International Journal of Applied Agricultural Sciences
2023; 9(3): 79-85
http://www.sciencepublishinggroup.com/j/ijaas
doi: 10.11648/j.ijaas.20230903.13
ISSN: 2469-7877 (Print); ISSN: 2469-7885 (Online)

Determination of Optimal Irrigation Using Soil Moisture Depletion on Yield and Water Productivity of Onion at Odo Shakiso District, Southern Ethiopia

Tesfaye Gragn*, Obsa Welde, Alemayehu Mamo

Department of Irrigation Engineering, Oromia Agricultural Research Institute, Bore Agricultural Research Center, Bore, Ethiopia

Email address:
tgragn@gmail.com (Tesfaye Gragn)
*Corresponding author

To cite this article:
Tesfaye Gragn, Obsa Welde, Alemayehu Mamo. Determination of Optimal Irrigation Using Soil Moisture Depletion on Yield and Water Productivity of Onion at Odo Shakiso District, Southern Ethiopia. *International Journal of Applied Agricultural Sciences*. Vol. 9, No. 3, 2023, pp. 79-85. doi: 10.11648/j.ijaas.20230903.13

Received: February 9, 2023; **Accepted**: May 16, 2023; **Published**: May 29, 2023

Abstract: Irrigation scheduling is the use of water management strategies to prevent over-application of water while minimizing yield losses due to water scarcity or drought stress. The experiment was conducted in Odo Shakiso district at a farm during the 2020/21 and 2021/22 irrigation seasons with the aim of determining the optimal irrigation schedule for yield, yield component and water productivity of onions based on the available soil moisture depletion levels. The experiment was performed in RCBD with three replicates randomly assigned to experimental plots with treatments. Five available soil moisture depletion levels (20% ASMDL, 40% ASMDL, 60% ASMDL, 80% ASMDL and FAO recommended ASMDL) were used for treatment. Results from two years of research showed that different levels of available soil moisture had a significant impact ($P<0.05$) on bulb diameter, bulb weight, unmarketable onion yield, marketable onion yield, and water productivity. However, different soil moisture depletion did not show a significant difference in plant height. The highest onion diameter (4.25 cm) and marketable onion yield (363.9 qt/ha) was recorded at 60% ASMDL. The highest water use efficiency at marketable onion yield (9.487 kg/m^3) was also achieved at 60% ASMDL, which was statistically comparable to the FAO-recommended ASMDL treatment. On the other hand, the minimum water use efficiency (6.234 kg/m^3) was recorded at 40 percent ASMDL. Therefore, based on the results of the current experiment, it is recommended to use 60% ASMDL under a furrow irrigation system for onion cultivation in areas around Shakiso and similar agro ecologies as it is the best option to increase yield and water use efficiency for onion production.

Keywords: ASMDL, Onion, Irrigation, Water Use

1. Introduction

In Ethiopia, the population is growing rapidly and is expected to continue to grow, leading unsurprisingly to an increased need for food. To maintain food self-sufficiency, one possible option is to increase production and productivity per land unit through irrigation. Water is essential for crop production and for efficient crop production and high yields, the available water must be used in the best possible way. The problem with watering is when and how much to water. The right amount and timing of irrigation water application is a key decision for a farm manager to meet crop water needs, avoid yield losses and maximize irrigation water use efficiency, resulting in beneficial use and conservation of local water resources [1].

Determining crop yield response to irrigation is critical to crop selection, economic analysis, and implementation of effective irrigation management strategies. In addition, this allows knowing the timing of irrigation and optimizing yield, water use efficiency and bottom line profit [13]. When irrigation water supply is limited, irrigation scheduling is one of the most important tools to develop best management practices for irrigated areas [14]. Irrigation scheduling is the technique of timely and accurate application of water to crops. It is key to saving water and improving irrigation performance and sustainability of irrigated agriculture [11]. The goal of irrigation scheduling is to keep soil moisture within a desired range, typically between field capacity (full point) and a predetermined replenishment point for optimal growth.

