Science Development
2025, Vol. 6, No. 3, pp. 181-188
https://doi.org/10.11648/j.scidev.20250603.26

Research Article

On Farm Evaluation and Demonstration of Onion Yield and Water Productivity Under Irrigation in Melka Irrigation Scheme, Western Hararghe Zone, Oromia Regional State, Ethiopia

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Abstract

Onion is one of the most important in the daily Ethiopian diet and the most economically vital horticultural crops in the country including west Hararghe zones. The lack of knowledge on efficient water utilization is the major constraint on onion production under irrigation which has to be addressed through efficient utilization of available water resources. This activity was initiated to evaluate and demonstrate the effect of crop water requirement based irrigation on onion yield and water productivity. The study was conducted at Melka irrigation scheme in Gemechis district of west Hararghe zone. Two FREGs (Farmer Research and extension Groups) which consist of 20 members per FREG was established, and a total of 40 farmers were grouped per schemes. Four trial farmers were selected on which to establish the experiment, whereas the remaining farmers were participated during training, field works like; land preparation, furrow layout and construction on selected trial farmers' field. Two treatments namely; cropwat based irrigation and farmers practice were used on total areas of 21 m x 10 m with 1 m spacing between plot areas of 10 m x 10 m per farmers on which experimental farmers were used as replication. The intra and inter space of 15 x 40 cm was used. The agronomic data such as single bulb weight (g), plant height (cm), marketable and un marketable yield were collected and analyzed using R software as well as farmer perception analyzed using direct matrix ranking method. The cropwat based irrigation treatment used about 387.3 mm total seasonal water use (Etc) throughout growing period of onion while the estimated traditional irrigation was about 490.7 mm. The cropwat based irrigation saved about 103 kg/ha/mm water throughout growing period and 28.53% yield advantage compared to farmers practice (traditional irrigation). Furthermore, improving farmers' awareness and knowledge through field demonstrations and giving training for farmers on improved water management practices is needed in the future.

Keywords

Onion, CROPWAT, FREG, Yield

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Received: 2 July 2025; **Accepted:** 15 July 2025; **Published:** 13 August 2025

1. Introduction

Onions are commonly cultivated in all tropical African countries, including Ethiopia. Onion is the most important part of the daily Ethiopian diet, and all plant parts are edible, although the bulbs are widely used as a vegetable in various dishes. It is one of the most economically important horticultural crops. The area under onions is increasing from time to time, mainly due to its high profitability per unit area, ease of production, and increase in small-scale irrigation practices. It is produced both under rain-fed in the "Meher" season and under irrigation during off-season that constitutes most of the areas under onion production. During 2018/19, the rainy season about 28,185.11 ha of lands were planted and more than 0.263 million tons of bulbs were obtained with an average yield of 9.14 tons/ha [1].

Onion is the second most produced and important vegetable crop next to potato in eastern Ethiopia [2]. The major crops cultivated using irrigation in the Western Hararghe zone of high-value crops includes hot peppers, tomatoes, onions, cabbage, and beet roots and others [3]. Onion is cultivated both under rain-fed and irrigation conditions in the Western Hararghe zone, particularly in the Gemachis, Guba Qoricha, Anchar, Habro, Oda Bultum, and Daro Labu districts. In Gemachis district, for instance, onion is produced in a total land area of 218.94 and 431.64 hectares during the main (Meher) and short (Belg) rainy seasons, respectively, and the average bulb yield obtained is 6.5 tons per ha, which is far less than both the national and world average yield of 9.14 and 13.4 tons per ha, respectively [4]. This may be due to the weak supply and distribution of vegetable seeds in the region, particularly in Ethiopia. A survey conducted in 2020/2021 showed that several constraints responsible for low onion yields were water shortages for irrigation, lack of knowledge on efficient water utilization, lack of improved seed varieties recommended for the area, disease and pest outbreaks, drought, and low product prices. Among these constraints, a lack of knowledge on efficient water utilization is the major one that must be addressed through efficient utilization of available water resources. Therefore, this study was undertaken to evaluate and demonstrate the effect of irrigation on onion yield and water productivity, as well as to improve farmers' awareness, knowledge, and skills in onion production.

