

Research Article

Effect of Drip and Furrow Irrigation Methods on Yield and Water Productivity of Onion In East Shewa, Oromia, Ethiopia

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Abstract

Water scarcity in the Central Rift Valley of Ethiopia severely constrains crop production, necessitating efficient irrigation methods. This study evaluated the performance of drip and furrow irrigation for onion production in a 2018 field experiment in Adama district, using a randomized complete block design with three replications. Irrigation method significantly ($p < 0.05$) influenced leaf number, bulb diameter, total and marketable bulb yield, and water productivity. Drip irrigation markedly outperformed furrow irrigation, achieving a total bulb yield of 40.76 t/ha and marketable yield of 37.39 t/ha compared to 37.14 t/ha and 34.05 t/ha, respectively, under furrow irrigation. The bulb diameter under drip irrigation was marginally greater, measuring 5.72 cm compared to 5.70 cm for furrow irrigation. This slight increase reflects the enhanced water efficiency associated with drip irrigation, contributing to marginally larger bulb size. Most notably, water productivity under drip irrigation (12.48 kg/m³) was substantially higher than that under furrow irrigation (7.45 kg/m³), demonstrating greater efficiency in water use. These results indicate that drip irrigation not only increases onion yield but also significantly enhances water productivity, making it a sustainable and water-saving irrigation strategy in this water-limited area. Adoption of drip irrigation could improve crop water use efficiency and contribute to better resource management in the region, addressing critical water scarcity challenges while boosting agricultural productivity.

Keywords

Irrigation Methods, Water Management, Water Saving, Water Productivity

1. Introduction

Water stands as one of the most indispensable and adaptable natural resources, particularly vital in agriculture for irrigation purposes. Irrigation involves the deliberate delivery of water to the soil to ensure sufficient moisture reaches the plant roots. This practice is essential for avoiding water stress, which can negatively impact crop yield and quality. By supplementing inconsistent or inadequate rainfall,

irrigation helps maintain optimal plant growth and enhances agricultural productivity [19].

Irrigated agriculture accounts for the highest water consumption compared to other sectors, creating competition with industrial and domestic demands for increasingly scarce water supplies. As the global population continues to rise and water resources dwindle, securing food for the future becomes

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a pressing concern. One key solution is to boost crop water productivity (CWP), which involves producing more food with less water. This can be achieved either by sustaining current yield levels while reducing water use or by increasing output without raising water consumption ultimately freeing up water for other essential uses [15].

Irrigation development in Ethiopia is advancing rapidly more than ever before. Expanding irrigated areas alongside efficient water management is crucial for achieving the country's goals of food security and poverty reduction. Despite Ethiopia's abundant water resource potential, the uneven distribution across regions and seasons, combined with limited infrastructure capacity, remains a major challenge that restricts the full socioeconomic benefits of water resources. Addressing these challenges through effective planning and management is essential to unlock the irrigation sector's potential for sustainable development [16].

In Ethiopia's Central Rift Valley, a semi-arid zone with scarce water resources, irrigation plays a vital role in supporting intensive agricultural activities, especially vegetable farming. Due to rising water demand and elevated evapotranspiration rates, it is crucial to identify strategies that enhance the efficient use of existing water supplies. Consequently, improving water use efficiency and maximizing crop output per unit of water are key priorities for promoting sustainable agricultural development in the region [20].

Onion ranks among the most significant vegetable crops grown commercially across the globe [5]. Globally, onions are grown on over 3.6 million hectares, producing approximately 80 million metric tons annually [13]. Onion farming is extensively carried out by Ethiopian farmers, serving as a major income-generating activity. According to [9], onion cultivation covered approximately 24,375.7 hectares in Ethiopia, yielding an average of 9.02 tons per hectare and producing over 2.2 million tons in total. In the Central Rift Valley, farmers mainly rely on furrow irrigation; a conventional surface method characterized by relatively low water-use efficiency. Achieving optimal onion yields with furrow irrigation relies on the precise and sufficient delivery of water, given the crop's shallow root system and high sensitivity to water stress. To prevent reductions in yield, onions generally require frequent, light irrigation applications [11].

Improving on-farm water use efficiency and water productivity can be achieved by adopting more efficient

irrigation systems. Both sprinkler and drip irrigation methods reduce non-effective water losses [1]. Modernizing and optimizing irrigation systems plays a crucial role in increasing water productivity [18]. Among these, drip irrigation stands out as one of the most efficient technologies currently available. It conserves water while boosting crop yields, especially beneficial for farmers in semi-arid regions or areas with escalating competition for water resources. Drip irrigation offers several advantages over furrow irrigation, including significant water savings, reduced labor requirements, minimized soil erosion, and enhanced crop productivity.