Onion (Allium cepa L.) is one of the most important commercially grown vegetables and play an important economic role in Ethiopia. The country has tremendous potential to grow the crop all year round for both domestic consumption and the export market. Since the crop has spread to different parts of the country, it has been grown as a source of income by many farmers in many parts of the country. Onion cultivation also contributes to the commercialization of the rural economy and creates many non-agricultural jobs [10]. Onion yield is reduced by both over- and under-watering. A deviation of just 10 percent from the optimal watering for the growing season can lead to a drop in yield. Yield declines due to overwatering can be attributed to poor soil aeration, increased disease problems, and nitrogen leaching.

Although irrigation has been practiced for a long time, the experience of farmers in irrigation water management in the study area was very limited. With the recent development and expansion of modern irrigation infrastructure in the country, improving irrigation water management is very important to improve water management on farms. Therefore, on-farm monitoring of available soil moisture levels and irrigation scheduling is an efficient technology that helps improve irrigation water management and increase irrigation water consumption under field conditions. Traditional irrigation methods are used in onion cultivation in different areas. However, the irrigation water requirement including irrigation planning is not known. Researchers have expressed that the soil moisture loss in onions should be 0.25 [1]. However, the recommendations must be checked in the operating environment, since the water needs of the crops depend on the type of soil and climatic conditions. Crop water requirements vary with time and space due to climate, management, crop phonological stage, and cultivar. Therefore, their assessment must be done locally [5]. For effective use of the available water resources, it is important to determine the amount of water required by the crop and the correct timing of water application (irrigation scheduling). The general aim of this study was therefore to evaluate the responses of onions to the irrigation regime (when and how much) and to identify WP under optimal irrigation regime.

2. Materials and Methods

2.1. Description of the Study Area

The experiment was carried out in 2020 and 2021 at Odo Shakiso District under Bore Agricultural Research Center for two consecutive years. The area is characterized by bimodal rainfall pattern with longest rain season (locally known as Hagayya) and a short rainy season (locally known as Ganna). The District has geographical location of 5°2'29” - 5°58'24” northing latitudes and 38°35'0”-39°13'38” easting longitudes. The district is characterized by three agro- climatic zones, namely highland (Bada), accounting for about 33%, midland (Bada dare), accounting for about 47% and lowland (Gamoji), accounting for about 20% district area coverage. Most of the earth surface of the district is ups and down of the land surface with an elevation ranging 1500-2000 m a.s.l. in the larger southern portion of North Western part. Plains, dissected hill plateau and mountain as well as valleys and gorges characterized the relief of the district. The mean annual rain fall about 900mm and the mean annual temperature of the district is 22.5°C. The soil textural class of the experimental area is clay with pH of 6.95. The most widely cultivated crops in the district are wheat, barley, maize, teff, Haricot bean, chick peas, Linseed, rapeseed, fruits, and Vegetable (District statistical abstract of 2014/15).