2. Materials and Method

2.1. Description of Study Area

The activity was conducted at the Melka watershed in the Gemachis district of West Hararghe zone of Ethiopia, which is located 333 km from Addis Ababa and 17 km from the zonal town of Chiro with an altitudinal range of 1300-3017 m above sea level. The minimum and maximum temperatures of the district are 16-30℃ respectively with a mean annual rainfall of 850-1000 mm. The main rainy season in the district is from March to May and from June to September. The agro ecologies of the district are 15% highland, 45% midland, and 40% lowland. The major crops produced by rain are onion, potatoes, cabbage, mango, sugarcane, carrot, avocado, sweet potato, hot pepper, coffee, chat, and maize. The dominant soil type in the district is sandy loam [3].

2.2. Site Selection

Site selection was conducted purposively at the Melka Watershed of PASDIP II, developed by the Melka small-scale irrigation scheme. Before the implementation of the project, training was conducted to create awareness among farmers and stakeholders.

2.3. Farmers Research Extension Groups (FREGs) Establishment and Farmer Selection

The farmers' research and extension group (FREGs)-based approach was used, which included farmers and concerned stakeholders encouraged to participate in trial management, technology selection, demonstrations, and promotion processes. Accordingly, two FREGs in the selected scheme were established, with 20 members per scheme. During FREG establishment, all categories of gender considered (i.e., adult men, adult women, young men, and young female) and at least 20% of the FREG members were female headed households. The selection of trial farmers from FREG members was considered to be farmers' willingness to be held as members, their interest and need for improved onions under irrigation, and who have good motivation and participation with groups.

2.4. Experimental Design and Treatments

The experiment was carried out during the off-season by irrigation of four experimental farmer's fields. The onion variety Bombay Red was used as the test crop. Two treatments, CROPWAT-based irrigation and farmers' practice (traditional based irrigation), were used on plot areas of 10 m x 10 m side by side with 1 m spacing between plots as demonstration per farmer. A total area of 10 m x 21 m was used per experimental farmer. The intra- and inter-spaces of 15 cm × 40 cm and farmers were used for replication. A recommended fertilizer rate of 200 kg/ha kg/ha NPS and 100 kg/ha urea was used. NPS fertilizer was applied at planting, whereas urea was used in two split applications: one at planting and the other at knee height or 30 days after sowing, and all necessary agronomic management was given.

2.5. Data Collection

2.5.1. Agronomic Data

Agronomic data on growth parameters, such as bulb weight (g), and marketable and unmarketable (kg/ha) were collected.

2.5.2. Soil Data

Soil samples were collected from the experimental field using a core sampler at soil depths of 0-20 cm, 20-40 cm and 40-60 cm. Soil physical properties, such as soil moisture (%), bulk density, FC, PWP, and TAW, were determined.

2.5.3. Climatic Data

Averages of 30 years (30) of climatic data (maximum and minimum temperature, relative humidity, wind speed, and sunshine hours) on a monthly basis were obtained from a nearby meteorological station. Potential evapotranspiration (ETo) was estimated using CROPWAT software version 8. The onion crop evapotranspiration (ETc) was computed by multiplying the ETo by the crop coefficient (Kc) values obtained from [6] for each of the four stages of onion *viz*., initial, development, mid, and late seasons.

2.5.4. Water Use Efficiency (WUE)

Crop water use efficiency (CWUE) was computed as the ratio of yield obtained to the seasonal evapotranspiration of the crop.

Water use efficiency was calculated as the ratio of the harvested yield per total water used.

$$\mathrm{CWUE} = \frac{\text{Harvested yield (kg)}}{\mathrm{ETC}} \tag{1}$$

Where: CWUE= Crop water use efficiency (kg/ha/mm)
ETc = Evapotranspiration of crop (mm)
Y= Yield of crop (kg/ha)

2.5.5. Technology Evaluation and Demonstration Methods/Techniques

Training was provided for the selected farmers, as well as for the respective DA's concerning the use and application of technology. To know the status of the activity, close supervision and following up of the activity is processed through joint action with stakeholders. Finally, field days were organized for FREG farmers to create awareness of the technologies and farmers' perceptions towards the technologies.

