

Response of Onion (*Allium Cepa* L.) to Different Irrigation Levels under Conventional Furrow Irrigation with and without Mulch at Melkassa, Central Rift Valley of Ethiopia

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Abstract: Water is a scarce resource in Central Rift Valley of Ethiopia and is a major limiting factor for crop production. Onion is one of the major economically important vegetable crops grown under irrigation in central rift valley. The field experiment was conducted at Melkassa agricultural research center during the dry season to identify conventional furrow irrigation and irrigation application level with and without mulch that maximizes productivity of onion per unit of water consumed and enhanced onion crop production. The experiment was carried out using RCB design having six treatments with three replications. The FAO's recommended allowable Manageable depletion level of onion is 100%. In this study 75%, 100% recommended and 125% were tested. The analysis of variance for the result of the study indicated highly significant ($P \leq 0.05$) differences for yield, yield components and WUE's. The highest yield of 320.7 ton/ha was obtained from the 75% MAD with mulch which was not significantly ($P \leq 0.05$) different to the 100% MAD irrigation level. In terms of irrigation and water use efficiency, 75% MAD irrigation level application gave the highest IWUE which was significantly different from all other treatment combinations. Yield and water use efficiency based comparison had shown that there was significant difference between the yield, CWUE, and IWUE obtained in the treatment. Therefore, it can be concluded that increased water saving and associated water productivity through the use of 75% MAD with Conventional furrow irrigation and mulch, can solve problem of water shortage which improve WUE without significant reduction of yield. 75% MAD irrigation level water applied system and mulch appears to be a promising alternative for water conservation and labor saving with negligible trade-off in yield.

Keywords: Furrow Irrigation, MAD, Onion, Water Productivity

1. Introduction

Water is man kind's most vital and versatile natural resource. It is also considered as an essential resource for irrigation. Irrigation can be defined as an artificial application of water to soil for the purpose of supplying the moisture essential in the plant root-zone to prevent stress that may cause reduced yield and/or poor quality of harvest of crops [16].

The competition for existing freshwater supplies will require a paradigmatic shift from maximizing productivity per unit of land area to maximizing productivity per unit of water consumed. This shift will, in turn, demand broad systems approaches that physically and biologically optimize irrigation water relative to water delivery and application

schemes, rainfall, critical growth stages, soil fertility, location, and weather [6].

Irrigation development is increasingly implemented in Ethiopia more than ever. Expansion of irrigated area combined with the efficient management of water will enhance the attainment of food security and poverty alleviation goals of the country. Although the country is well known for its vast water resources potential its erratic distribution both in space and time coupled with limited capacity is the most challenging problem that limited the contribution of the resources to the socio-economic development of the country [13].

Agricultural production particularly vegetable crops are intensively cultivated under irrigation in Central Rift valley

(CRV) Ethiopia. The region is a semi-arid with limited water resources. Considering increasing demand for water combined with high evapotranspiration rates in the region, effective and efficient use of existing water resources need to be discovered.

Onion is one of the most important vegetable crops widely grown and economically important vegetable crops throughout the world [4]. It is also widely cultivated as source of income by many farmers in many places of Ethiopia. The country has a great potential to produce the crop throughout the year both for local consumption and export. The majority of onion production is found in the CRV of Ethiopia. The climate and soil condition of the region favors the production of the crop.

Traditionally, farmers in the central rift valley of Ethiopia have been using the most conventional surface irrigation system, most commonly the furrow irrigation system, for growing the crops. Furrow irrigation is characterized by low irrigation efficiency. Under common furrow irrigation, over irrigation is inevitable, particularly in the upper part of a field near the water source. Over-irrigation leads to greater water losses and leaches the pesticides and chemicals into the groundwater causing lower water application efficiency and pollution problems as well. The crop productivity under

furrow irrigation can be achieved by applying the required amount at the right time. The crop is shallow rooted and sensitive to water stress. As a result it is commonly given light and frequent irrigation to avoid water stress [5]. Maximum yield could be achieved with the achievement of the entire crop water requirement.

Management allowed depletion (MAD), sometimes called the readily available water (RAM) is the fraction of the total available soil water which is most easily extracted by the plant roots without creating stress. The water content approaching permanent wilting point (PWP) cannot be easily extracted by the plant roots. As ET occurs, the soil water reservoir begins to be depleted. As the soil dries, the remaining water is held more tightly by capillary forces in the soil, making it more difficult for the plant to extract it. For this reason, ET will start to decrease long before the PWP is reached. Since the lowest ET will generally reduce yields, growers should irrigate before the root zone water content reaches the level that restricts ET [14].

So, the importance of this study is to identify optimal irrigation application level with and without mulch that will improve yield and water productivity of onion at Awash Melkassa, Central Rift Valley of Ethiopia.