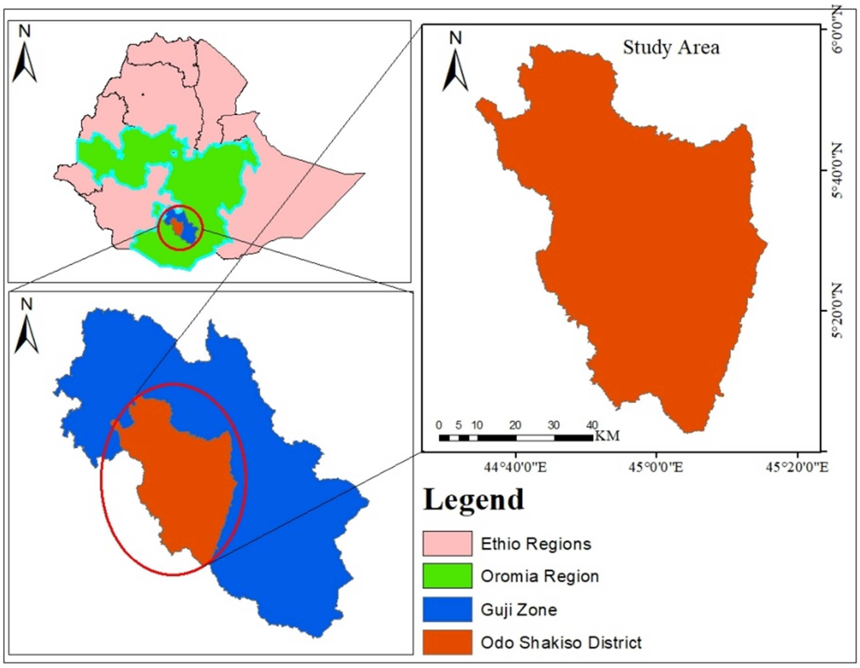

Figure 1. *Location Map of the study area.*

2.2. Soil Sampling and Analysis

Soil samples were taken from two depths of 0-30 cm and 30-60 cm along the diagonal of the experimental field to determine soil texture, pH, electrical conductivity (EC), organic carbon (OC), bulk density (BD), field capacity. FC) and permanent wilting point (PWP). The particle size distributions in the soil profiles were determined using the hydrometric method [16]. The pH of the soil was measured in a soil-water mixture of 1:2.5 using a pH meter. The organic carbon content was determined by the titration method using chromic acid (potassium dichromate + H2SO4) [17]. The field capacity and the permanent wilting point of the soil were analyzed in the laboratory with a ceramic plate apparatus at a pressure of 1 bar (for field capacity) and 5 bar (for permanent wilting point). The soil was also examined for infiltration using double ring Infiltrometers. Soil bulk density was determined from undisturbed soil samples using a core sampler measuring 2.5 cm diameter and 2.5 cm (12.27 cm3) high. The bulk density was then calculated as the ratio of the dry weight of the soil to the known volume of the cylindrical core sampler [8].

$$p_b = \frac{M_c}{V_t} \quad (1)$$

where, p_b: Bulk density (g/cm^3), M_c: Dry weight of soil (g), V_t: Volume of core sampler (cm^3).

2.3. Experimental Design and Treatment Application

The experiment included five levels of soil moisture depletion depending on the FAO soil moisture depletion level. The five ASMDL levels were (20% ASMDL, 40% ASMDL, 60% ASMDL, 80% ASMDL and 100% ASMDL (FAO recommended ASMDL)). The specified amount of irrigation water was applied to each plot using a partial flume. Irrigation scheduling was based on percentage depletion of available soil water in the root zone. Experimental treatments were set up in three replication with randomized complete block design (RCBD) in which soil moisture depletion levels (SMDL) were randomly assigned to experimental plots. The experiment was tested on the onion variety Bombay Red with a test plot area of 3x4m (12m^2). The distance between plots and replication was 1 m and 1.5 m, respectively. Onion seedlings were transplanted in ten rows with eight harvestable rows. The plant row spacing across the furrow, across the ridge and along the ridge was 40 cm, 20 cm and 10 cm, respectively. All agronomic practices were implemented at the required time.

Table 1. *Treatment setting for field experiment.*

Treatment	Description
ASMDL1	20% ASMDL
ASMDL2	40% ASMDL
ASMDL3	60%ASMDL
ASMDL4	80% ASMDL
ASMDL5	100% ASMDL*(Control)

Where: *ASMDL- available soil moisture depletion level according to FAO (33).

2.4. Crop Water Requirement

Fifteen year (2004–2018) climate data includes monthly high and low temperature data, relative humidity, wind speed, and hours of sunshine. Daily ETo values (mm/day) were calculated from the collected data using the Windows model FAO CropWat 8.0. In addition, the effective amount of precipitation was calculated with this model. The Kc values were taken from the FAO Irrigation and Drainage Paper No. 56 [1]. Then the water requirement of was calculated from [2]:

$$ETc\ (mm/day) = ETo \times Kc \quad (2)$$

Where:
ETc = crop water requirement;
ETo = estimation of reference crop Evapotranspiration in mm/day and
Kc = crop coefficient.

