International Journal of Natural Resource Ecology and Management
2025, Vol. 10, No. 2, pp. 59-67
https://doi.org/10.11648/j.ijnrem.20251002.11

Research Article

Determination of Optimum Irrigation Scheduling and Water Productivity for Onion Production in Mandura District, North-West Ethiopia

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Abstract

Knowing how much water a plant has access to and how effectively it can use it is crucial for irrigation scheduling in order to prevent overwatering or under watering. To assess how onions responded to the irrigation schedule, a field experiment was carried out. (When and how much) and to identify water productivity under optimal irrigation regime. The recommended levels of soil moisture depletion for onions served as the basis for setting the treatments. Then, in order to assess the best irrigation timing, there are five degrees of available soil moisture depletion namely, 60% Available Soil Moisture Depletion Level, 80% Available Soil Moisture Depletion Level, 100% Available Soil Moisture Depletion Level, 120% Available Soil Moisture Depletion Level and 140% Available Soil Moisture Depletion Level of the FAO recommended value of onion were used. Three replications of the experiment were set up using a Randomized Complete Block Design. The highest total bulb yield obtained at 60% Available Soil Moisture Depletion Level that was 211.65 q/ha followed by 80%, 100% and 120% Available Soil Moisture Depletion Level with the values of 210.85q/ha, 191.89q/ha and 188.18q/ha respectively without any significant difference. The highest irrigation water productivity of onion to convert irrigation water to bulb yield were obtained under 60% Available Soil Moisture Depletion Level which had 3.87kg/m^3/ha followed by 80%, 100% and 120% Available Soil Moisture Depletion Level with the values of 3.77, 3.63 and 3.37 kg/m^3/ha respectively without any significant difference. Therefore, according to the current findings, the highest bulb production and irrigation water productivity are obtained when irrigation scheduling is applied for onions in the research and related agroclimatic areas and soil types at 60% Available Soil Moisture Depletion Level.

Keywords

Optimum Irrigation Scheduling, Water Productivity, Onion, Available Soil Moisture Depletion Level

1. Introduction

Irrigation scheduling is an element of proper irrigation water management including the full decision, when to irrigate and how much water to release to the field [1]. Irrigation scheduling is also highly helpful in deciding irrigation strategies when the irrigation water supply is limited. One of the most crucial methods for creating effective management practices for irrigated area is irrigation scheduling [2]. Water conservation, irrigation performance, and the sustainability of irrigated agriculture all depend on irrigation scheduling, which is the process of accurately and timely applying water

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Received: 1 March 2025; **Accepted:** 22 March 2025; **Published:** 14 April 2025

to the crop [3].

Irrigation scheduling requires determining the appropriate quantity and timing of water application. This decision is influenced by three key factors: the water requirements of the crop, known as evapotranspiration, the availability of water resources, and the soil's capacity to retain moisture [4].

Onion is among the most significant crops for cool-season vegetables. After tomatoes, it is the second most economically significant vegetable worldwide [5]. Onion requires varying temperature and day length for the purpose bulb production [6]. It is not advised to grow onions in poorly drained soils, particularly due to the prevalence of bulb diseases during harvest, which might pose further issues while marketing [7]. For a small-seeded crop, the soil needs to be sufficiently well-structured to allow for the creation of a fine seedbed. Bulb formation requires a lengthy photoperiod and relatively high temperature, and temperature is far more important for seed generation than day length [8].

One of the most crucial elements affecting onion productivity is soil moisture. Due to their shallow and small root system, onions need to be watered frequently because they don't absorb much water [9]. Throughout the growing season, this crop needs to be irrigated often. The formation of new roots depends on soil moisture; if the newly created roots from the stem are to grow into the soil, the soil moisture must periodically reach the base of the bulb. Dry soil will not support the growth of new roots [10].

It is most vulnerable to water scarcity during the yield-formation phase, especially while the bulb is growing quickly and being transplanted. Bulb yield was significantly reduced when there was a 50–75% water deficit throughout the growth season during the yield development period [11]. In tropical regions with significantly higher evapotranspiration, onions may require more water than the 350–550 mm needed for optimal yield [12]. Onions, on the other hand, grow best when permitted depletion is kept above 70% of the total amount of water available; otherwise, yield will decrease [7, 12].