2. Materials and Methods

2.1. Description of the Study Area

2.1.1. Location

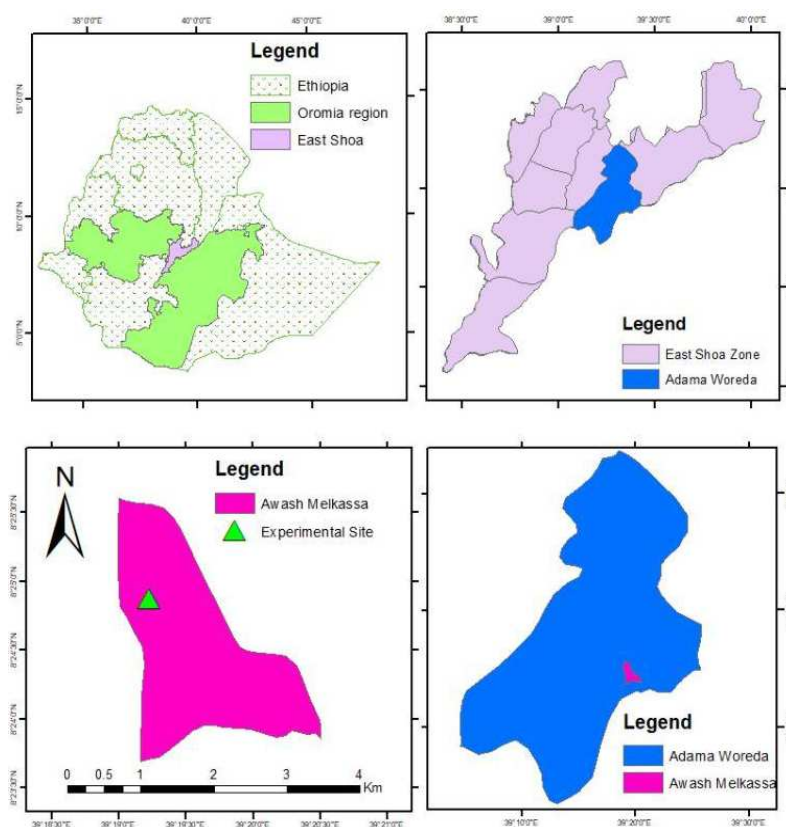


Figure 1. Location of the study area.

The study was conducted at Melkassa Agricultural Research Center experimental site during 2017/18 dry season. The area is Located in the Central Rift Valley of Ethiopia. It is geographically located between latitude of 8024' to 8026' N, longitude of 39019' to 39019' E and the mean altitude of the area is 1550 m.a.s.l (Figure 1). It is located about 107 km to the East of Addis Ababa, capital city of Ethiopia and 17 km Southeast of Adama. Loam and clay loam soil textures are the dominant soils of the area, which is classified as Lithosols with pH of 7.

2.1.2. Climate

Long-term (1977 – 2017) climatic record from station, average annual rainfall in the area is 824.9 mm. The climate of the area is characterized as semi-arid with uni-modal low and erratic rainfall pattern. Kiremt season have got more rainfall about 67.4% of the total rainfall of the area occurs from June to September, with peak month of July and August. The mean maximum and minimum monthly rainfall is 204.2 and 9.6 mm occurs in the month of August and November, respectively. The mean maximum temperature varies from 26.3 to 31.0°C while the mean minimum temperature varies from 10.4 to 16.4°C, with the average of 21.3°C (Figure 2).

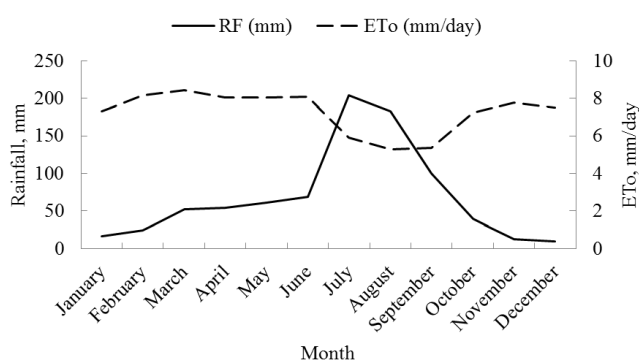


Figure 2. Long-term monthly climatic water balance of the study area.

2.1.3. Agronomic Practice

Farmers in the area grow crops three times a year of which two using traditional furrow irrigation during cool (September to January) and warm (February to May) seasons and the other during the rainy season (June–September) using rainfall and irrigation as a supplementary. The crops grown include pepper, tomato, onion, potato, shallot, haricot beans, sweet potato, papaya, wheat, maize and teff. Most of the time, vegetable crops grow during dry season and cereal crops during rainy season [18]. The source of irrigation water in the study area is Awash River.