Enhancing water use efficiency and productivity at the farm level can be effectively achieved through the adoption of advanced irrigation technologies. Sprinkler and drip irrigation systems are particularly effective in minimizing non-beneficial water losses [2]. Upgrading and fine-tuning irrigation infrastructure is vital for improving water productivity [18]. Among these technologies, drip irrigation is recognized as one of the most efficient options available. It not only conserves water but also increases crop yields, making it especially valuable for farmers in semi-arid regions or areas facing growing water scarcity. Compared to traditional furrow irrigation, drip systems offer notable benefits such as substantial water savings, lower labor demands, reduced soil erosion, and improved agricultural output.

Therefore this research focused on assessing how furrow and drip irrigation techniques influence onion yield, its contributing factors, and water use efficiency.

2. Materials and Methods

The study was conducted in 2018, at Melkasa Agricultural Research Center, situated in Adama Woreda of the Oromia Regional State, within Ethiopia's Central Rift Valley. The center is positioned at approximately 8°24' N latitude and 39°21' E longitude, with an elevation of around 1,550 meters above sea level. The region experiences an average annual rainfall of 825 mm, and typical temperatures range from a minimum of 13.8°C to a maximum of 28.7°C. Located roughly 107 kilometers southeast of Addis Ababa and 17 kilometers from Adama town, Melkasa serves as a prominent hub for agricultural research in the area.

Table 1. Monthly climate data for the long-term period of 1977 to 2017 from MARC.

Month	Tmin (°C)	Tmax (°C)	RH (%)	U ₂ (m/s)	n (hr)	RF (mm)	ETo (mm/day)
January	11.71	27.93	51.04	8.59	9.05	16.02	6.30
February	13.42	29.12	48.74	9.08	9.17	24.05	7.14
March	15.06	30.47	49.21	8.63	8.52	52.31	7.47

Month	Tmin (°C)	Tmax (°C)	RH (%)	U ₂ (m/s)	n (hr)	RF (mm)	ET _o (mm/day)
April	15.47	30.49	50.76	7.84	8.23	53.88	7.20
May	15.54	31.00	51.17	7.46	8.76	61.03	7.13
June	16.37	30.19	53.11	9.00	8.36	69.01	7.25
July	15.67	26.85	66.36	9.07	7.03	204.21	5.39
August	15.36	26.31	69.20	6.97	7.07	183.07	4.87
September	14.47	27.62	65.76	4.88	7.32	99.75	4.90
October	11.68	28.76	50.02	6.58	8.66	39.35	6.22
November	10.76	28.33	46.67	8.26	9.60	12.64	6.63
December	10.37	27.55	48.76	8.87	9.47	9.60	6.33
Average	13.82	28.72	54.23	7.94	8.44	68.74	6.40

Source: Melkasa Agricultural Research Center meteorological station.

2.1. Treatments and Design

The study incorporated two types of irrigation techniques: traditional furrow irrigation (FI) and modern drip irrigation (DI). It was arranged in a randomized complete block design (RCBD) with three replications. Each experimental plot measured 3.6 m by 4 m, accommodating five furrows spaced 60 cm apart. A buffer zone of 1 m was maintained between plots, and 1.5 m between blocks to prevent interference.

2.2. Installation of Drip Irrigation System

To ensure consistent water distribution across all plots, the drip irrigation system was carefully engineered and installed with pressure regulation maintained at the plot endpoints. Each plot featured five drip laterals, each measuring 4 meters in length and spaced 60 cm apart. Emitters were positioned every 20 cm along the laterals, delivering water at a rate of 2 liters per hour. The drip lines, 16 mm in diameter, were placed centrally between crop rows spaced 20 cm apart. Water was gravity-fed from a storage tank elevated 2 meters above ground level. The system included 32 mm mainline and 25 mm sub-mainline pipes, which connected the tank to the drip laterals. A gate valve near the filtration unit on the mainline enabled precise control of water flow to each plot.

2.3. Crop Establishment and Agronomic Management Strategies

The onion variety used for the experiment was Nafis (*Allium cepa* L.). Seeds were initially sown in carefully prepared nursery beds and the seedlings were transplanted into well-structured experimental plots. Transplanting was carried out on both sides of the ridges, maintaining a spacing of 20 cm between rows and 10 cm between plants. Each plot

contained 10 rows, with a total of 400 plants per plot. To ensure successful establishment, irrigation was applied consistently for the first 10 days following transplanting.