2.5. Soil Moisture Determination

The soil sample was taken using soil auger based on the root depth of the crop (0-15 cm, 15-30 cm and 30-60 cm) to monitor the moisture content of the soil and oven dried at 105°C until the weight change is constant. The oven dried sample was then weighed to determine the water content of the soil. The water content in the soil was determined on a weight basis using the following equation. Then the gravimetric water content was converted to a volumetric water content by multiplying it by the soil bulk density and the root depth of the onion to get the available field/actual moisture at the time of irrigation.

$$\theta_{dw} = \frac{w_{ws} - w_{ds}}{w_{ds}} * 100 \quad (3)$$

Where Wws = weight of wet soil (g), θdw = water content expressed on weight basis in (%) and Wds = weight of dry soil (g).

The soil infiltration capacity was measured using the double ring Infiltrometers.

2.6. Determination of Irrigation Requirement and Irrigation Scheduling

The total available water (TAW) for crop use in the root zone was calculated from field capacity and permanent wilting point using following expression [4]

$$TAW = 1000 \sum(\theta FC - \theta PWP) * BD * Zr \quad (4)$$

Where: TAW: volumetric total available water in the root zone (mm/m) FC: volumetric moisture content at field capacity (m^3 /m^3) and PWP: volumetric moisture content at permanent wilting point (m^3 /m^3). BD: bulk density (gm. /cm^3).

Then, RAW (mm) which is equal to net irrigation depth (dnet) was computed from total available water using the following equation [5]:

$$RAW = TAW * \rho \quad (5)$$

Where: RAW in mm which is equal to net irrigation depth (mm) TAW: Total available water ρ : water depletion fraction/management allowable depletion (%), for onion (ρ =0.25). Then, irrigation interval was computed from the expression [6]:

$$Interval\ (days) = \frac{RAW}{ETc} \tag{6}$$

Where, RAW in mm which is equal to net irrigation depth (dnet) and ETc in mm/day is crop evapotranspiration.

Then, gross irrigation requirement (dg):

$$dg = \frac{dnet}{Ea} \tag{7}$$

Where, dg in mm and Ea is the field irrigation application efficiency of a short, end diked furrow was taken as 60% [3].

The amount of water applied to the experimental field was measured by 3-inch Parshall flume. The time required to deliver the desired depth of water into each plot was calculated using the equation [8]:

$$t = \frac{dg \times A}{6 \times Q} \tag{8}$$

Where: dg = gross depth of water applied (cm) t = application time (min) A = Area of experimental plot (m^2) and Q = flow rate (discharge) (l/s).

2.7. Irrigation Water Application

The ETo values estimated using the CROPWAT model based on climatological parameters have to be adjusted to the actual crop. A 3 inch standard Parshall flume was installed near the trial field to measure irrigation water applied to individual plots. A mean discharge was diverted into the test field from a canal. This runoff could flow into one plot at a time. Using a calculator and a stopwatch, immediately after water was placed in the plots, the flow rate into each plot and the time required to apply the desired depth of water were calculated. For the calculated time, water was let into the plot and each furrow. Immediately after reaching the desired depth, the plots were closed with the banks of the canal to prevent water from entering the plots.

2.8. Water Productivity

Water productivity was estimated as a ratio of fruit yield of onion to the total crop water consumption by evapotranspiration (Etc) through the growing season and it was calculated using the following equation.

$$CWP = \frac{Y}{ET} \tag{9}$$

Where, CWP is crop water productivity (kg/m³), Y Onion yield (kg/ha) and ET is the seasonal crop water consumption by evapotranspiration (m³/ha).

2.9. Data Collection

Plant height: Plant height (cm) was calculated for five randomly selected plants with a tape measure from soil to leaf tip in the experimental plot at physiological maturity.