2.2. Experimental Procedures

2.2.1. Experimental Design and Treatments

To identify the level of soil water depletion for achieving optimum crop yield and water productivity of onion crop in central rift valley of Ethiopia, conventional furrow irrigation systems were used with two levels of soil water depletion, 25% below and above FAO's recommended allowable Manageable depilation level of onion (75% of ASMDL and 125% of ASMDL) and a control irrigation application, FAO's recommended allowable Manageable depilation level of onion (100%ASMDL*) and two mulching techniques: no mulch [NM], and white plastic mulch [PM] making a total of six treatments. Depending up on irrigation level value there is no standard value put but different researcher use different values. The design of the level was in line with [10] he used the same level of deficit for the same crop type. Control irrigation implies the amount of irrigation water applied in accordance with the computed crop water requirement with the aid of CROPWAT program. The treatments were replicated three times resulting in a total of 18 plots. The plots and replications had a buffer zone of 2 m and 3 m between plots on none supplying and supplying canal sides, respectively, to eliminate influence of lateral water movement.

Table 1. The experimental treatments combinations.

| Treatment | Description |
|-----------|---|
| T1 | Furrow irrigation method with 75% of MAD level with plastic mulch |
| T2 | Furrow irrigation method with 75% of MAD level without plastic mulch |
| T3 | Furrow irrigation method with 100% of MAD level with plastic mulch |
| T4 | Furrow irrigation method with 100% of MAD level without plastic mulch |
| T5 | Furrow irrigation method with 125% of MAD level with plastic mulch |
| T6 | Furrow irrigation method with 125% of MAD level without plastic mulch |

2.2.2. Preparation of the Experimental Area

Field experiment was carried out during dry cropping season (October – February) 2017/18 and the field was ploughed using tractor, leveled and made ready for plot layout. The experimental field plot layout was made by dividing the field in to 18 plots and each experiment plot has plot sizes of 3 m by 4 m to accommodate five furrows with spacing of 60 cm between ridges and 4 m furrow length. The plots and replications plot had a buffer zone of 2 m and 3 m

between plots on none supplying and supplying canal sides, respectively to eliminate influence of lateral sub-surface water movement.

2.3. Crop Management Practices

The experimental plots were pre-irrigated before three days to planting. Onion variety Nafis was planted on well prepared experimental field plots in third week of October 2017. This variety was selected because of it's widely acceptance by local farmers and for its higher yield

performance and disease resistance. The recommended rate of 200 kg/ha DAP and 100 kg/ha urea was uniformly applied to the plots. DAP was applied at planting time only whilst urea was applied in split application, half at planting and another half twenty days after planting.

Light irrigation was applied prior to start of treatments applications for ten days. Water applications for control irrigation treatments (ASMDL*) were based on the predetermined amount of irrigation water allowable soil moisture depletion for Onion ($p = 0.25$) and those two levels of soil water depletion treatments (75% of ASMDL, and 125% of ASMDL) were imposed as planned. Each plot was irrigated using Parshall flume and all cultural practices were done in accordance to the recommendation made for the area.

2.4. Irrigation Water Source and Management

2.4.1. Irrigation Water Source and Quality

The source of water for this experiment was used from Awash River. Water quality analysis has been made. The electrical conductivity of (EC) of the irrigation water was 1.12 dS/m, which is between 700 μ mhos/cm and 3000 μ mhos/cm. Thus there is moderate limitation to use this water for irrigation.

2.4.2. Irrigation Management

The amount of water that can be extracted by plant roots is held in the soil in an 'available' form. The actual volume of water that can be obtained from the soil profile depends on the depth of the root system. Not all of the water found in the root zone was actually be taken up by roots. The total available water (TAW), stored in a unit volume of soil, is approximated by taking the difference between the water content at field capacity (FC) and at permanent wilting point (PWP). The TAW is expresses as:

$$TAW = (FC - PWP) * BD * Dz / 100$$

Where; FC and PWP in% on weight basis, BD is the bulk density of the soil in $gm\ cm^{-3}$, and Dz is the maximum effective root zone depth in mm. The bulk density, BD, is the mass of a soil in a unit volume for undisturbed soil condition and is expressed on dry weight basis of the soil as:

$$BD = Ms / Vt$$

Where Ms is the weight of oven dry soil (gm), and Vs is the volume of the same soil (cm^3).

For maximum crop production, the irrigation schedule will be fixed based on readily available soil water (RAW). The RAW is the amount of water that crops can extract from the root zone without experiencing any water stress. The RAW was computed from the expression:

$$RAW = p * TAW$$

Where; RAW in mm, p is in fraction for allowable/permissible soil moisture depletion for no stress and TAW is total available water in mm.