After planting, water is typically irrigated more frequently every 4-5 days for the first 3 to 4 weeks, and then every 7 to 9 days after that. Irrigation should stop 15 to 25 days before to harvest, when the onion is starting to mature and the tops start to fall. According to [10], it has been observed that thick-necked, uneven, and poorly storable bulbs are the result of late and intermittent irrigation water application. For onions, especially in Ethiopia's Rift Valley, the best plant spacing and nitrogen recommendation have been developed. These recommendations call for double row spacing of 10 cm and 20 cm between plants, as well as applications of 46 kg N ha^{-1} and 92 kg (P_2O_5) ha^{-1} [13]. The recommended fertilizer rate in Ethiopia, for the onion is, 200 kg/ha (DAP) and 100 kg/ha for urea [10].

Onion yield is not as expected potential in the study area since its production reduced by both over- and under-irrigation. Over irrigation can be attributed to poor soil aeration, increased disease problems, leaching of nitrogen and finally cause yield reductions. The farmers practice their irrigation work without considering how much amount of irrigation water should be applied and when to irrigate for their irrigated onion. Therefore, how much irrigation water should be applied and when to irrigate should be determined for the study area for enhancing production of onion.

2. Materials and Methods

2.1. Description of the Study Area

The research was carried out in the Mandura district, located within the Metekel zone of the Benishangul Gumuz Regional State in the northwestern part of Ethiopia. According to [14] state that the Metekel Zone's surroundings have a wide range of climatic conditions, including hot to warm subhumid lowlands and hot to warm moist lowlands. The annual maximum and minimum temperature Metekel Zone are 35 ℃ and 20 ℃ respectively and geographically, Mandura district metrology station located at 36.32° longitude and 11.06 latitude with an altitude of 1161m.a.s.l. The Permanent welting point and field capacity ranges from 21.3% to 30%, and 41.9%, to 34.1% respectively [15].

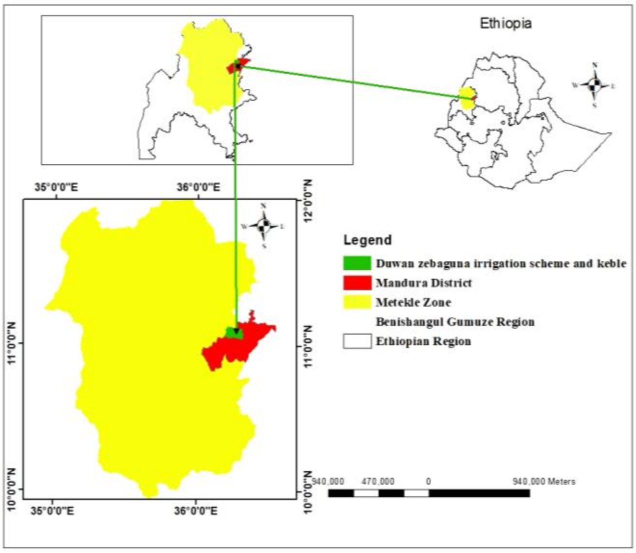

Figure 1. Location of the study area.

2.2. Experimental Design and Treatment Combination

The experiment was carried out in Mandaura District for two years (2010 and 2011 E.C.) at diwazin baguna small scall irrigation scheme. The experiment was designed as a randomized complete block design with three replications. The treatments were evaluated across five levels of available soil moisture depletion (ASMDL). These levels included 60%

ASMDL, 80% ASMDL, 100% ASMDL, 120% ASMDL, and 140% ASMDL. According to [16], the recommended allowable soil moisture depletion (p) or management allowable depletion (MAD) for onion is 25%.

Table 1. *Treatments.*

Treatments	Descriptions
1	60% Available Soil Moisture Depletion Level
2	80% Available Soil Moisture Depletion Level
3	100% Available Soil Moisture Depletion Level * control
4	120% Available Soil Moisture Depletion Level
5	140% Available Soil Moisture Depletion Level

2.3. Experimental Procedure and Management Practice

The plot size was 3m wide and 3m long. Spacing between row and plant was 30cm and 10cm respectively. Distance between plot 2m and distance between replication was 4m.