2) Bulb weight: Bulb weight (gm $plant^{-1}$) was measured on five randomly selected individual bulbs and their average weight was calculated.

3) Bulb diameter: The bulb diameter (cm) was measured at the widest part of the bulb of five sample plants in each experimental unit. Onion diameter was determined as one of the parameters of crop quality [18].

4) Marketable Yield (QT/ha): The marketable yield (QT/ha) is healthy and average to large Bombay Red onion bulbs without disease were recorded from the central three harvestable rows. The marketable onion was sorted out from the whole onion bulb depending on the color of the onion, the absence of surface defects on the onion (due to insects, diseases or physiological disorders) and its firmness.5) Non-marketable onion (kg/ha): The Bombay Red onion bulbs were recorded as the weight of the non-marketable onions from the central three harvestable rows. Non-marketable onions were sorted out from the marketable onion crop based on onion disease, discoloration, cracking, insect damage, smallness of size, and consumer avoidance of unwanted bulbs.

2.10. Data Analysis

All necessary data collected were managed properly using the Genstat software 18th edition. When the treatment effect was found significant, the mean separation was tested using least significant difference (LSD) at 5% probability level.

3. Results and Discussion

3.1. Physical and Water Properties of Soil in the Study Area

Table 2. *Soil Physical properties of experimental site.*

Soil Depth (cm)	BD (g/cm^3)	FC mass base (%)	PWP mass base (%)	TAW (mm)	%Sand	%Silt	%Clay	
0-30	1.34	25.8	18.0	31.4	38	36	26	Loam
30-60	1.37	25.4	17.9	31.0	32	28	40	Clay
Total available water in 60 cm				62.4				

Where: BD- bulk density, FC- field capacity, PWP- permanent wilting point, TAW- total available water.

The soil result of the study area showed that the average composition of sand, silt and clay fractions was 35%, 32% and 33% respectively. Per USDA soil texture classification, determination of percent particle size for the test site indicated that the soil texture could be classified as clay loam. The result of the bulk density of the soil in the test field varies slightly with its depth. It varied between 1.34 (g/cm^3) and 1.37 (g/cm^3) from the top to the bottom soil layer. The subsoil has a slightly higher compaction than the top layer of soil. It can be for a variety of reasons. The average bulk density of the soil in the trial field was 1.36 g/cm^3, which is below the critical threshold of 1.45 g/cm^3 and suitable for crop root growth. The average soil moisture content of the test sites was 25.8% at field capacity and 18% at the permanent wilting point. As indicated in (Table 2), the average total water volume available was 106 mm/m.

3.2. Chemical Properties of Soil in the Study Area

*T*he average pH of the trial site was within the recommended range based on the analyzed soil profile with an average value of 6.95% (Table 3). The average soil organic carbon and organic matter content averaged 1.64% and 2.82%, respectively, over a 90 cm depth of soil profile. The average electrical conductivity of a test floor is 0.089 ds/m. In general, according to the USDA soil classification, soils with an electrical conductivity of less than 2.0 dS/m at 25°C and a pH of less than 8.5 are considered normal. The soils in the study area are therefore normal soils. The soil infiltration rate of the study site was 6 mm/hour. The trial site therefore had a favorable soil pH (close to neutral) for onion growth. The ECe value of the soil, which ranged from 0.43 at a depth of 0.30 cm to 0.192 at shallower depths (3060 cm), indicates that the soil is non-saline and non-sodium. Research reports have found that crops cannot tolerate saline above (>4 dS/m) [6].

Table 3. *Soil Chemical properties of experimental site.*

Soil Depth (cm)	pH (H_2O)	ECe (dS/m)	%OC	%OM
0-30	6.5	0.430	1.97	3.40
30-60	7.4	0.192	1.30	2.24
Average	6.95	0.311	1.64	2.82

Where: EC: Electrical conductivity, OC-Organic carbon and OM- organic matter.