2.6. Data Analysis

Agronomic data such as bulb weight (g), plant height (cm), marketable yield, and unmarketable yield (kg/ha) were analyzed using simple descriptive statistics, whereas farmers' preferences were analyzed using the direct matrix method.

2.7. Economic Analysis

A partial budgeting analysis approach, based on the economic evaluation of onion production, was used. To assess the economic feasibility of onion with CROPWAT-based irrigation, both fixed and operating costs were calculated using partial budget analysis.

3. Result and Discussions

3.1. Determination of Crop Water Requirement and Irrigation Requirement

The crop water requirement of onion for the growing season was determined from the reference evapotranspiration and crop coefficient using Equation (2) and the FAO CROPWAT version_8 program. Subsequently, net irrigation requirements were determined [5]. Finally gross irrigation requirement was calculated by considering 60% of field application efficiency.

$$\mathrm{ETC} = \mathrm{ETO} * \mathrm{KC} \tag{2}$$

Where: ETC = crop water requirement or crop evapotranspiration (mm/day)
KC= crop coefficient
ETO= reference crop evapotranspiration (mm/day)

3.2. Determination of Reference Evapotranspiration (Eto)

Table 1. *Long term monthly average climatic data of the experimental area (1990-2020).*

Months	Tmin (℃)	Tmax (℃)	RH (%)	Rad. (MJ/m2/day)	Wind (2m) m/s	Eto (mm/day)
January	11.6	27	53.9	78	1	3.9
Febraury	12.9	28.1	56.2	77.3	1	4.3
March	14.8	29.5	58.9	73	1.1	4.7
April	16.1	29.3	66.6	65.9	1.3	4.6

Months	Tmin (℃)	Tmax (℃)	RH (%)	Rad. (MJ/m2/day)	Wind (2m) m/s	Eto (mm/day)
May	16.7	30.2	70.3	66	1.3	4.6
June	17.5	30.6	65.4	61.3	1.6	4.7
July	16.3	28.7	64.5	51.8	1.5	4.3
August	15.8	27.9	65.3	55.9	1.4	4.3
September	15.7	28.5	65.9	64.8	1.2	4.4
October	13.9	28.5	69.3	67.6	1	4.1
November	11.8	27.2	67.3	75.6	1.1	3.9
December	10.9	26.5	62.5	82.1	1.1	3.8

The reference evapotranspiration (Eto) for all months in a year in the study area is shown in Table 1. The onion growing season by irrigation starts in mid-November and is harvested at the end of March by irrigation under the Melka small-scale irrigation scheme. [5] divided the crop cycle into four stages: initial, crop development, and mid- and late-season. Accordingly, the length of the onion growing stage in the Gemechis condition was approximately 120 days, 25 days, 30 days, 40 days, and 25 days at the initial, development, mid, and maturity stages, respectively. The average Kc values of onions planted during the growing season were 0.57, 0.78, 1.03 and 0.77 at the initial, development, mid, and late seasonal stages, respectively.

The average ETc of onion planted during the irrigation season at Melka scheme with monthly water use were 44.40 mm, 87.60 mm, 168.80 mm and 86.50 mm for the initial, development stage, middle-season stage and late-season stage, respectively (see Table 2). Cropwat-based irrigation used approximately 387.3 mm total seasonal water use (Etc) throughout the growing period of onion. The amount of water applied throughout the growth period falls within the range of values reported by [7] for onions, which varies from 350 mm to 550 mm, depending on the region’s climate and variety. In addition, the result agreed with the work done by [8] who reported that the crop water requirement of onion with a growing period of 100 days to maturity requires a 366.0 mm depth of water in the off season.