Crop water requirement was calculating using CropWat program based on FAO penman-monteith method. Irrigation scheduling was done based on soil water depletion replenishment using CropWat program. Furrow irrigation method was used and the amount of water applied was measured with parshall flume.

Depending on the local transplanting date of onion, the selected verity of onion (Bombay-red**)** was transplanted on December 10th in 2010 and 2011 E.C. in *Mandura* wereda in *Diwazin Baguna* irrigation scheme.

2.4. Data Descriptions and Input Parameters

2.4.1. Long Term Climatic Data

Long-term climatic data for the study area were obtained from the Pawe Agricultural Research Center and Mandura district metrology station. The parameters chosen for this analysis included rainfall measured in millimeters, maximum and minimum temperatures recorded in degrees Celsius, relative humidity expressed as a percentage, wind speed quantified in kilometers per day, and sunshine duration indicated in hours.

Then monthly reference-evapotranspiration (ETo) in millimeter per day of the study area including effective rain fall (pe) in millimeter and Solar radiation (SR) in Mega Joule Per Square meter per day, were estimated by CROPWAT 8 software.

2.4.2. Analyzed Soil Data

Composite disturbed soil samples had been collected at five soil depths (0-15 cm, 15-30 cm, 30-60 cm), from experimental site for texture and Particle size distribution was measured in the laboratory by the modified Bouyoucos hydrometer method [17].

Soil-plant air-water (SPAW) determined field capacity (FC), permanent wilting point (PWP), and total available water (TAW), which are dependent on soil textural class. Using the double ring infiltrometer, the maximum rooting depth (m), the initial soil moisture depletion (%), the initially available soil moisture (mm), and the total available soil moisture (mm/m), the maximum rain infiltration rate (mm/day) of the experimental site was calculated.

2.4.3. Crop Characteristics Data

Inputs for CropWat were gathered from onion characteristics, including growth stages, maximum rooting depth, and crop coefficient, critical depletion in fraction, yield response factor, and crop height.

2.5. Crop and Irrigation Water Requirement and Irrigation Scheduling

2.5.1. Crop and Irrigation Water Requirement

Crop water and irrigation water requirements of onion had been calculated using CropWat model by considering equation (1, and 2).

$$CWR = ETo \times Kc \quad (1)$$

$$IR = CWR - \text{Effective rainfall} \quad (2)$$

In this context, CWR represents the crop water requirement measured in millimeters per day, while Kc is a dimensionless coefficient that serves as an empirical ratio of the actual water usage by crops to the reference evapo-transpiration. The Kc values were sourced from established literature, specifically FAO Irrigation and Drainage Papers No. 33 and 56. For this analysis, the CWR was calculated utilizing the Penman-Monteith method [16] through computer-based CropWat models, with IR denoting the irrigation requirement in millimeters.

Effective rainfall refers to the portion of rainfall that infiltrates the soil and becomes accessible for crop growth, also measured in millimeters. Various formulas exist for calculating effective rainfall within the CropWat model; however, this study employed equations (3) and (4) as they were formulated based on analyses of diverse arid and sub-humid climates [1].

$$Pe = [P \times (125 - 0.2 \times 3 \times P)] / 125; \text{ for } P < 250/3 \quad (3)$$

$$Pe = 125 / 3 + 0.1P; \text{ for } P > 250 \quad (4)$$

In these equations, Pe denotes effective precipitation in millimeters, while P signifies the total precipitation recorded during the crop growing season in the specified area, also in millimeters.

$$TAW = (FC - PWP) \times BD \times Rd \times 10 \quad (5)$$

$$ASMDL = PxTAW \quad (6)$$

In these equations, TAW represents the total available soil moisture measured in millimeters per meter (mm/m); FC denotes the field capacity of the soil expressed as a percentage of weight bases (%); PWP indicates the permanent wilting point of the soil, also in percentage of weight bases (%); BD refers to bulk density measured in grams per cubic centimeter (g/cm^3); Rd signifies root depth in meters (m); ASMDL stands for the available soil moisture depletion level or net irrigation requirement measured in millimeters (mm); and P represents the allowable soil moisture depletion for the crop, quantified as 0.25.

