experiences and opportunities for promoting small-scale micro irrigation and rain water harvesting for food security in Ethiopia. *International water management institute,* Addis Ababa, Ethiopia, V86p.

[5] Ayers, R. S., 1996. Water quality for agriculture. Irrigation and Drainage paper no. 29. Rome, Italy.

[6] Baker, D. M., Rain S. R., Robertson, M. S., 1993. A preliminary investigation of irrigation systems for sugar cane production. Bed fold, London.

[7] Bresler, E. R., 1990. Drip irrigation technology in semi-arid regions. *international co-operation journal of irrigation Engineering and Rural planning* 19:48-62. Nairobi, Kenya.

[8] Brouwer, C., 1990. Design of Trickle irrigation systems. Department of irrigation and civil engineering, Agricultural University Combater, TNAU press, India.

[9] Chary, T., 1997. Vegetable production in tropics. McGraw, Englewood cliffs, USA.

[10] Clark, W., 1991. Crops and Drops. Land and water development division, Rome, Italy.

[11] Crithchley, W., 1991. Water Harvesting Techniques. FAO. Rome, Italy.

[12] Dastan, C., 1998. Crop Evapotranspiration Guidelines for computing Crop water requirement FAO irrigation pap. 56, FAO, Rome, 300p.

[13] Donald, J., 1998. Use of Mulches for Agriculture practice. Monograph, Revised printing, Bed fold.

[14] Doorenbos, J., 1986. Yield response to water. Irrigation and Drainage paper 33. Kasam. Rome, Italy.

[15] FAO, 2002. Crop Water Requirement Guide Lines. Water development division , Rome, Italy.

[16] Phocaides, A., 2000. Technical hand book on pressurized irrigation techniques. FAO, Rome, Italy.

[17] Fekadu Y. and Teshome T., 1997. Effect of drip and furrow irrigation on the yield of tomato in Dire Dawa. Agriculture water Management 35, Alemaya University of Agriculture, Dire Dawa, Ethiopia.

[18] Frederick R. Troeh , 1980. Soil and water conservation for productivity and environmental protection. Prentice-Hall, Englewood cliffs. New Jersey, USA.

[19] Hachum, A,. 2001. Water harvesting indigenous knowledge for future of the drier environments, CARDA, Aleppo, Syria.

[20] Hanson, B., 1994. Irrigation pumping plants. Davis, University of California. Cooperative Extension, California, USA.

[21] Hillel, D., 2001. Small-scale irrigation for arid zone. FAO Development series 2, Rome, Italy.

[22] Hune Nega and Paul M. Kimeu, 2002. Water harvesting techniques. RELMA, Ministry of Agriculture, Addis Ababa, Ethiopia.

[23] Isaya, R. F., 2001. Small-scale drip irrigation systems. RELMA, Nairobi, Kenya.

[24] Jensen M. E., 1983. Design and operation of farm irrigation systems. ASAE monograph, Revised printing No. 3.

[25] Michael, A. M, 1997. Irrigation theory and practice. Ashanti printers, Delhi, India.

[26] Mizyed, N. and E. G., Kruse, 2008. Emitters discharge variability of subsurface drip irrigation in uniform soils. Effect on application uniformity. Trans. of the ASAE, 26: 451-458.

[27] Mosh, S., 2006. Guidelines for planning and design of micro irrigation in arid and semiarid regions. Int. Comm. Irri. And Drai. (ICID).

[28] Sandra Postel, Paul Polak, Fernando Gonzales and Jack Keller, 2001. Drip irrigation for small farmers. Water international, 26:1, 3-13, DOI:10.1080/0250806018686882.

[29] Sivanappan, R.K., 1994. ‘’Prospects of micro-irrigation in India. *Irrigation and drainage systems 8:49-58*

[30] Smith M., 1993. CLIMWAT for CROPWAT, a climate database for irrigation planning and management. FAO irrigation and drainage paper 49, Rome, 113pp.

[31] Paul Polak, Bob Nanes, and Deepak Adhikari, 1996. Low cost drip system for small farmers in developing countries. Journal of water resources association, vol 33No.1, USA.

[32] Walker D., 1989. Design and operation of farm irrigation system. Prentice hall. Englewood cliffs, USA.