Weeding and cultivation were carried out manually using hand hoes as needed throughout the growing period. Fertilization was uniformly applied across all plots with 200 kg/ha of diammonium phosphate (DAP) at planting and 100 kg/ha of urea split into two applications [17]. Pesticides and fungicides Selecron and Redomil Gold were applied at their recommended rates to protect the crop from insect pests and fungal infections. The crop growth was classified into four FAO-recommended stages: initial (20 days), crop development (25 days), mid-season (45 days), and late season (20 days).

2.4. Irrigation Scheduling and Water Management

Crop water demand

Reference evapotranspiration (ET_o) was calculated with the FAO Penman-Monteith procedure, a standardized method that relies on meteorological inputs. Seasonal crop water use (ET_c) was obtained by multiplying daily ET_o values by the crop coefficient (K_c). The K_c values applied were 0.5 during the initial stage, 1.05 at mid-season, and 0.85 at the end stage. K_c values for the developmental and late-season periods were derived graphically following [2] guidelines.

$$ET_c = K_c \times ET_o \quad (1)$$

Where ET_c = crop evapotranspiration in millimeters per day, ET_o = reference evapotranspiration in millimeters per day, K_c = crop coefficient.

Irrigation water supply Soil water measurement and conversion

Soil water in the experiment was determined by regular

gravimetric soil moisture sampling. Samples were taken with an auger immediately before and after irrigation, weighed wet, oven-dried at 105 °C for 24 hours to obtain dry weight, and the gravimetric water content was converted to an equivalent depth (D) using the equation below.

$$D = \left(\frac{W_w - W_d}{W_d} \right) * BD * drz \quad (2)$$

where; D = depth of available soil moisture (mm), W_w = wet soil weight (g), W_d = dry soil weight (g), BD = soil dry bulk density (g/cm^3) and drz = sampling depth within the crop root zone (mm)

The soil moisture depleted between irrigation was obtained from:

$$dn = Fc - D \quad (3)$$

where: dn denotes the net irrigation requirement in millimeters and FC denotes the soil moisture at field capacity in millimeters.

Irrigation scheduling procedures

Total available water (TAW) was calculated from the soil moisture at field capacity and at the permanent wilting point using the equation given by [2].

$$TAW = (FC - PWP) * BD * D_z \quad (4)$$

Where; TAW is the total available water in the root zone measured in millimeters; FC and PWP are the soil moisture at field capacity and at permanent wilting point given as percentages; D_z is the maximum effective root depth of onion at irrigation times measured in millimeters.

Irrigation timing for optimal yield was set according to the management allowed depletion (MAD). MAD guided irrigation decisions, with water applied when the soil water deficit reached or neared the MAD threshold to prevent crop water stress. For onion, MAD was taken as 25% ($\rho = 0.25$) of the total available soil moisture [11]. Readily available water (RAW) was calculated using the expression below.

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

where: RAW (mm) denotes readily available water, ρ denotes the permissible depletion fraction of soil moisture, and TAW (mm) denotes total available water.

Irrigation frequency, defined as how often water is applied to a crop during a specific growth stage, was determined using the equation from [10].

$$f = \frac{RAW}{ETc} \quad (6)$$

Where: f is the irrigation frequency in days, RAW is readily available water in millimeters, and ETc is crop evapotranspiration in millimeters.

The net irrigation depth applied at any moment was

calculated using a simplified water-balance equation.

$$I_n = ETc - P_{eff} \quad (7)$$

Where: I_n is the net irrigation depth in millimeters, ETc is crop evapotranspiration in millimeters, and P_{eff} is effective rainfall in millimeters.

Effective rainfall was calculated with the dependable-rainfall FAO method implemented in the CROPWAT software.

$$P_{eff} = 0.6 \times P - 10 \text{ for month} \leq 70 \text{ mm} \quad (8)$$

$$P_{eff} = 0.8 \times P - 24 \text{ for month} > 70 \text{ mm} \quad (9)$$

where: P is rainfall in millimeters and P_{eff} is effective rainfall in millimeters.