2.5.2. Irrigation Scheduling Using CropWat Model

Irrigation scheduling was worked out using CropWat 8.0 windows by irrigating at critical depletion time criteria and applies at refile to field capacity depth criteria.

The interval for irrigation water application was calculated utilizing the CropWat model, taking into account equation 7. Additionally, the total volume of water required for application to the field was established based on 60% irrigation efficiency, as reported by [18].

$$\text{Interval(days)} = \frac{NIR}{ETC} \quad (7)$$

$$GIR = \frac{NIR}{Ea} \quad (8)$$

NIR represents the Net Irrigation Requirement or ASMDL (in millimeters), ETc denotes Crop Evapo-transpiration (in millimeters per day), GIR indicates the gross volume of water (in millimeters), and Ea refers to the irrigation application efficiency, which is set at 60%.

2.6. Irrigation Water Productivity

Irrigation water productivity was determined utilizing equation (9) and subsequently analyzed with SAS software.

$$IWP = BY/IWR \quad (9)$$

Where: IWP represents irrigation water productivity (kg/m^3), indicating the quantity of onion bulb grain yield per cubic meter of irrigation water utilized, BY denotes the bulb yield of onion (kg/ha), and IWR signifies the total water required (m^3/ha).

2.7. Yield and Yield Related Data

During the implementation period yield and yield related parameters were collected following the data sheet including, stand count at harvesting, average plant Height, bulb diameter, biomass yield and bulb yield explained as follows:

1) Stand count at harvest: Total number of plants in harvestable row during harvesting at maturity.
2) Average plant height (cm): A measuring tape was used to measure the height of five randomly chosen plants in the experimental plot at physiological maturity, starting from ground level and ending at the tip of the leaf.
3) Bulb diameter (cm): Using an automatic caliper, the width of the bulbs of five sample plants in each experimental plot was measured at their widest points.
4) Total biomass yield (q/ha): Total weight of bulbs including leaves.
5) Total bulb yield (q/ha): The total weight of healthy bulbs produced by every plant in the central three double or six single harvestable rows per plot was used to calculate the total bulb yield.

2.8. Data Analysis

Result of Yield and yield components data and water productivity data were analyzed statistically using R software. All collected data were analyzed and compared with least square differences (LSD) and when the treatments mean difference was tested using LSD test at 95%.

3. Results and Discussion

3.1. Climate Characteristics of the Study Area

The study area's long-term climate data were examined, and reference evapotranspiration (ETo) was computed using CropWat model as given in the following tables.

Table 2. Long term monthly climate and analysis ETO data of Mandura district.

Month	Min.T. (°C)	Max.T. (°C)	R.H. (%)	W.S. (km/day)	Sun (h)	S.R. ($MJ/M^2/day$)	Eto (mm/day)
January	15.3	33.0	33	156	8.1	19.0	5.10
February	18.5	34.9	33	164	7.0	18.7	5.56

Month	Min.T. (°C)	Max.T. (°C)	R.H. (%)	W.S. (km/day)	Sun (h)	S.R. (MJ/M^2/day)	Eto (mm/day)
March	19.8	36.5	24	181	7.6	20.8	6.60
April	21.3	35.7	34	164	6.9	20.2	6.17
May	20.4	31.5	61	138	6.5	19.2	4.85
June	19.0	27.7	78	112	7.0	19.7	4.12
July	18.1	24.7	87	121	6.0	18.3	3.49
August	17.7	24.2	88	121	4.9	16.9	3.18
September	18.2	26.5	84	104	6.3	18.8	3.65
October	18.1	27.7	77	95	6.5	18.2	3.68
November	16.5	28.4	66	95	7.7	18.7	3.77
December	15.5	30.3	54	104	7.9	18.2	3.92
Average	18.2	30.1	60	130	6.9	18.9	4.51

As indicated in Table 2, the reference evapotranspiration was found to be 3.18 mm/day in August at the lowest and 6.6 mm/day in March at the highest. The annual mean long term reference evapotranspiration was 4.51mm/day.

3.2. Analyzed Soil Characteristics of the Study Areas

Table 3. Soil sample analysis in Mandura district.

