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Research Article

Effect of Different Irrigation Regimes on Yield and Crop Water Productivity of Onion in Gobu Sayo and Bako Tibe Districts, Western Oromia

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ABSTRACT

Onions play an important role in human nutritional needs and have medicinal properties and are mainly used because of their unique taste or ability to enhance the taste of other foods. Despite its importance in the human diet and its increasing area coverage, the productivity of onion in the country is much lower than of other African countries with an average value of 10.1 t ha^{-1}. Moreover, quality and yield of particular onion variety greatly affected by amount and method of irrigation water applied during dry season. The field experiment was conducted at farmers' field in Gobu Sayo District of East Welega Zone and Bako Tibe District of West Shewa zone. The experiment was consisted five levels of soil moisture depletion percentage- 50%, 60%, 70%, 80% and 100%. Generally this study focuses on effect of different water depletion level on yield, water productivity and seasonal water production function of onion crop under furrow irrigation. The result from the variance analysis showed that the marketable yield of the onion was significantly affected by soil moisture deletion level at both sites. The highest marketable yield of 17623.7 kg/ha and 19097 kg/ha were obtained from D3 (70% soil moisture Depletion level) treatment at Gobu Say and Bako Tibe sites respectively. The lowest marketable bulb yield of onion 14383.3 kg/ha and 15442 kg/ha were recorded from the treatment of 50% FAO (Food and Agriculture Organization) recommended ASMDL (Agricultural Soil Moisture Depletion Level) at Gobu Sayo and Bako Tibe sites respectively. The highest water productivity values 14.6 kg/m^3 and 16.7 kg/m^3 were obtained from D3 (70% soil moisture Depletion level) at Gobu Sayo and Bako Tibe sites respectively. However, the lowest water productivity values 7.5 kg/m^3 and 8.5 kg/m^3 were obtained from D1 (50% soil moisture Depletion level) at Gobu Sayo and Bako Tibe sites respectively. Therefore, result of this study suggest that irrigating at 70% soil moisture depletion level can increase yield and water productivity by saving irrigation water for onion production in the study area and similar agroecology.

Keywords: Allowable soil moisture depletion, Water productivity, Water production function

INTRODUCTION

Onion is very important in the Ethiopian diet. Commonly, all portions of onions can be eaten by people except seeds. Onions play an important role in human nutritional needs and have medicinal properties and are mainly used because of their unique taste or ability to enhance the taste of other foods [1]. Onions and/or shallot are grown almost in all tropical countries of Africa including Ethiopia Onions are grown under rainy and irrigated conditions. Onion is valued for its distinct pungency or mild-flavored form of essential ingredients of many dishes. Fresh onion has about 86.6% moisture, 11.6% carbohydrate including 6-9 soluble sugars, 1.2% protein, 0.1% fat, 0.2%-0.5% Ca, 0.05% P, traces of Al, Cu, Fe, Mn, Zn and vitamin A, B and C [2]. It is consumed universally in small quantities almost daily in many homes primarily as a seasoning for flavoring of dishes and sandwiches in the world [3]. It has nutritional value that helps alkaline reaction in our body and important in neutralizing the

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acid substance produced during the course digestion of meat, cheese and other food [4]. In Ethiopia, it has an economically important place among other vegetable crops due to ease of production, high profitability per unit area and increase in small-scale irrigation schemes, the area under production of the onion is increasing from time to time. According to 10.05 t ha^{-1} and 10.13 t ha^{-1} yields were obtained during the year 2013 and 2014/2015 [5]. Despite its importance in the human diet and its increasing area coverage, the productivity of onion in the country is much lower than of other African countries with an average value of 10.1 t ha^{-1}. One of the major problems associated with its production is inappropriate agronomic practices used by farmers which have quite a great contribution to lowering crop yields. Yemane et al., also reported the limited use of improved seeds and fertilizers by small scale farmers [6]. Moreover, quality and yield of particular onion variety greatly affected by amount and method of irrigation water applied during dry season. The water production function (wpf) represents the relationship between crop yield and seasonal water applied. The relationship between yield and seasonal evapotranspiration can be characterized by the evapotranspiration production function (Etpf). Water production function (wpf) can be useful to determine the capacity of irrigation systems and irrigation amount and timing, as well as to compare relative water use efficiencies. The wpf is not unique but varies among climate zones and between years, varieties, and crops. Thus, determining Etpf for a site-specific location is usually required. Because the wpf varies according to management skills of the irrigator and the type of irrigation system, no unique wpf can be determined for a crop. The objectives of this study were to determine the water production function (wpf) under drip irrigation on a sandy loam soil and the evapotranspiration production function (Etpf) for onions, which is independent of the irrigation system and soil type.