Gross irrigation requirement was calculated assuming field application efficiencies of 60% for furrow irrigation and 90% for drip irrigation [8].

$$I_g = \frac{I_n}{E_a} \quad (10)$$

Where I_g = gross irrigation depth in millimeters, I_n = net irrigation depth in millimeters and E_a = application efficiency (unit less fraction or percentage)

A 3-inch Parshall flume was used to measure discharge for furrow irrigation; the required application time to supply the specified depth to each plot was then calculated using the formula given.

$$T = \frac{A \times I_g}{6 \times q} \quad (11)$$

Where: T = application time in minutes, I_g = gross irrigation depth in mm, A = plot area in m^2 ; q = flow rate at the Parshall flume in L/s

Under drip irrigation, the gross depth of water applied (I_g) was determined from the expression:

$$I_g = \frac{I_n \times Wa}{E_a} \quad (12)$$

Where: I_g is the gross irrigation requirement in millimeters, wa is the wetting area as a percentage, I_n is the net irrigation depth in millimeters, and E_a is the drip irrigation application efficiency as a percentage.

The time necessary to apply the intended depth of water via drip to each plot was obtained from:

$$T = \frac{I_g \times A}{Nl \times Ne \times q} \quad (13)$$

Where: T is the irrigation time in hours, A is the plot area in square meters, Nl is the number of laterals, Ne is the number of emitters per lateral, and q is the emitter discharge in liters per hour.

2.5. Data Collection

Climatic data

Daily climate records-rainfall, temperature, relative humidity, sunshine duration, and wind speed-were collected from the Melkasa Agricultural Research Center (MARC) meteorological station. These observations were input into CROPWAT 8.0 to calculate reference evapotranspiration (ET_o) and effective rainfall, enabling precise estimation of crop water needs over the growing season.

Soil data

Representative soil samples were taken to characterize properties such as moisture at field capacity and permanent wilting point, bulk density, organic matter, texture, electrical conductivity, and pH across the study area. Sampling was done in 15 cm increments down to the effective onion root depth, assumed to be 50 cm. All soil tests were performed at the Oromia Water Works Design and Supervision Enterprise Laboratory. Prior to starting the experiment, infiltration rates were measured using a double ring infiltrometer.

Soil bulk density (ρ_b) was measured by collecting undisturbed soil samples using a core sampler of known volume. The soil cores were oven-dried at 105 °C for 24 hours to remove moisture. Bulk density was calculated by dividing the oven-dried soil mass by the volume of the core sampler, following the method described by [4].

$$\rho_b = \frac{M_s}{V_b} \quad (14)$$

where: M_s is the oven-dry soil mass in grams and V_b is the soil bulk volume in cubic centimeters; bulk density is in g/cm³.

Common Drip uniformity parameters and definitions

The drip irrigation system's performance was evaluated using standard metrics such as distribution uniformity and the coefficient of uniformity.

Distribution uniformity (Du)

Distribution Uniformity is the ratio between the mean discharge of the quarter of the system that receives the least water and the mean discharge of the whole system, and it indicates the expected variation in emitter flow along a lateral. It was estimated by:

$$DU = \frac{\bar{q}_{\text{lowest } 25\%}}{\bar{q}} \times 100 \quad (15)$$

Coefficient of uniformity (CU)

Also called Christiansen's uniformity coefficient, it is defined as the average amount applied minus the mean absolute deviation from that amount, divided by the average amount applied. Mathematically, it is expressed as:

$$CU = \left(1 - \left(\frac{\sum |q_i - \bar{q}|}{n\bar{q}} \right) \right) \times 100 \quad (16)$$

Where: q_i denotes the discharge of an individual dripper, $\bar{q}$ is the mean discharge, and n represents the total number of drippers.

Agronomic data

Agronomic measurements, such as plant height and leaf count per plant, were taken from five randomly chosen, tagged plants located in the central rows of each plot, omitting border rows and plants. Plant height was recorded from the soil surface to the tip of the main stem leaf with a ruler, and all fully expanded leaves were counted. Leaf length was measured on the same plants from the leaf base to the tip. Yield traits-bulb height, bulb diameter, and bulb weight-were also measured on these plants. Yield increase attributable to drip irrigation was computed using the formula given by [21].

$$\text{Increase in yield} = \left(\frac{Y_1 - Y_2}{Y_1} \right) \times 100 \quad (17)$$

Where Y_1 is the yield under drip irrigation and Y_2 is the yield under furrow irrigation, both measured in kg/ha.

Water productivity (WP)

Water productivity was determined by dividing the total onion bulb yield by the volume of irrigation water applied to the crop, following [14].

$$WP = \frac{Y}{ET_c} \quad (18)$$

where: WP denotes water productivity in kg/m³, Y is the total bulb yield per unit area in kg/ha, and ET_c represents crop evapotranspiration in mm.