Depths(cm)	Sand (%)	Silt (%)	Clay (%)	TAW (mm/m)	PWP (vol%)	FC (vol%)
0-15	38	24	38	127	23.5	36.2
15-30	36	26	38	129	23.5	36.4
30-60	40	26	34	128	21.3	34.1
ATASM (mm/m)				128		

* ATASM=Average total available soil moisture

As shown in Table 3, up to maximum root depth of onion(0-60cm), the PWP on a volume basis in mandura district ranges from 21.3% to 23.5%, and FC ranges from 34.1% to 36.4% and the average total available soil moisture was 128 mm/m.

3.3. Characteristics of Onion Used as Input

The FAO suggested values for onion growth stages are used to calculate CWR and make irrigation schedules because the crop coefficient, rooting depth, critical depletion, and yield response factor have not yet been identified for this location. The calculation had been based on the crops' planting date.

Table 4. Characteristics of onion used as input for CropWa.

Characteristics	Growing Stages				
	Initial	Developments	Mid	Late	Total
Kc Values	0.5	0.7-0.8	1.15	0.99	
Stages (day)	20	25	35	20	100

Characteristics	Growing Stages				
	Initial	Developments	Mid	Late	Total
Root depth (m)	0.4	-	0.6		
Critical depletion	0.3	-	0.45	0.5	-
Yield Response factor	0.9	1	1.3	1.2	
Crop Height (m)			0.4m (optional)		

**Source (FAO, 1998)

3.4. Irrigation Water Requirements of Onion

In the study, the transplanting date of onions was December 10 for both cropping seasons, and CROPWAT 8 was utilized to estimate the crop water demand (CWR) and irrigation schedule of onions. The seasonal water requirements and irrigation requirements were equal (566.2mm) since there was no rainfall and effective rain was zero during the growing season. Refill to field capacity depth requirements and critical depletion time criteria were used to establish irrigation timing.

The seasonal net irrigation water requirements for onions in the research area were, thus, 546.5 mm, 546.5 mm, 528.2 mm, 526.9 mm, and 508.2 mm for 60% ASMDL, 80% ASMDL, 100% ASMDL, 120% ASMDL, and 140% ASMDL, respectively.

Table 5. Irrigation events and applied irrigation depths during the cropping season.

Treatments	IF (days)	NIR depth (mm)	GIR depth (mm)	AII (days)
60%ASMDL	28	546.5	912.1	3.57
80%ASMDL	22	559.7	933.1	4.55
ASMDL (control)	17	528.2	880	5.88
120%ASMDL	14	526.9	878.2	7.14
140%ASMDL	12	508.2	847.2	8.33

*IF=irrigation frequency, NIR=net irrigation requirements, GIS=gross irrigation requirements, AII=Average irrigation interval.

Relatively height and low Gross and net amount of irrigation water applied at 80%ASMDL and 140%ASMDL. Depending on the stages of growth and the degree of soil moisture loss, different watering times were used.

Onion Yield and Yield Components

Table 6. Onion Yield and Yield Components combined results in Mandura wereda.

Treatments	SC/ha	Aph (c.m)	Tbmy(q/ha)	Tbuy(q/ha)	Abd (c.m))
60%ASML	241805.7^{a}	43.98^{ab}	273.83^{a}	211.65^{a}	5.93^{a}
80%AMDL	253796.5^{a}	47.38^{a}	263.33^{ab}	210.85^{a}	5.26^{ab}
AMDL (control)	244305.7^{a}	48.41^{a}	246.29^{abc}	191.89^{a}	5.10^{ab}
120%ASMDL	242222.2^{a}	41.5^{b}	232.08^{bc}	188.18^{ab}	4.87^{b}
140%ASMDL	245324.2^{a}	44.26^{ab}	217.5^{c}	157.42^{b}	4.93^{ab}
CV (%)	4.58	9.44	13.83	14.42	16.26

Treatments	SC/ha	Aph (c.m)	Tbmy(q/ha)	Tbuy(q/ha)	Abd (c.m))
LSD (@5%)	Ns	5.21	41.75	33.89	1.04

*At P < 0.05, means that are followed by the same letter are not significantly different from those that are followed by different letters in a column. CV (%) is the coefficient of variation expressed as a percentage, and LSD stands for least significant difference. NS=No significant difference, Aph (cm)=Average plant height in centimeter, Tbmy (q/ha) = Total biomass yield in quintal per hectare. Tbuy (q/ha) =Total bulb yield in quintal per hectare, Abb=Average bulb diameter in centimeter, IWP (kg/m^3/ha) =irrigation water productivity in kilogram pee meter cube per hectare.