3.3. Yield and Yield-Related Effects

3.3.1. Plant Height

The study result showed that varying the soil moisture depletion level from 20% to 100% of the FAO recommendation had no effect on plant height (Table 4). Numerically, among treatments, the tallest plant height (42.83 cm) was recorded when irrigated at 60% water, while the shortest plant height (39.07 cm) was recorded when treated with irrigated at 20% ASMDL (Table 4). In a similar study, it was reported that irrigation treatments with different available soil moisture losses showed no significant difference between all treatments in terms of plant height [15]. This result was also consistent with findings reporting that variations in the degree of irrigation depletion resulted in a non-significant difference in plant height of wheat plants [15].

3.3.2. Bulb Diameter

Onion bulb diameter was determined as an indicator of size and found to be significantly affected by different irrigation water treatments ($p<0.05$). The highest bulb diameter was obtained from 60% with no significant difference with 20% ASMDL and 100% ASMDL (FAO recommended ASMDL). The lowest bulb diameter was measured when applying irrigation water at 80% available soil moisture decrease (Table 4) and this was consistent with the results where the highest bulb diameter was obtained at 60% ASMDL [12]. Similar results have been reported for larger bulb diameters [2].

3.3.3. Bulb Weight

The analysis of ANOVA indicates that, there was significant ($P < 0.05$) difference on the different treatment of available soil moisture depletion level (ASMDL) on onion weight. The heaviest bulb weight (65.27 gm) was obtained from treatments which received 60% ASMDL followed by FAO recommended ASMDL (53.83 gm). However, there is no statistically significant different between treatment application 20% ASMDL, 60% ASMDL, 80% ASMDL and 100% FAO recommended ASMDL regarding to average bulb weight. The lightest bulb weight was recorded from the irrigation water application under treatment 40% ASMDL (Table 4). This result is in agreement with the result which reported that the average bulb weight significant different with different irrigation water application of available soil moisture level [2].

Table 4. *Effects of optimal irrigation scheduling on onion yield, yield component and water productivity.*

Treatments	PH (cm)	BD (cm)	BW (g)	MBY (Qt/ha)	UMBY (Qt/ha)	WUE (Kg m^{-3}
ASMDL 1	39.07	4.162^{ab}	50.00^{ab}	249.9^{ab}	10.76^{b}	6.515^{ab}
ASMDL 2	40.37	3.835^{bc}	41.73^{b}	239.1^{b}	10.70^{b}	6.234^{b}
ASMDL 3	42.83	4.250^{a}	65.27^{a}	363.9^{a}	12.50^{b}	9.487^{a}
ASMDL 4	41.97	3.560^{c}	46.40^{ab}	310.0^{ab}	18.33^{a}	8.082^{ab}
ASMDL 5*(Control)	39.93	3.985^{ab}	53.83^{ab}	333.9^{ab}	9.72^{b}	8.704^{ab}
LSD (5%)	4.028	0.383	18.940	105.69	5.57	1.329
CV (%)	8.2	8.1	30.7	29.5	37.5	29.5

*Means in column followed in the same letters had non-significant difference at 5% probability level, Where; PH: plant height, BD: bulb diameter, BW: bulb weight, MBY: marketable bulb yield, UMBY: unmarketable bulb yield, CV: coefficient of variation and WUE: water use efficiency: LSD (%) = Least significant Difference at 5% of significance and CV (%) = Coefficient of variation.

3.3.4. Marketable Onion Yield

The analysis result shows that the highest marketable yield (363.9 qt/ha) was at 60% ASMDL, followed by (333.9 qt/ha) at 100% ASMDL treatment, while the lowest marketable yield (239.1 qt/ha) at treatment was achieved by 80% of the ASMDL (Table 4). But statistically, there was no significant difference between the four treatments (60% ASMDL, 80% ASMDL, 100% ASMDL, and 20% ASMDL) except for treatment with 40% ASMDL. These results were consistent with the reported results, according to which maximum onion yield and maximum water use efficiency were achieved at 60% of available soil moisture [12]. This was also consistent with findings that the highest yield of onion bulbs was obtained at 60% of the available soil moisture deficits [18].