Water saved

Water saved by the drip system relative to the furrow system was calculated as follows:

$$W_s = \frac{W_f - W_d}{W_f} \times 100 \quad (19)$$

Where W_s is the water saved expressed as a percentage, W_f is the total water used under furrow irrigation, and W_d is the total water used under drip irrigation, both in m³/ha.

2.6. Data Analysis

The collected data were analyzed using analysis of variance (ANOVA) with SAS 9.0 software. When significant treatment effects were detected, mean comparisons among treatments were conducted using the least significant difference (LSD) method.

3. Results and Discussions

3.1. Soil Physical and Chemical Characteristics of the Study Site

Table 2 displays particle size distribution data for soils at

the experimental site across various depths. The percentage composition shows the soils are mainly loam.

Table 2. Summarized soil particle size distribution.

Soil depth (cm)	% Particle size distribution			Textural class
	Sand (%) (2-0.05)	Silt (%) (0.05-0.002)	Clay (%) (<0.002)	
0-15	36	38	26	Loam
15-30	30	44	26	Loam
30-45	36	40	24	Loam
45-60	34	36	30	Clay loam
Average	34	39.5	26.5	Loam

Source: [3]

Soil bulk density varied with depth (Table 3), ranging from 1.09 to 1.23 g/cm³; topsoil values were generally lower than subsurface values, likely reflecting compaction at depth. The

weighted average bulk density at the experimental station was 1.14 g/cm³.

Table 3. Soil moisture characteristics and bulk density for the study location.

Sampling depth (cm)	Bulk density (gcm ⁻³)	FC (% wt.)	PWP (%wt.)	TAW (mm/m)
0-15	1.09	35.5	20.6	162.4
15-30	1.12	37	21.2	177.0
30-45	1.12	39	21.8	192.6
45-60	1.23	39.9	22.8	210.3
Mean	1.14	37.8	21.6	185.6

Source: [3]

Field capacity (FC) and permanent wilting point (PWP) varied by depth, with FC from 35.5% to 39.9% and PWP from 20.6% to 22.8% on a gravimetric basis; topsoil values were lower than subsurface values. The mean total available water (TAW) was 185.6 mm per meter of soil depth (Table 3).

Table 4 shows organic matter declining with depth, with the surface (0-15 cm) having the highest OM at 2.07% and the lowest at 45-60 cm with 1.50%; the mean OM was about 1.8%. Mean soil pH was 6.47, near neutral and suitable for onion, and mean ECe was 0.16 dS/m.

Table 4. Selected chemical properties of soils from the experimental field.

Soil depth (cm)	PH	ECe (ds/m)	OM (%)
0-15	5.81	0.18	2.07
15-30	6.65	0.16	1.88
30-45	6.50	0.15	1.74
45-60	6.91	0.16	1.50

Soil depth (cm)	PH	ECe (ds/m)	OM (%)
Average	6.47	0.16	1.80

Source: [3]

3.2. Distribution Uniformity of Drip Emitters

Analysis of emitter discharge under different conditions

showed excellent performance, with distribution uniformity (Du) of 97.57% and coefficient of uniformity (Cu) of 98.20% (Table 5). Following [7], the DU falls in the excellent category and emitter flow variation is acceptable.

Table 5. Uniformity of drip irrigation.

Parameters	Units	Average
Distribution uniformities (Du)	%	97.57
Emitter flow variation (q_v)	%	6.77
Coefficient of variation (Cv)	%	2.10
Uniformity coefficient (Cu)	%	98.20

3.3. Crop Water Requirement

Onion crop water requirements were 498.65 mm under furrow irrigation and 326.66 mm under drip irrigation; an

identical irrigation depth of 27.26 mm was applied twice between transplanting and ten days after transplanting; drip irrigation achieved roughly 60% water savings relative to furrow irrigation [3].

Table 6. crop Irrigation and crop water demand for onion.

Treatments	IR _n (mm)	P _{ef} (mm)	CWR (mm)	IR _g (mm)	Rws (m ³ /ha)	(%)
Furrow	429.97	68.68	498.65	716.62	0	0
Drip	257.98	68.68	326.66	286.64	4299.72	60

IR_n is the net irrigation requirement, IR_g is the gross irrigation requirement, CWR denotes crop water requirement, P_{ef} stands for effective rainfall, and Rws is relative water saved

3.4. Comparative Effects of Furrow and Drip Irrigation on Crop Growth Parameters and Productivity

Table 7 shows the highest mean leaf number per plant (12.87) under drip irrigation (DI) and the lowest (11.80) under furrow irrigation; [5] similarly found that drip irrigation improved growth parameters.