Soil moisture will be monitored gravimetrically at 15 cm

and soil depth increments up to 60 cm soil depth (15-30, 30-45 and 45 – 60 cm) with neutron probe in a single replication. Permissible soil moisture depletion will be taken as ASMDL* requirement and all other treatments will be adjusted accordingly to irrigate the plots. The depth of irrigation supplied at any time will be obtained from a simplified water balance equation which is expressed as:

$$In = ETc - Pe$$

where In is the net irrigation depth (mm), ETc is the crop water requirement (mm) and Pe is the effective rainfall (mm) which is a part of rainfall that enters in to the soil and makes available for crop production. The effective rainfall we estimated using dependable rain (FAO/AGLW formula) method as given by [1] as.

$$Pe = 0.6 * P - 10 \text{ for month } \leq 70 \text{ mm}$$

$$Pe = 0.8 * P - 24 \text{ for month } \geq 70 \text{ mm}$$

Where Pe is the effective rainfall (mm) and P is total rainfall (mm).

The gross irrigation requirement will be obtained from the expression:

$$Ig = \frac{In}{Ea}$$

Where; Ig is the gross irrigation depth (mm) and Ea is the field application efficiency (%). Knowing the application efficiency of the furrows (60%), the time required to deliver the desired depth of water into each furrow will be calculated using the equation:

$$T = (dxWxL) / (6xQ)$$

Where; d = gross depth of water applied (cm), W and L = width and length (m) of the experimental plot, T= application time (min) and Q is flow rate (discharge) (l/s). Soil moisture depletion at any soil moisture level will be observed with the following expression as:

$$SMD = (FC - MC) \times Dzr$$

Where, SMD = soil moisture depletion (mm), FC = volumetric soil moisture content at field capacity (mm), MC = volumetric moisture content at time of irrigation (mm), and Dzr = Depth of effective root zone (mm).

2.5. Data Collection

2.5.1. Climatic Data

Data on daily climate of the site was collected from the Melkassa Agro-meteorological observatory. The reference evapotranspiration (ETo) was computed using Penman-Monteith method, CROPWAT ver. 8.0 window based computer model from the climatic data gathered from Melkassa Agricultural Research Center. The Onion crop evapotranspiration (ETc) for each day was computed by multiplying the ETo by the crop coefficient (Kc) values obtained from [7] for each of the four stages of Onion, initial,

development, mid and late season. The Kc values represented the ratio of crop evapotranspiration (ETc) and reference evaporation (ETo) rate each day. The effective rainfall was computed by the CROPWAT program from the monthly total rainfalls. The net daily crop water requirement was computed by reducing the ETc by the daily effective rainfall. The gross water requirement was computed by applying field application efficiency.

2.5.2. Crop Data

Data on plant height, leaf height and leaf number per plant was recorded from five randomly selected plants in three middle rows of each experimental plot and the same plant was used for subsequent measurement. Data on total yield and yield components such as the Total bulb yield, Marketable bulb yield, bulb diameter, bulb height from each experimental plot were collected.

2.5.3. Soil Sampling and Analysis

To study and characterize the soil at the study site representative samples were taken and determination of organic matter content, pH, texture, bulk density, moisture content at field capacity (FC) and permanent wilting point (PWP) were made. Moisture content of the experimental plots before irrigation was estimated.

Prior to land preparation for the experiment, soil samples were collected from the experimental field using core sampler from the soil depths of 0 – 15 cm, 15 – 30 cm, 30 – 45 cm and 45-60 cm before the field was ploughed for determining physical and chemical properties of soil. Soil physical properties like textural class, bulk density, and infiltration rate, FC, PWP and TAW were determined. Soil chemical properties like pH, Organic carbon content, Organic matter content (OM) and electrical conductivity (EC) were analyzed.

(i) Bulk Density

To determine bulk density, undisturbed soil sample of known volume were taken using core sampler from three representative places in the trial plot at four different depths (0-15 cm, 15-30 cm, 30-45 cm and 45-60 cm). The samples were dried in an oven to determine the dry weight fraction. Then bulk density was calculated as the ratio of dry weight of the soil to known cylindrical core sampler volume [11].

$$BD = Ms/Vt$$

Where BD = bulk density (g/cm³), Ms = dry weight of the soil (g) and Vt = total volume of the soil (cm³).