Water production functions are very useful in irrigation water management applications. They are useful in evaluating economic implication of different levels of crop water use and in determining irrigation strategies when water supply is limited [7]. Water production function is very useful in determining irrigation strategies when water supply is limited. Crop water production function is often linear and is not unique but varies among varieties of crops and climate zones. Thus, determining crop water production function for a site-specific location is usually required. Generally this study focuses on effect of different water depletion level on yield, water productivity and seasonal water production function of onion crop under furrow irrigation. Therefore, the objective of the study is to determine effect of different water depletion level on yield and crop water productivity of onion in the study area.

MATERIALS AND METHODS

Description of the study area

The field experiment was conducted at farmers' field in Gobu Sayo District of East Welega Zone and Bako Tibe District of West Shewa zone. The area experiences a bimodal type of rainfall with the first and second rainfall during April to May and September to October, respectively. The first site was located in Gobu Sayo District of East Welega Zone and the second site was located in West Shewa Zone Bako Tibe District are shown in Figure 1.

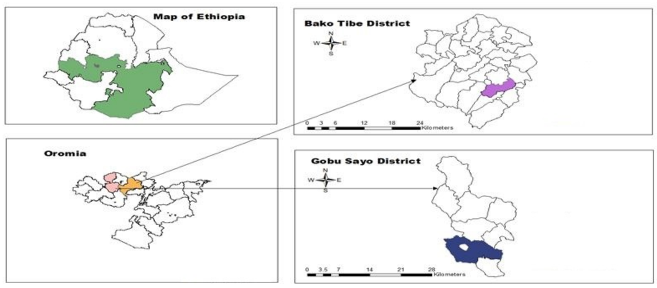


Figure 1: Farmers' field in Gobu Sayo District of East Welega Zone and Bako Tibe District of West Shewa zone.
NOTE: (▭) All over the valures; (▬) Odo Haro; (▬) Ongobo Bekenisa; (▬) East Wellega; (▬) West Shewa

Treatments and experimental design

The treatments consists five levels of soil moisture depletion percentage: 50%, 60%, 70%, 80% and 100%. A total of five treatments were arranged in Complete Block Design (RCBD) with three replications. The experimental area consisted of 15 equal plots of size 30 m^2 which was managed similarly over the 2 seasons. To avoid interaction effects 1 m wide were used to create a buffer zone between experimental plots (Table 1).

No	Treatments	Description
1	50% Dep	Water application at 50% depletion level
2	60% Dep	Water application at 60% depletion level
3	70% Dep	Water application at 70% depletion level
4	80% Dep	Water application at 80% depletion level
5	100% Dep	Water application at 100% depletion level

Table 1: Field treatment arrangements.

Seedling production

Onion seedling production was done on seed bed prepared at irrigation site of Bako agricultural research center. An experimental field was prepared manually and planting was done on both sides of ridge of furrows.

Soil sample collection

To identify some of physical properties of the soil, representative composite soil samples were collected from the experimental site from depths of 0 cm-30 cm, using an auger. The samples were sent to soil laboratory of Bako agricultural research center for analysis. Soil sample was collected to determine FC, PWP, Bulk density d and texture of experimental sites. Infiltration test was done by double ring infltrometer for both locations.