3.3.5. Unmarketable Onion Yield

Analysis of variance revealed that non-marketable onion yield was significantly (P<0.05) influenced by the irrigation system. Based on the result, the highest yield of non-marketable onions (18.33 qt/ha) was recorded on a plot with 80% ASMDL irrigation, while the low yield of non-marketable onions was on the FAO-recommended plot with ASMDL irrigation was achieved (Table 4). This result is consistent with reported results that 80% ASMDL under a furrow irrigation system produces maximum non-marketable onion yield [2]. This may be due to very small bulbs leading to a reduction in the level of unmarketable bulbs through improper use of available soil moisture.

3.4. Water Use Efficiency

As shown in (Table 4), the highest water use efficiency (9.487 kg m^{-3}) was achieved with 60% ASMDL, followed by (8.704 kg m-3) with 100% ASMDL treatment, while the lowest marketable yield (6.234 kg m^{-3}) Was obtained from treatment of 40% of ASMDL (Table 4). But statistically, there was no significant difference between the four treatments (100% ASMDL, 80% ASMDL, 60% ASMDL, and 20% ASMDL) except for treatment with 40% ASMDL. According to the water use efficiency, the crop yield for bulbs with 85 to 90% moisture is 8 to 10 kg/m^3 [5]. The results obtained from this experiment are within the recommended range of the FAO 33. These results were consistent with the finding that the highest water use efficiency of onions was achieved at an irrigation water application of 60% ASMDL [12].

4. Conclusions and Recommendations

Irrigation water management is the most important constraint for the development of irrigated agriculture. Therefore, the effective use of available water with optimal irrigation scheduling has significant implications for irrigated agriculture. Onions (Allium cepa L.) are a widely recognized crop and are most successfully grown under irrigated conditions in various parts of Ethiopia. However, due to information and irrigation systems, the productivity of the crop is much lower. The aim of this study was to investigate the effect of the irrigation system on the yield, the yield component and the WUE of the anion. Five available soil moisture depletion levels (20% AMADL, 40% AMADL, 60% AMADL, 80% AMADL and FAO recommended AMADL) were used as treatments in the Completely Randomized Block Design (RCBD). The effect of irrigation treatments was evaluated on growth parameters, yield and water productivity such as plant height, average bulb weight, bulb diameter, non-marketable yield and marketable yield at the level of significance (p<0.05).

Based on this study, the tallest plant height (42.83 cm) was measured in an irrigation water application with 60% ASMDL. Maximum onion diameter (4.25 cm) and average onion weight (65.27 g) were also determined in treatments receiving 60% ASMDL. The highest marketable yield (363.9 qt/ha) was at 60% ASMDL, followed by (333.9 qt/ha) when treated with 100% ASMDL, while the lowest marketable yield (239.1 qt/ha) was achieved at treatment with 80% ASMDL. But statistically, there was no significant difference between the four treatments (60% ASMDL, 80% ASMDL, 100% ASMDL, and 20% ASMDL) except for treatment with 40% ASMDL. Analysis of variance revealed that non-marketable onion yield was significantly (P<0.05) influenced by the irrigation system. The highest water use efficiency (9.487 kg m^{-3}) was achieved with 60% ASMDL, followed by (8.704 kg m^{-3}) under treatment with 100% ASMDL, while the lowest marketable yield (6.234 kg m^{-3}) was achieved with treatment 40% of the ASMDL. In general, the application of different %ASMDL responds differently to onion productivity. Therefore, based on the results of the current experiment, it is recommended to use an allowable soil moisture level of 60% with a shorter watering interval under a furrow irrigation system for onion production in the study area with similar agro ecology and soil types.

References

[1] Allen, R. G., Pereira, L. S., Raes, D., & Smith, M. (1998). Crop evapotranspiration-Guidelines for computing crop water requirements-FAO Irrigation and drainage paper 56 (vol. 300, pp. D05109).