(ii) Field Capacity and Permanent Wilting Point

The soil moisture content at field capacity (FC) and permanent wilting point (PWP) were determined after soil samples were saturated for one day (24 hrs) using the pressure plate apparatus. Field capacity was determined by exerting a pressure of 0.33 bars and permanent wilting point was determined by exerting a pressure of 15 bars until no change in moisture was observed. The FC and permanent wilting point PWP values were further used to determine

total available water (TAW)

$$TAW = 10(\theta_{FC} - \theta_{PWP})$$

Where TAW = total available water in the root zone (mm/m), FC = moisture content (vol. %) at field capacity and PWP = moisture content (vol. %) at permanent wilting point.

(iii) Soil Texture

Soil texture was determined by hydrometer method and the soil textural class was determined using the textural triangle of USDA system as described by [17]

(iv) Organic Matter and PH Measurements

Titration method, which is oxidation under standardized condition with potassium dichromate in sulphuric acid, was followed for organic carbon determination. Finally, conversion of organic carbon to organic matter is therefore obtained by multiplying percentage organic carbon by 1.724 described as by [19]. The degree of acidity or alkalinity is expressed by pH. Hence, the pH of the soil was measured by means of pH meter in the supernatant suspension of 1:2.5, soil: liquid mixture as described by [12].

(v) Soil Moisture Depletion and Infiltration Capacity

Soil samples were also collected from each experimental plot for determining moisture depletion by using gravimetric method. The gravimetric soil moisture was determined using the expression:

$$SMC (\%) = \frac{Wws - Wds}{Wds} \times 100$$

Where SMC is the soil moisture content at time of sampling (%), Wws is weight of wet soil (gm) and Wds is weight of dry soil (gm).

The soil moisture depletion at any time was computed from the expression:

$$SMD = (FC - SMC) * BD * Drz$$

Where SMD is the soil moisture depleted in mm, FC = field capacity (%), SMC is the soil moisture content (%) BD = bulk density (g/cm³) and Drz = root depth (m).

The volumetric water content was calculated from the gravimetric water content using the following expression.

$$\theta_v = \frac{\rho_b}{\rho_w} \times \theta_m$$

Where: θ_v is volumetric moisture content in (%); ρ_b is soil bulk density (gcm⁻³), and ρ_w is water density gcm⁻³. Soil infiltration capacity was made using the double ring infiltrometer. Infiltration measurement was made at four random spots and the average value was made to represent the infiltration rate of the experimental site before land preparation for the experiment. Infiltration characteristics of the soil was determined by ponding water in the metallic double cylinders installed in the field and observing the rate at which the water level in the cylinder was lowering.

Stopwatch was used to record time and all measurements replicated three times to come on conclusion.

2.6. Distribution Uniformity and Water Use Efficiency

2.6.1. Distribution Uniformity of Furrow Irrigation

To fully express the efficiency of an irrigation system, the uniformity of water applied needs to be evaluated. Distribution uniformity (DU) is a term that describes how uniformly water is applied in the field. It is the ratio of the average depth infiltrated in the low one-quarter of the field divided by the average depth infiltrated over the entire field. It is expressed as:

$$DU = \frac{D_{lq}}{D_{av}} \times 100$$

Where, DU = distribution uniformity (%),

D_{lq} = average depth of water infiltrated in the low one-quarter of the field (mm)

D_{av} = average depth of water infiltrated over the field (mm)

2.6.2. Crop Water Use Efficiency

The crop water use efficiency was determined using the expression:

$$CWUE = \frac{Y}{ET_c}$$

Where: CWUE = crop water use efficiency ($\text{kg ha}^{-1} \text{mm}^{-1}$)

Y = yield (kg ha^{-1}) and

ET_c = crop evapotranspiration (mm)

2.6.3. Irrigation Water Use Efficiency

The field water use efficiency was calculated from the expression:

$$IWUE = \frac{Y}{I_g}$$

Where: IWUE = Irrigation water use efficiency ($\text{kg ha}^{-1} \text{mm}^{-1}$)

Y = yield (kg ha^{-1})

I_g = gross irrigation (mm)

2.7. Data Analysis

The effect of furrow and drip irrigation under different irrigation levels and mulching practices on the growth and yield of Onion were analyzed by using SAS statistical software and if there is a significant difference among the treatments mean separation was made using Least Significant Difference (LSD) or Duncan's Multiple Range Test (DMRT) method. To quantify the relation among irrigation levels, crop water use efficiency, Irrigation water use efficiency, and yield and yield components, correlation and regression analyses was carried out.

3. Results and Discussion

3.1. Soil Properties

Some of the physical and chemical properties of the soil at

the experimental site (texture, bulk density, field capacity and permanent wilting point, organic matter content and pH), were analyzed and the summarized results are presented and discussed as follows.

3.1.1. Soil Physical Properties

The result of the soil analysis from the experimental site showed that the composition of sand, silt and clay percentages were in the range of 36.0 – 28.5%, 45.0 – 35.0% and 29.0 – 24.0%, respectively. Thus, according to the USDA soil textural classification, the percent particle size distribution for experimental site was classified as loam.