Assessment of water productivity

Water productivity was used to evaluate various treatments to determine which treatment produce maximum yield per unit of water applied for each crops. Water productivity, expressed as the weight of yield in kg/m^3 of water applied during growing seasons was computed to evaluate water management practices is shown in equation 1.

$$WP = \frac{ya}{ETc} \qquad \text{.................. (1)}$$

Where, WP is water productivity (kg/m^3), Ya: marketable yield (kg/ha); Etc: is the amount of applied irrigation water (m^3/ha).

Water Production function (wpf)

The relationship between crop yield and water application is called water production function (wpf) while the relationship between crop yield and evapotranspiration is called crop water production function (cwpf). Water production function is linear in the deficit irrigation range, because all the applied water is used as evapotranspiration (wpf=cwpf) shown in equation 2.

Generally, Water production function (wpf) is expressed as a second or third order polynomial:

$$Y = f(x) = a_1x^3 + a_2x^2 + a_3x + a_4x \qquad \text{............. (2)}$$

Where, Y is the crop yield (kg/ha), x is the applied water (mm) and a1, a2, a3, a4 the coefficients to be determined. Because the wpf varies according to management skills of the irrigator and the type of irrigation system, no unique wpf can be determine for a particular crop in a given area.

For both years, WPF's and CWPF's were determined by linear regression of the bulb yield to the total water applied (rainfall +irrigation) and to total crop water use (ETc), respectively. In addition, the effect of water stress on yield was quantified by the calculating the yield response factor (Ky) shown in equation 3 [8]:

$$1 - \frac{Ya}{Ym} = Ky\left(1 - \frac{ETa}{ETm}\right) \qquad \text{............. (3)}$$

A useful way to express the cwpf is on a relative basis, where, actual yield (Ya) is divided by maximum yield under the given management conditions (Ym) and actual evapotranspiration (ETa) is divided by crop evapotranspiration for non-limiting water conditions (ETc). The crop yield response factor gives an indication of whether the crop is tolerant of water stress or not. If Ky is greater than unity, the expected relative yield decrease for a given evapotranspiration deficit is proportionately greater than the relative decrease in evapotranspiration [8].

RESULTS AND DISCUSSION

Yield components and bulb yield

Marketable bulb yield (t ha^{-1}): Marketable yield further categorized by weight in to large (100 g-160 g), medium (50 g-100 g) and small (21 g-50 g) and expressed as kg/plot and converted into t ha^{-1}. Total weight of clean, disease and damage free bulbs with greater than 21 g in weight was considered as marketable bulb yield

Unmarketable bulb yields (t ha^{-1}): were determined by classified as: under sized below 20 g, contaminated, rotten and disordered physiologically (tick-necked and divided bulbs). These bulbs weighed and expressed as unmarketable bulbs from net plot area and later extrapolated to per hectare basis.

Data analysis

All measurements were checked for normality before analysis and subjected to Analysis of Variance (ANOVA) using SAS version 9.3 procedures and Least Significant Difference (LSD) test was used to separate means at 5% probability level.

Climate data

The following data provides a snapshot of the climatic conditions observed across the months in a specific location (Table 2).

Months	Min. Temperature (^{0}C)	Max. Temperature (^{0}C)	Relative humidity (%)	Wind speed at 2m (km/hr)
January	12.68	31.48	53.35	2.31
February	13.06	32.76	49.39	2.67

March	14.29	32.7	50.05	3.06
April	14.69	32.14	53.24	3
May	15	30.06	58.18	3.1
June	15.14	27.03	65.2	2.72
July	15.3	25.41	70.73	2.11
August	15.23	25.27	71.04	1.71
September	15	26.4	68.56	1.62
October	14.32	28.53	62.88	1.6
November	12.96	29.9	59.11	1.76
December	12.04	30.71	56.14	1.9

Table 2: Climate data of the experimental site (1992-2022).