Table 2. *Determination of crop water requirement (Etc) for onion.*

Months	Growth stage	Eto (mm/day)	Kc	Etc (mm/day)	Seasonal water use (mm)
Mid Nov-5 Dec	Initial	3.9	0.57	2.22	44.4
6 Dec-5 Jan	Development	3.8	0.77	2.92	87.6
6 Jan-15 Feb	Mid-season	4.1	1.03	4.22	168.8
16 Feb.-12 Mar	Maturity	4.5	0.77	3.46	86.5
Total					387.3

Source: own computed data of 2023

The total number of irrigation intervals during the growing period of onions ranged from four to six days. The irrigation interval of 4 days used during the initial growth stage and from the development to maturity stage was in the range of 5 to 6 days. Both crop water requirement-based water application and farmers’ practices were irrigated at the same time, and their differences were on the depths of water applied at each irrigation event. All farmers applied water at similar dates to that of the crop water requirement-based treatment. The farmers practice (traditional irrigation) treatment using excess water, which results in overtopping of their plots because farmers irrigate without considering crop water requirements (how much and when to irrigate). Traditional irrigation causes waterlogging and soil erosion. However, crop water requirement saves water and improves crop production. As shown in Table 3, crop water requirement based onion production saved about 103 kg/ha/mm water throughout growing period, which is 28.53% yield advantage with that of farmers' practices. Therefore, irrigation water management contributes significantly to improving crop production and water use efficiency compared to farmers' practices. Therefore, improving farmers' awareness and knowledge is important for improving onion production and water productivity through field demonstrations based on crop water requirements.

3.3. Water Productivity (WUE)

Table 3. Total yield (kg/ha), seasonal water use (mm) and water saved at Melka scheme in 2022/2023.

Treatments	Total Yield (kg/ha)	Total seasonal water use (mm)	WUE (kg/ha/mm)	Water saved (mm)	Yield adv (%)
ETC	15593	387.3	40.2	103.4	28.53%
Farmers practice	12131	490.7	24.7	-	-
Mean	13862	439	31.57		

Source: own computed data of 2023

Crop water use efficiency (CWUE) was computed as the ratio of yield obtained to the seasonal evapotranspiration of the crop. Based on the results, higher water productivity was found in the crop water requirement based irrigation (Etc) plot compared to the farmer practice. The irrigator aims to increase the water use efficiency (WUE) by reducing the amount of water required for irrigation or by reducing the number of irrigations [9, 10].

3.4. Yield and Yield Components

The mean growth parameters and total onion bulb yield (kg/ha) are listed in Table 4.

Table 4. Mean growth parameters and yield of onion at Melka SSI in 2023.

Treatments	Bulb weight (gm)	Plant height (cm)	Unmark. yield (kg/ha)	Mark. Yield (kg/ha)	Total Yield (kg/ha)
CWR	209.7	76.53	2540	13053	15593
Farmers practice	178.33	70.20	2531	9600	12131
Mean	194.00	73.37	2536	11326	13862

Source: own computed data of 2023

3.4.1. Plant Height

The length of onion plants is influenced by variations in water application. Based on the results, the higher plant height found in the crop water requirement-based irrigation plot compared to farmer practices that apply above or below water requirements. This is due to optimum soil moisture availability, which enhances the vegetative growth of plants by increasing cell division and elongation. This study is in agreement with the findings of [11], who reported that the increase in plant height with increased irrigation water could be mainly due to the better availability of soil moisture.

3.4.2. Bulb Weight

The mean weights of the bulbs from crop water based irrigation (100% Etc) and farmers practice about five samples were taken from each plot randomly. A higher mean onion bulb weight of approximately 209.7 gram was obtained from crop water based irrigation (100% Etc) compared to farmers' practices which was 178.3 g (Table 4). This is because the onion transplanted on crop water requirement based irrigation (Etc) used water efficiently, while the farmer practiced above or below crop water requirements.

3.4.3. Un Marketable and Marketable Yield (Kg/ha)

The marketable onion was sorted out of the total onion bulb depending on the color of the bulb, absence of surface defects on the onion (due to insects, diseases, or physiological disorders), and firmness. A higher marketable yield (kg/ha) was found in the crop water requirement-based irrigation (Etc) plot compared to farmer practices that apply above or below water requirements.

3.4.4. Total Bulb Yield (Kg/ha)

The total bulb yield is the sum of the unmarketable and marketable yields. As shown in Table 4 above, a higher total bulb yield of 15593 kg/ha was obtained from crop-based water requirement irrigation compared to the yield obtained from farmers practice, which is 12131 kg/ha. This shows that crop water application based water requirements has about 28.53% yield advantage compared with farmers' practices or traditional irrigation. This is because farmers apply an excess amount of water to their land, which causes water logging or soil erosion, resulting in yield reduction; however, crop water requirement crop water use efficiency is improved because of water application based on crop water requirements.