3.1.2. Bulk Density, Field Capacity and Permanent Wilting Point

It varied between 1.057 and 1.247 (gm/cm^3). The top soil surface has slightly lower bulk density than the subsurface and this may be due to compaction of soil in greater depth of soil layer. In general, the weighted average bulk density of the soil was found to be 1.162 (gm/cm^3).

The observed average soil moisture content at FC was varied within a narrow range of 33.8 – 39.3% on volume basis. The top 0-15 cm light soil surface was having lower field capacity (FC) while 15-30, 30-45, and 45-60 cm soil layers were having larger FC values on volume basis. The observed soil moisture content at PWP was also showed a variation with depth in a narrow range of 20.8 – 23.5% on volume basis.

The total available water (TAW) that is the amount of water that a crop can extract from its root zone was directly related to variation in FC and PWP. As a result, high value of TAW was found in the soil depth of 30-45 cm; whereas the lower values were observed at 0-15 cm soil depth.

3.2. Soil Chemical Properties

The pH of the experimental area varies from 6.74 for the depth 0 -15 cm to 7.2 for the depth 45-60 cm indicating that soil is slightly alkaline and hence, suitable for crops. The soil has an electrical conductivity of 0.2 to 0.30 dS/m through the 60 cm soil profile. The saturated extract electrical conductivity of the soil was varied from 0.30 to 0.2 dS/m for soil depths considered. This indicates that the soil is none saline and suitable for crop production [8]. The organic matter content of the soil varied from as low as 3.4% to as high as 7.4%. The average organic matter content of the soil was about 7.0%. The OM content of this experimental field had highest 7.4% in the surface soil (0-15 cm depth) where as lowest 3.4% OM found in the bottom 45- 60 cm soil depth. The average value of organic matter content was found to be 7.0% indicating that all the values of OM were with range of 3.36–7.40% and could be rated as moderate, that the field had an average structural condition with average structural stability.

3.3. Irrigation Water Application in the Experimental Area

Seasonal crop water requirement of onion determined based on the seasonal water application depth from transplanting to harvest and vary based on the irrigation level

of treatments. Common irrigation depth of 26.5 mm was applied for all treatments from transplanting for well establishment of the onion before treatment start. During the experiment there were rainfall and the total rainfall recorded was 21.5 mm then effective precipitation was calculated. The total result of calculated effective rainfall was 12.25 mm that reduced from net irrigation depth during the next irrigation treatment application.

The total net of irrigation water determined in mm for no mulch treatment (from 75% MAD to 125% MAD) were 595.5, 581.6 and 569.5 at the entire growing of the crop as it was determined from multiplication of total available water (TAW) and depletion fraction (75% MAD, 100% MAD and 125% MAD). The total gross of irrigation water applied in mm for no mulch treatment (from 75% MAD to 125% MAD) were 992.4, 969.4 and 949.1. In other ways the total net of irrigation water determined in mm for mulch treatment (from 75% MAD to 125% MAD) were 476.4, 465.3 and 455.6 at the entire growing of the crop as it was determined from multiplication of total available water (TAW) and depletion fraction (75% MAD, 100% MAD and 125% MAD). The total gross of irrigation water applied in mm for mulch treatment (from 75% MAD to 125% MAD) were 794.0, 777.5 and 759.3. The total net and gross depths of irrigation water applied in mm for mulch and no mulch treatments were varied (Table 2). The variation of application depth occurred between these treatments were due to the effectiveness of plastic mulches to conserve moisture.

Table 2. Seasonal Crop and irrigation water requirement of onion crop.

| Treatments | IRn (mm) | Pef (mm) | CWR (mm) | IRg (mm) |
|------------|----------|----------|----------|----------|
| T1 | 476.4 | 12.25 | 488.65 | 794.0 |
| T2 | 595.5 | 12.25 | 607.75 | 992.2 |
| T3 | 465.3 | 12.25 | 477.55 | 777.5 |
| T4 | 581.6 | 12.25 | 593.85 | 969.4 |
| T5 | 455.5 | 12.25 | 467.75 | 759.3 |
| T6 | 569.5 | 12.25 | 581.75 | 949.1 |

IRn = net irrigation requirement, IRg = gross irrigation requirement, CWR = crop water requirement and P_{ef} = effective rainfall.

