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Evaluation of Onion Response for Deficit Irrigation in Maskan Woreda, Gurage Zone, Ethiopia

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Abstract

Agricultural water is scarce in many parts of the world and becoming a global agenda. It is the largest among sectors which are consuming huge fresh water. This experiment was carried out for three years to investigate the yield and water productivity of onion under different deficit irrigation levels. The method used was field experiment contains combination of five treatments (100% ET_c throughout the season, 85% of ET_c throughout the season, 70% of ET_c throughout the season, 50% of ET_c throughout the season and farmers practice laid out in randomized complete block design (RCBD) with three replications. The combined yield results showed that maximum yield was obtained from 100% ET_c (26.44 t/ha) and minimum yield was obtained from 50% of ET_c (18.5 t/ha). Among treatments 100% ET_c, 85% of ET_c, 70% of ET_c and farmers practice, there was insignificant yield difference with minimum yield reduction. But the treatment 50% of ET_c had the significant yield difference with 100% ET_c and 85% ET_c. Maximum and minimum water productivity was obtained from 50% of ET_c (7.8 kg/m^3) and farmers practice (3.877.8 kg/m^3), respectively. Water productivity of 85% of ET_c (6.24 kg/m^3) was greater than 100% ET_c (5.56 kg/m^3). The result of economic analysis indicated that Irrigating 85% of ET_c earns best marginal rate of return next to 70% of ET_c. From these result it can be concluded that in water scarce area using 85% of ET_c provides a better yield, Water productivity and earns better income.

Keywords: Deficit irrigation; ET_c; Economic analysis; Maskan woreda; Onion; Water use efficiency

Introduction

Water is becoming an economically scare resource even in areas of the world that have relatively plentiful water [1]. Agriculture under unfavorable climatic conditions and limited water resources cannot be profitable practice unless on-farm water management techniques are designed to meet the present growing demands of water for increased food production [2].

Deficit irrigation (DI) has been considered worldwide practice to maximize water use efficiency (WUE) by eliminating irrigation water that has minimum impact on Crop yield [3]. Deficit irrigation strategy is exposing crops to a certain level of water stress either during a particular period or throughout the whole growing season [4].

To quantify the level of deficit irrigation, it is firstly necessary to define the full crop ET requirements. Fortunately, since Penmann developed the combination approach to calculate ET, research on crop water requirements has produced several reliable methods for its calculation [5]. At present, the Penman–Monteith equation is the established method for determining the ET of the major herbaceous crops with sufficient precision for management purposes [6]. Under conditions of scarce water supply, application of deficit irrigation deficit irrigation could provide greater economic returns than maximizing yields per unit of water.

Onion is grown in many countries in the world. It was primarily consumed for their unique flavor to enhance the flavor of other foods [7]. In addition, Onion is known for its anti-bacterial, anti-viral, anti-allergenic and anti-inflammatory potential [8]. It also contains some important vitamins (A, B and B_2) and minerals (Ca, P, Fe, Cu and Zn) in addition to some soluble sugars and nicotinic acid [9].

The study area had highly potential to Onion production by irrigation. But farmers irrigation practice were not well managed which result competition among them. Therefore, this study was conducted on field level to evaluate the effects of deficit irrigation levels on yield and water productivity of Onion.

Methodology

Description of the study area

The experiment was conducted at Meskan woreda, Gurage Zone, in southern Ethiopia. The study area was geographically located at an altitude of 1817 masl, 38°28'50"E longitude and 08°04'32"N latitude. The altitude of the woreda ranges from 1700 to 2076 masl. and the annual rainfall ranges from 500 to 800 mm and seasonal rainfall pattern varying in depth. The mean annual temperature ranges from a minimum of 11.8°C to a maximum of 27.4°C. The soil of the experimental area is dominated by red and gray color with loam and clay loam texture.

Experimental design

The experiment has five levels of treatments (100% ET_c throughout the season, 85% of ET_c throughout the season, 70% of ET_c throughout the season, 50% of ET_c throughout the season and farmer practice) with three replications made a total of 15 experimental plots that were arranged in a randomized complete block design (RCBD). Each plot had (3.25 m × 4.0 m)=13 m^2 area. The space between plots and blocks were 1 m and 1.5 m, respectively. The space between onion plants and rows kept at 10 cm and 20 cm, respectively. Fertilizer rate used was 200 kg/ha NPS and150 kg/ha urea.