Soil physical property

The soil texture, field capacity, permanent wilting point, pH, and bulk density are essential factors influencing soil health and productivity. Understanding these properties is crucial for agricultural planning, water management, and environmental assessment in these specific areas (Table 3).

Yield and Yield component

The result from the variance analysis showed that the marketable yield of the onion was significantly affected by soil moisture deletion level at both sites. The highest marketable yield of 17623.7 kg/ha and 19097 kg/ha were obtained from D3 (70% soil moisture depletion level) treatment at Gobu Say and Bako Tibe sites respectively.

The effect of soil moisture depletion levels on Water Productivity (WP), Marketable Yield (MY) and Unmarketable Yield (UMY) of onion at both locations are shown in Table 4. Statistical analysis revealed that the SMD levels had a significant ($P<0.05$) effect on MY and UMY. The maximum values for unmarketable yield were obtained from the D1 (50% soil moisture Depletion level) treatment and these values were greater than those of D2, D3 and D4). Increasing soil moisture depletion levels from 50%-70% increases the onion yield (marketable) by 2430.9 kg/ha and 3240.4 kg/ha for D2 and D1, respectively, compared with D3 at Gobu Sayo. Similarly, increasing soil moisture depletion levels increases the onion yield (marketable) by about 3652 kg/ha and 2477.6 kg/ha for D1 and D2, respectively, compared with D3 at Bako Tibe site. However, increasing soil moisture level beyond 70% showed decreased marketable yield at both sites. The lowest marketable bulb yield of onion 14383.3 kg/ha and 15442 kg/ha were recorded from the treatment of 50% FAO recommended ASMDL at Gobu Sayo and Bako Tibe sites respectively. The better performance of yield parameters with 70% may be attributed to significant increase in growth parameters. The result was in agreement with the finding of Bagali et al. reported that scheduling of irrigation onion at shorter interval with higher level of irrigation recorded significantly higher bulb yield [9].

Water productivity was significantly affected by soil moisture depletion treatments as shown in Table 4. The highest water productivity values 14.6 kg/m^3 and 16.7 kg/m^3 were obtained from D3 (70% soil moisture depletion level) at Gobu Sayo and Bako Tibe sites respectively. However, the lowest water productivity values 7.5 kg/m^3 and 8.5 kg/m^3 were obtained from D1 (50% soil moisture Depletion level) at Gobu Sayo and Bako Tibe sites respectively. Due to the reason of too much water frequently irrigated water and low water productivity.

Location	Soil texture	FC (%)	PWP (%)	PH	Bd (g/cm^3)
Gobu Sayo	Silty clay loam	37	21.7	5.7	1.33
Bako Tibe	Silty clay	38.7	24.3	5.73	1.36

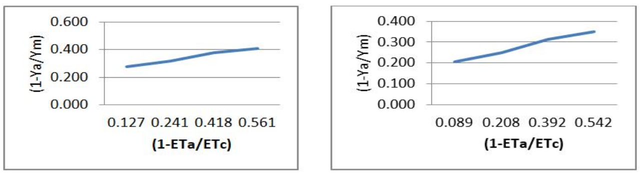
Table 3: Soil physical properties of experimental site.

Treatments	Location					
	Gobu Sayo			Bako Tibe		
	Water productivity (kg/m^3)	Marketable yield (kg/ha)	Unmarketable yield (kg/ha)	Water productivity (kg/m^3)	Marketable yield (kg/ha)	Unmarketable yield (kg/ha)
50% Dep (D1)	7.5e	14383.3e	453.2a	8.5e	15442e	503.8a
60% Dep (D2	10.5d	15192.8d	425.7b	11.7d	16619.4d	385b
70% Dep (D3)	14.6a	17623.7a	343.2e	16.7a	19097a	344.3e
80% Dep (D4)	12.5b	16926.8b	376.2d	13.5b	17689b	357.5d
100% Dep (control)	11.2c	16623.2c	427.8c	12.3c	16965.3c	387.2c
LSD	0.09	273.98	2.07	0.08	204.6	2.07
CV	9	13	10	10	13	9

Table 4: Effect of soil moisture depletion level water productivity and yield of onion.