As shown in table 6, there were no a significant different at (p<0.05) among irrigation treatments on stand count at harvest of onion. The highest stand recorded on treatment at available moisture depletion level (80%AMDL) that was 253796.5 and the lowest stand recoded on treatment at available moisture depletion level (60%AMDL) that was 241805.7.

There was significant effect at (p<0.05) among irrigation treatments on average heights of onion, total biomass yield, total bulb yield and average bulb diameter. The highest average plant height was obtained from treatment which received FAO recommended ASMDL (48.41c.m) and the lowest recorded at treatment 120% ASMDL (41.5c.m). The highest total biomass yield obtained at 60% ASMDL that was 273.83 q/ha followed by 80% and 100% FAO recommended ASMDL with the result of 263.33q/ha and 246.29q /ha respectively.

The highest total bulb yield obtained at 60% ASMDL that was 211.65 q/ha followed by 80% and 100% FAO recommended ASMDL with the result of 210.85q/ha and 191.89q and 188.18q/ha respectively without any significant difference. The bulb yield advantage of 60%ASMDL over 80%, 100% and 120% ASMDL were 0.8, 19.76, 23.47q/ha respectively. The lowest bulb yield obtained at 140%ASMDL that was 157.42q/ha and it was statistically differ from the others. The bulb yield advantage of 80%ASMDL over 100% and 120% ASMDL were 18.96 q/ha and 22.67 q/ha respectively. From the result at 60%ASMDL and at 80%ASMDL, almost similar bulb yield results obtained and they are best. With no significant difference between these treatments, the largest bulb diameter was achieved at 60%, 80%, 100%, and 140% of the available soil moisture depletion levels with the result of 5.93c.m, 5.26 c.m, 5.10 c.m and 4.93c.m respectively. The lowest bulb yield obtained at 120% ASMDL (4.87 c.m).

The selected treatments with height bulb yield and irrigation water productivity result were in agreement with the finding of [19] that states the highest marketable bulb yield (363.9 qt/ha) and efficiency of water use on marketable onion yield (9.487 kg/m^3) at Odo Shakiso District, Guji zone Odo Shakiso District, Guji zone recorded at 60%ASMDL. Therefore, based on the experimental finding, they proposed that using 60%ASMDL under furrow irrigation system for onion to be cultivated in areas surrounding Shakiso and similar agro-ecology as optimal solutions to boost yield and water use efficiency for the production of onion.

Around fogera at 80% available soil moisture depletion levels, the highest marketable bulb yield and water productivity (35222.2 kg/ha and 7.06 kg/m3) were observed. These results were suggested for similar agro ecology as the best options to increase yield and water use efficiency for onion production using furrow irrigation systems [20]. At 60% of the available soil moisture depletion level, Assossa achieved the maximum bulb production of 139.58qt/ha and the highest water use efficiency of 45.81kg/ha-mm [21].

Ethiopia produces onion in low production than the global and African averages, though. The average yield tons per hectare for the world, Europe, Asia, America, Africa, and Ethiopia are 17.05, 15.7, 20.64, 10.47, 12.14, and 10, respectively, According to [22], 9.6 tons of onion bulbs are produced nationwide per hectare Even though onions are quickly overtaking other vegetables as the most popular vegetable among Ethiopian producers and consumers, the current level of production is not keeping up with the nation's demand. Its productivity is also far below the level realized at global level 19.5 t ha-1 [12].

3.5. Irrigation Water Productivity

Table 7. Combined Irrigation water productivity.

Treatments	IWP (kg/m^3/ha)
60%ASML	3.87^{a}
80%AMDL	3.77^{a}
AMDL (control)	3.63^{ab}
120%AML	3.37^{ab}
140%AML	3.08^{b}
CV (%)	14.45
LSD (@5%)	0.63

*In a column, means that are followed by different letters differ significantly, while means that are followed by the same letter do not differ significantly at P < 0.05. Productivity of irrigation water is known as IWP.