Table 7. Impact of irrigation systems on crop physiology.

Treatments	Number of Leaves per plant	Plant height (cm)	Leaf height (cm)
Furrow	11.80 ^b	63.60	59.47
Drip	12.87 ^a	65.87	61.33
LSD (0.05)	0.59	ns	ns
CV (%)	2.09	4.39	4.37

Although the differences were not statistically significant, the mean plant height and leaf height recorded under the drip irrigation method were higher than those recorded under the furrow irrigation method. This finding aligns with [6], who found maximum height under drip irrigation.

3.5. Effects of Irrigation Methods on Yield and Yield Parameters

Analysis of variance (ANOVA) revealed that irrigation

methods had a significant ($P < 0.05$) impact on both total bulb yield and marketable onion bulb yield. As shown in Table 8, the highest total bulb yield of 40.76 t/ha and marketable bulb yield of 37.39 t/ha were achieved using the drip irrigation method, whereas the lowest total yield of 37.14 t/ha and marketable bulb yield of 34.05 t/ha were obtained from the furrow irrigation method.

Table 8. Effect of irrigation method on yield and yield components.

Irrigation methods	Total bulb yield (t/ha)	Marketable bulb yield (t/ha)	Bulb diameter (cm)	Bulb height (cm)
Furrow	37.14 ^b	34.05 ^b	5.70	5.81
Drip	40.76 ^a	37.39 ^a	5.72	5.94
LSD (0.05)	3.01	2.84	ns	ns
CV (%)	3.41	3.58	1.86	2.74

As shown in Table 8, although there was no statistically significant difference in bulb diameter between the drip and furrow irrigation methods, the slightly higher bulb diameter of 5.72 cm was recorded under furrow irrigation, compared to 5.70 cm under drip irrigation. This result is consistent with the findings of [12].

ANOVA showed irrigation method did not significantly affect bulb height ($P < 0.05$), although the greatest bulb height (5.94 cm) occurred with drip irrigation; this agrees with [5].

3.6. Water Productivity

Irrigation treatment significantly influenced water productivity ($P < 0.05$). The drip system produced the maximum water productivity (12.48 kg/m³), representing a 40.30% increase over the furrow system (7.45 kg/m³). This higher efficiency likely stems from greater yields and reduced water use under drip irrigation, echoing [21] findings of 7.1 kg/m³ (drip) and 4.7 kg/m³ (furrow).

Table 9. Comparative effects of drip and furrow irrigation on water productivity.

Irrigation methods	Water productivity (kg m ⁻³)	% of water productivity increased
Furrow	7.45 ^b	0
Drip	12.48 ^a	40.30

Irrigation methods	Water productivity (kg m ⁻³)	% of water productivity increased
LSD	0.83	
CV (%)	3.66	

4. Conclusions and Recommendations

4.1. Conclusions

Irrigation methods did not significantly ($P < 0.05$) affect onion vegetative traits-number of leaves per plant, plant height, and leaf height or bulb diameter, but they did significantly influence bulb height, total bulb yield, marketable bulb yield, and water productivity. Drip irrigation produced higher values for vegetative and yield parameters, with the highest total bulb yield (40.76 t/ha), marketable yield (37.39 t/ha), and water productivity (12.48 kg/m³).

4.2. Recommendation

Based on these research findings, it is recommended that:

The study recommends that farmers in water-limited areas switch from surface irrigation to drip irrigation, especially for high-value crops requiring regular moisture to reach optimal yields.

Since the experiment was conducted in a single season and at one site, it is recommended to replicate the study across multiple locations and growing seasons to validate and strengthen the reliability of these findings.

Efforts should be made to demonstrate the drip irrigation technology to end users to promote wider adoption.

Abbreviations

CWP	Crop Water Productivity
DI	Drip Irrigation
ETc	Crop Water Use
ETo	Reference Evapotranspiration
FI	Furrow Irrigation
Kc	Crop Coefficient
n	Sunshine Hour
RCBD	Randomized Complete Block Design
RF	Rainfall
RH	Relative Humidity
T _{max}	Maximum Temperature
T _{min}	Minimum Temperature
U2	Wind Speed

Author Contributions

Anbese Ambomsa is the sole author. The author read and approved the final manuscript.

Conflicts of Interest

The authors declare no conflicts of interest.

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