3.5. Effects of Irrigation Levels and Mulch on Onion Yield and Yield Component

Table 4. Effects of Irrigation levels and mulch on crop yield and yield component.

| Treatment | Marketable Bulb yield (ton) | Total Bulb yield (ton) | Bulb Diameter (cm) | Bulb height (cm) |
|------------|--------------------------------|---------------------------|-----------------------|------------------|
| 75% MADPM | 278.8 ^a | 320.7 ^b | 5.2 ^a | 5.5 |
| 75% MADNM | 267.2 ^a | 314.6 ^b | 4.9 ^b | 5.3 |
| 100% MADPM | 273.2 ^a | 313.3 ^a | 5.0 ^b | 5.0 |
| 100% MADNM | 256.3 ^{ab} | 306.5 ^a | 4.9 ^b | 4.8 |
| 125% MADPM | 239.3 ^b | 277.9 ^a | 4.7 ^c | 4.7 |
| 125% MADNM | 235.0 ^b | 275.9 ^a | 4.6 ^c | 4.1 |
| LSD (0.05) | 25.65 | 19.25 | 0.14 | Ns |
| Cv (%) | 5.46 | 1.24 | 1.56 | 7.14 |

ns= not significant.

3.5.1. Total Bulb Yield

Irrigation amount increased Bulb yield significantly

3.4. Effects of Irrigation Levels and Mulch on Agronomic Characteristics of Onion

The response of onion physiology like plant height, leaf height and number of leaves per plant to irrigation method and MAD level with and without mulch is presented in table 3.

Table 3. Effects of Irrigation levels and mulch on crop physiology.

| Treatment | Plant height (cm) | Leave height (cm) | Leave Number |
|------------|-------------------|-------------------|--------------|
| 75% MADPM | 58.9 | 48.0 | 12.0 |
| 75% MADNM | 60.0 | 48.9 | 11.7 |
| 100% MADPM | 60.6 | 49.4 | 12.0 |
| 100% MADNM | 58.5 | 47.7 | 11.0 |
| 125% MADPM | 58.6 | 47.8 | 11.0 |
| 125% MADNM | 54.7 | 44.6 | 12.0 |
| LSD (0.05) | Ns | Ns | Ns |
| Cv (%) | 7.08 | 7.10 | 6.22 |

ns=not significant.

3.4.1. Plant Height

The irrigation levels were no significantly different from each other in plant height at ($p < 0.05$). The analysis of variance has indicated that the higher plant height of 60.6 cm was recorded by 100% MADPM (full irrigation with plastic mulch) of irrigation depth of water applied while 125% MADNM of irrigation depth of water applied recorded the lowest plant height of 57.4 cm.

3.4.2. Leave Height

There is no significance difference on number of leaves per plants at ($p < 0.05$). The analysis of variance has indicated that the higher Leave height of 49.4 cm was recorded by 100%MADPM (full irrigation with plastic mulch) of irrigation depth of water applied while 125%MADNM of irrigation depth of water applied recorded the lowest plant height of 44.6 cm.

3.4.3. Leave Number

There is no significance difference on number of leaves per plants. As irrigation level 100% MAD of water applied with mulch 12 were the highest while the lowest value 11.7 was observed in 75% MAD of water applied without mulch.

($P < 0.05$), producing higher Bulb yield of 320 ton with 75% MAD and significantly lower yield of 275.9 ton with 125% MAD. In addition, total yield of the crop was also highly

significantly affected ($p < 0.05$) due to different level of water application under mulching. Table 4 revealed that, the application of 75% MAD under plastic mulch and 125% MAD under plastic mulch showed a significant decreasing total yield of the crop as compared to 100% MAD under plastic mulch respectively. However, total yield were decreasing within the same water application level under mulch respectively. The maximum total yield was obtained from treatment received 75% MAD under plastic mulch (37.1 ton/ha) followed by 100% MAD under plastic mulch (35.2 ton/ha) while, the lowest mean total yield was observed on the application of 125% MAD under no mulch (30.5 ton/ha).

3.5.2. Marketable Bulb Yield

Irrigation amount increased Marketable Bulb yield significantly ($P < 0.05$), producing higher Marketable Bulb yield of 278.8 ton with 75% MAD and significantly lower yield of 235.0 ton with 125% MAD. In addition, Marketable yield of the crop was also highly significantly affected ($p < 0.05$) due to different level of water application under mulching. Table 4 revealed that, the application of 75% MAD under plastic mulch and 125% MAD under plastic mulch showed a significant decreasing total yield of the crop as compared to 100% MAD under plastic mulch respectively. However, total yield were decreasing within the same water application level under mulch respectively. The maximum total yield was obtained from treatment received 75% MAD under plastic mulch (37.1 ton/ha) followed by 100% MAD under plastic mulch (35.2 ton/ha) while, the lowest mean total yield was observed on the application of 125% MAD under no mulch (30.5 ton/ha).