As shown in Table 7, there were a significant effect @

($p<0.05$) among irrigation treatments on irrigation water productivity of onion. The highest irrigation water productivity of onion to convert irrigation water to bulb yield were obtained 60% ASMDL) which had 3.87kg/m^3/ha followed by 80%, 100% FAO recommended ASMDL and 120%ASMDL with the values of 3.77, 3.63 and 3.37 kg/m^3/ha respectively without any significant difference. However; the minimum irrigation water productivity was 3.08kg/m^3 that obtained at 140% ASMDL and less with significant difference relative to the others.

4. Conclusion and Recommendations

4.1. Conclusion

This study demonstrated that both bulb yield and irrigation water productivity increased when the allowable soil moisture depletion level was lowered below the FAO-recommended level. Onion bulb output and irrigation water productivity were both greatly impacted by a 40% reduction in ASMDL from the optimum level. For the chosen treatments, the average irrigation interval was around 4, 5, 6, 7, and 8 days. Onion productivity reacts differentially to the application of varying percentages of ASMDL. 60% ASMDL provided the highest irrigation productivity and bulb yield based on the total results of the two years.

The highest total bulb yield obtained under 60% ASMDL that was 211.65 q/ha followed by 80%, 100% FAO recommended ASMDL and 120%ASMDL with the result of 210.85q/ha and 191.89q and 188.18q/ha respectively without any statistical difference The highest irrigation water productivity was obtained under 60% ASMDL) which had 3.87kg/m^3/ha followed by 80%, 100% FAO recommended ASMDL and 120%ASMDL with the result of *3.77, 3.63* and 3.37 kg/m^3/ha respectively without any statistical difference.

4.2. Recommendations

According to the results of the current experiment, the best ways to boost onion bulb output and irrigation water productivity are to use 60%ASMDL for furrow irrigation systems for onion cultivation in regions surrounding Mandaura District and comparable agro-ecology. Although it is advised to utilize irrigation intervals based on growth stages to get the best onion bulb production and irrigation water use efficiency, the results showed that an average irrigation interval of 4 days (60%ASMDL) was necessary. The experiment was conducted at clay loam soil texture with 128mm/m total available water; therefore, the experiments should be tested at different soil textural class.

Abbreviations

ASMDL	Available Soil Moisture Depletion Level
FAO	Food and Agricultural Organization
q/ha	Quintal
ha	Hectare
kg	Kilogram
m^3	Meter Cub
DAP	Di-ammonium Phosphate
N	Nitrogen
c°	Degree Centigrade
m.a.s.l	Meter Above Sea Level
E.C.	Ethiopian Colander
MAD	Management Allowable Depletion
P	Recommended Allowable Soil Moisture Depletion
m	Meter
c.m	Centimeter
SPAW	Soil-plant Air-water
FC	Field Capacity
PWP	Permanent Welting Point
mm	Millimeter
Eto	Reference-evapotranspiration
TAW	Total Available Water
CWR	Crop Water Requirement
SR	Solar Radiation
Pe	Effective Rain Fall
Kc	Crop Coefficient
IR	Irrigation Requirement
P	Total Precipitation
BD	Bulk Density
Rd	Rooting Depth
NIR	Net Irrigation Requirement
GIR	Gross Irrigation Requirements
Ea	Irrigation Application efficiency
BY	Bulb Yield of Onion
IWR	Total Water Required
CV	Coefficient of Variation
LSD	Least Significant Difference
IWP.	Irrigation Water Productivity
NS	No Significant Difference
Aph	Average Plant Height
Tbmy	Total Biomass Yield
Tbuy	Total Bulb Yield
Abd	Average Bulb Diameter
IF	Irrigation Frequency
AII	Average Irrigation Interval
Min.T.	Minimum Temperature
Max.T.	Maximum Temperature
R.H.	Relative Humidity
W.S.	Wind Speed
Sun	Sunshine

Acknowledgments

The Ethiopian Institute of Agricultural Research provided financial support and technical assistance for the experiment's execution, for which the authors are thankful. The authors also express their gratitude to the entire personnel of the Soil and Water Management Research process at Pawe Agricultural Research Center for providing technical assistance and field management support throughout the experiment's investigation.

Conflicts of Interest

The authors declare no conflicts of interest.

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