Water production function

The Water production function for onion is depicted in Figures 2a and 2b. The relationship between bulb yield and seasonal water applied was used to determine the CWPF Figures 2(a) and 2(b) for at Gobu Sayo and Bako Tibe sites respectively. In both years, yields increased linearly with the total depth of water applied between planting and harvest. The Water Production Function varies from a water application at 50% soil moisture depletion and a yield of 14383.3 kg/ha to a water application at 70% and a yield of 17623.7 kg/ha at Gobu Sayo site Figure 2a. The Water Production function varies from a water application at 50% soil moisture depletion and a yield of 15442 kg/ha to a water application at 70% and yield of 19097 kg/ha at Bako Tibe Site Figure 2b.



2(a) 2(b)

Figure 2: 2a: Water production function for onion at Gobu Sayo; 2b: Water production function for onion at Bako Tibe.

Economic analysis and evaluation

According to CIMMTY, the average yield was adjusted by 10% downwards. The gross returns were estimated by multiplying average market price rate with yield of respective treatments at the time of harvesting. The seasonal gross expenditure, net return and BC ratio for each treatment were estimated (Table 5).

Treatment (D3) showed that the least variable cost (100000.00 birr) and treatment (D1) showed the maximum variable cost (106000.00 birr) and all the remaining treatments were confined between these two treatments. The economic analysis revealed that the highest net benefit of (542612.3 birr) with total variable cost (100000.0 birr) was recorded from the application of 70% soil moisture depletion. The treatment (D1) application of water at 50% soil moisture depletion level gave the minimum benefit (415942.8 birr). The Minimum Acceptable Marginal Rate of Return (MARR%) should be between 50% and 100%CIMMYT (International Maize and Wheat Improvement Center). This showed that D4 and 100% SMDL treatments are economically important as per the MRR (Monthly Recurring Revenue) is greater than 100%. Hence, the most economically attractive for small scale farmers with lower total variable cost and higher net benefits is irrigating at 70% SMDL (Soil Moisture Depletion Level) [10].

Treatment	Yield (kg/ha)	Total cost (ETB)	Total return (ETB)	Net benefit	MR	BCR
50% Dep (D1)	14912.7	106000	521943	415943		3.2
60%Dep (D2	15906.1	104000	556714	452714	90.14	3.6
70% Dep (D3)	18360.4	100000	642612	542612	80.22	4.1

80% Dep (D4)	17307.9	102000	605777	503777	109.86	4.5
100% Dep(control	16794.3	103000	587799	484799	104.93	3.9

Table 5: Partial budget, MRR and BCR analysis.

CONCLUSION

Soil water availability is a major limiting factor in agricultural production systems. Knowledge of crop response to water supply, full and limited, in localized environments can aid in the development of effective irrigation strategies for improving farm level water management and crop productivity. The experiment was conducted to study the effect of irrigation regime on plant marketable yield, Unmarketable and water productivity of onion. The result showed that there was significant difference among the treatments regarding bulb yield and water productivity of onion. Based on the obtained results of the effect of different soil moisture depletion level, the highest bulb yield was obtained from the treatment of 70% ASMDL with significance difference compared with other the three treatments. In the other hand, the higher water productivity of onion was obtained from 70% FAO recommended ASMDL.

Therefore; based on the current findings; application of irrigation scheduling for onion in study and similar agro-climatic area and soil type application of irrigation at 70% ASMDL showed highest bulb yield and water productivity. The results of this study suggest that the increasing depletion level for furrow irrigation system in the study area increases marketable yields and water productivity up to 70% ASMDL. Generally knowing of crop response to water supply, at different depletion level helps in the development of effective irrigation strategies for improving water management and crop productivity.

Therefore, result of this study suggest that irrigating at 70% soil moisture depletion level can increase yield and water productivity by saving irrigation water for onion production in the study area and similar agroecology.

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