This reveals that there was a decreasing trend in bulb yield for an increase in MAD level, indicating that increasing the irrigation application interval resulted in a corresponding decreasing of mean yield values. Increased bulb yield of onion by a shorter interval of irrigation may be due to the better performance of growth parameters like plant height and number of leaves. The shorter interval of irrigation ensures the optimum growth of the crop by assuring balanced water and nutrient supply throughout the crop growth period. The current result agreed with study result of [15] and [3].

3.5.3. Bulb Diameter

The analysis of variance indicated that MAD level had a highly significant ($P < 0.05$) effect on bulb diameter. As indicated in table 4, the largest bulb diameter (5.2 cm) was obtained from 75% MAD level with mulch which was significantly ($P < 0.05$) different from that obtained from other treatments, while the smallest bulb diameter (4.6 cm) was obtained from 125% MAD level without mulch. This reveals that there was a decreasing trend in bulb size for an increase in MAD level, indicating that increasing the irrigation application interval was resulted in a corresponding decreasing of mean bulb size. The shorter irrigation interval ensures the optimum growth of the crop by assuring balanced water and nutrient supply throughout the crop growth period. [2], reported that bulb diameter increased with increasing soil

moisture level and with increasing the level of irrigation application.

3.5.4. Bulb Height

The analysis of variance indicated that MAD level had a highly significant ($P < 0.05$) effect on bulb height.

The largest bulb height (5.5 cm) was obtained from 75% MAD with mulch and was significantly different to all other treatments, while the smallest bulb height (4.1 cm) was obtained from 125% MAD without mulch. This reveals that there was a decreasing trend in bulb height for an increase in MAD level, indicating that increasing the irrigation application interval was resulted in a corresponding decreasing of mean bulb size. The shorter irrigation interval ensures the optimum growth of the crop by assuring balanced water and nutrient supply throughout the crop growth period. [2], reported that bulb height increased with increasing soil moisture level.

Table 5. Effects of MAD levels and mulch on crop and irrigation water use efficiency.

| Treatment | CWUE (kg/m ³) | IWUE (kg/m ³) |
|------------|---------------------------|---------------------------|
| 75% MADPM | 0.41 ^a | 0.66 ^a |
| 75% MADNM | 0.32 ^c | 0.52 ^c |
| 100% MADPM | 0.40 ^a | 0.65 ^a |
| 100% MADNM | 0.32 ^c | 0.52 ^c |
| 125% MADPM | 0.36 ^b | 0.59 ^b |
| 125% MADNM | 0.29 ^d | 0.47 ^d |
| LSD (0.05) | 0.02 | 0.04 |
| Cv (%) | 3.49 | 3.74 |

3.6. Water Use Efficiency

3.6.1. Crop Water Use Efficiency

CWUE significantly change when irrigation levels increased. However, CWUE values ranged from 0.29 kg/m³ for 125% MADNM irrigation depth of water applied to 0.41 kg/m³ 75% MADPM of irrigation depth of water applied. Little higher CWUE values were obtained from 100% MADPM and 125% MADPM, as 0.40 and 0.36 kg/m³, respectively. My results are in agreement with [9] who reported that WUE values decreased with increasing water use.

3.6.2. Irrigation Water Use Efficiency

The mean value of irrigation level with mulch was higher than that of irrigation level and the means were significantly different at ($p < 0.05$) (Table 5). The results resembled the findings of Begum et al., (2001). The highest IWUE value under limited water supply, i.e. 0.66 kg/m³ was observed to the 75% MADPM irrigation level (Table 5).

Generally, CWUE and IWUE are influenced by crop yield potential, irrigation method, estimation and measurement of ET, crop environment, and climatic characteristics of the region.

4. Conclusion

The water productivity associated with irrigation treatments were evaluated by CWUE, IWUE. Irrigation level

application of 75% MAD with mulch was very effective and statistically significant in maintaining the same yield as the full irrigation (100% MAD) with and without mulch. Most importantly, the CWUE and IWUE obtained due to significant water saving at this new irrigation schedule were significantly high. In this research, the yield production functions toward the irrigation level of Onion in the Melkassa were investigated. The results showed that the curves of the yield production function are under the influence of the irrigation water on the consumed water use meaningfully. The yield and its components are increased by increasing the amount of water up to the optimal consumption level, and if the irrigation water is used more or less than the Onion's requirement, further run off over irrigation or moisture stress will cause the reduction of the yield and loss of water. Generally, optimum application of irrigation level applied was efficient in conserving significant irrigation water at the same time attaining higher yield.

5. Recommendation

Based on the findings obtained from the research, the following recommendations are made: Onion response to different irrigation level has a major importance for establishing the priorities in water application in where water stress/shortage areas. Among all tested treatments furrow irrigation method under 75% MAD with mulch was the best practice because of its high yield and water productivity.

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