[2] Belachew Muche Mekonen, Minybel Fentahun Moges. 2022. Determination of Optimal Irrigation Scheduling for Onion (Allium cepa L.) in Gumara Scheme, North Western Ethiopia. International Journal of Natural Resource Ecology and Management, 7 (1), p. 6.

[3] Brouwer, C. and Prins, K. 1989. Irrigation Water Management: Irrigation Scheduling. Training manual no. 4. FAO. Rome, Italy.

[4] Doorenbos J, A H Kassam, C L Bentvelsen, V Branscheid, J M Plusje, M Smith, G O Uittenbogaard, and H K Van DerWal. 1986. Yield Response to Water. FAO Irrigation and Drainage paper 33, FAO, Rome.

[5] Doorenbos, I. and Pruitt, W. O. 1977: Crop water requirements, FAO Paper 24, Rome, Italy, 144 pp.

[6] Ecocrop, K. (2003). Plant production and protection information system (online).

[7] FAO. 2010. CropWat for windows version 8.0. Food and Agricultural Organization (FAO), Rome, Italy. pp. 97-99.

[8] Fikire, M., & Olani, N. (2010). Onion seed production techniques manual for extension agents and seed producers.

[9] Kandiah, A. 1981. A guide for measurement of irrigation water using Parshall flumes and siphons. Technical Bulletin no. 1 Irrigation Agronomy Section Melka Werer Research Station Institute of Agricultural Research, FAO irrigation Specialist. Addis Ababa. p. 87.

[10] Lemma Dessalegn and Shemelis Aklilu, 2003. Research results and experiences in onion dry bulb and seed production in Ethiopia. Vegetable crops improvement research, EARO, Melkassa Agricultural Research Centre. 39p.

[11] Lopez-Urrea, R., Olalla, F. M. D., Montoro, A. and Lopez-Fuster, P. 2009. Single and dual crop coefficients and water requirements for onion (Allium cepa L.) under semiarid conditions. Agricultural Water Management, 96: 1031-1036.

[12] Miniebel, 2021. Determination of Optimal Irrigation Scheduling for Onion (Allium cepa L.) at Assosa District, North West of Ethiopia. Int. J. Adv. Res. Biol. Sci, 8 (7), pp. 103-109.

[13] Payero, J. O., D. D. Tarkalson, S. Irmak, D. Davison and J. L. Petersen. 2009. Effect of timing of deficit-irrigation allocation on corn evapotranspiration, yield, water use efficiency and dry mass. Agricultural water Management, 96: 1387-1397.

[14] Pejić, B., Gvozdanović-Varga, Vasić, J., Maksimović, M. and Milić, L. 2008. Yield and evapotranspiration of onion depending on different preirrigation soil moisture. (In Serbian). A Periodical of Scince Research Field and Vegetable Crops, 44: 195-202.

[15] Samuel L., Bakasho I., Mehiret H., Kassu T., Wubengida A. (2019). Determination of Optimal Irrigation Scheduling and Water Productivity for Wheat (Triticum aestevum L.) at Kulumsa, Arsi Zone, Ethiopia. Acad. Res. J. Agri. Sci. Res. 7 (5): 289-296.

[16] Stanley, W. C. and Yerima, B. 1992. Improvement of soil services for agricultural development: guidelines for soil sampling and fertility evaluation. Ministry of Natural Resources Development and Environmental Protection, Addis Ababa, Ethiopia.

[17] Walkley, A. and Black, I. A. 1934. An Examination of Degtjareff Method for Determining Soil Organic Matter and a Proposed Modification of the Chromic Acid Titration Method. Soil Sci. 37: 29-37.

[18] Yemane M., Haftamu T., and Ahmmed M., 2019. Determination of Optimal Irrigation Scheduling for Onion (Allium cepa L.) in Raya Valley, Northern Ethiopia. Results of Natural Resources Management Research.