3.5. Farmers' Perceptions

The mini-field day was organized; about 20 farmers (7 females and 13 males) participated in it. Farmers' preferences toward the demonstrated technologies were assessed by setting their own selection criteria. The farmers' selection criteria, such as water saving, yield obtained, disease resistance, and soil erosion reduction, are listed in Table 5. Based on the criteria they set, they preferred water application based on crop water requirements, which increased the onion yield and improved water productivity. Based on the results, farmers prefer crop water requirement based irrigation (Etc) in-terms of water efficient utilization (4), improving crop yield (4), disease resistance (4), and reduced soil erosion or no waterlogging.

***Table 5**. Farmers preference criteria of technologies.*

Farmers selection criteria	Treatments	
	ETC	Farmers Practices
Water saving	4	2
Yield increment	4	2
Disease resistant	4	3
Soil erosion reduction	5	2
total	17	9
Mean	4.25	2.2

**1-5 scale shows, 5- is v. good, 4-good, 3- sufficient, 2-poor, 1- v. poor
Source: own computed data of 2023

3.6. Benefit Cost Analysis

The partial budget analysis result revealed that the highest cost benefit ratio of 7.03 was obtained for crop water requirement based irrigation (Etc), while the lowest was recorded for farmers practices (see Table 6).

***Table 6**. Cost benefit analysis.*

Treatments	Total cost (ETB)	Yield obtained (kg/ha)	Gross benefit (ETB)	Net benefit (ETB)	B/C ratio
ETC	65,000	13053	522,120	457,120	7.03
Farmers Practice	60,000	9600	384,000	324,000	5.4

Source: own computed data of 2023

4. Conclusion and Recommendation

Onion is the most important part of the daily Ethiopian diet and one of the most economically important horticultural crops cultivated under irrigated conditions in different parts of Ethiopia, but due to lack of knowledge on efficient water utilization, it is the major crop that has to be addressed through efficient utilization of available water resources. Therefore, this study was undertaken to evaluate and demonstrate the effect of irrigation on onion yield and water productivity, as well as to improve farmers' awareness, knowledge, and skills in onion production. The effect of irrigation treatments was evaluated using growth parameters, yield, and yield components, such as plant height, total yield, marketable yields, farmers' preferences, profitability per unit of area, and water productivity.

The crop water requirement based treatment applied at about 387.3 mm of the total seasonal water use (Etc) throughout the growing period of onion. The crop water requirement based irrigation water application saved approximately 103 kg/ha/mm water throughout growing period and 28.53% yield advantage with compared to farmers' practice (traditional irrigation). This is due to farmers' practice (traditional irrigation) treatment using excess water, because farmers irrigate without considering crop water requirements (how much and when to irrigate). Traditional irrigation causes waterlogging and soil erosion. In addition, farmers preferred crop water requirement-based treatment up on water saved and improved crop yield compared to farmers' practices. Therefore, irrigation water management plays an important role in improving onion production and water use efficiency compared to farmers' practices. Furthermore, improving farmers' awareness and knowledge through field demonstrations and providing training on improved water management practices are needed in future interventions.

Abbreviations

CWR	Crop Water Requirement
CROPWAT	Crop Water Requirement Model
ETC	Crop Evapotranspiration
ETO	Reference Crop Evapotranspiration (mm/day)
FAO	Food and Agriculture Organization
FREG	Farmers Research Extension Group
KC	Crop Coefficient
PASIDP	Participatory Small Scale Irrigation Project
WUE	Water Productivity

Acknowledgments

We would like to acknowledge Oromia Bureau of Agriculture office and Participatory Small-scale Irrigation Project Phase II (OBoA-PASIDP II) Coordination for financing research project and district PASIDP II focal persons for supporting us on Farmers Research and Extension Groups (FREGs) establishment. In addition, we would like to appreciate efforts of Mechara Agricultural Research center directors and researchers for providing logistics and capacity building of farmers through providing need based training. The PASIDP II project improved livelihood of many subsistence smallholder farmers of study area.

Conflicts of Interest

The authors declare no conflicts of interest.

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