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Soil data

The water content of the soil at field capacity and permanent wilting point were determined in the laboratory by using a pressure plate apparatus. The pressure plate was adjusted to 0.33 bar to determine field capacity and 15 bar to determine permanent wilting point to a saturated soil sample. Total available Water (TAW) in the root zone was computed as the difference in moisture content between FC and PWP [6]. It is computed as follows:

$$BD = \frac{Weight\ of\ dry\ soil\,(gm)}{Volume\ of\ the\ same\ soil\,(\mathrm{cm}^3)} \quad (1)$$

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$$TAW = \frac{(FC - PWP) * Dr}{100} * BD \quad (2)$$

Where: TAW: Total Available Water (cm), FC: Water content at filed capacity (%), PWP: Water content at permanent willing point (%) and Dr: Effective depth of root zone (cm) and BD: Bulk Density (g/cm^3)

The infiltration rate of the soil in the experimental field was determined using double ring infiltrometer method before the staring of the experiment.

Determination of crop water requirement

Determination of water required (CWR) to compensate the amount of water lost through evapotranspiration (ET_c), requires climatic and crop input data. Crop water reqiurment or ET_c over the growing season was calculated from reference evapotranspiration (ET_o) and crop coefficient (K_c) for that stage:

$$ET_c = k_c * ET_o \quad (3)$$

Where: ET_c: Crop water requirement (mm), k_c: Crop coefficient, ET_o: Reference evapotranspairation (mm)

Climatic data

Maximum and minimum temperature (˚C), humidity (%), wind speed (km/day) and sunshine (hours) and Rainfall (mm) of the experimental site was obtained from New locClim1.10 model since there is no meteorological station near the area. The reference evapotranspiration (ET_o) of each month were computed by incorporating local climate information listed above in to the crop wat8.0 model.

Crop data

The crop data was clearly explained in Table 1.

Irrigation water requirement determination

Crop water requirement refers to the amount of water that needs to be supplied, while crop evapotranspiration refers to the amount of water that is lost through evapotranspiration [6]. For the determination of crop water requirement, the effect of climate on crop water requirement, which is the reference crop evapotranspiration (ET_o) and the effect of crop characteristics (K_c) are important [9]. The long term and daily climate data like maximum and minimum air temperature, relative humidity, wind speed, sunshine hours, and rainfall data of the study area were collected to determine reference evapotranspiration, crop data like crop coefficient, growing season and development stage, effective root depth, critical depletion factor of tomato and maximum infiltration rate and total available water of the soil was determined to calculate crop water requirement using Cropwat model.

	Growth stage				
Crop data	**G1**	**G2**	**G3**	**G4**	**Total**
Growing period	20	30	30	15	95
k_c	0.7		1.05	0.95	
Rooting(m)	0.3		0.6	0.6	
Depletion le (p)	0.3		0.45	0.5	
Yield response(k_y)	0.8	0.4	1.2	1	
Source: FAO Irrigation and Drainage Paper No.56 [6].					

Table 1: Onion crop data required for CWR determination.

$$ET_c = ET_o * K_c \quad (4)$$

Where ET_c: Crop evapotranspiration, K_c: Crop coefficient, ET_o: Reference evapotranspiration.

Net irrigation requirement was determined by:

$$IRn = ETc - P_e \quad (5)$$

Where: IR_n=Net irrigation requirement (mm) and P_e: Effective rainfall (mm) which is part of the rainfall that enters into the soil and makes available for crop production. The effective rainfall (p_e) is estimated using the method given by [6].

$$P_e = (P\ (125 - 0.2*P))/125 \text{ for } P <= 250 \text{ mm} \quad (6)$$

(or)

$$Pe = 125 + 0.1*P \text{ for } P > 250 \text{ mm} \quad (7)$$

Where: P: Total rainfall (mm).

However, since there was no rainfall during the experimental period, p_e is equal to zero and net irrigation requirement was taken as equal to the crop water requirement.

Gross irrigation requirement was calculated by:

$$IR_g = IR_n/60\% \quad (8)$$

Where IR_g: Gross irrigation, IR_n: Net Irrigation, 60% is the application efficiency of furrow irrigation.

$$\text{Irrigation interval (days)} = IR_n/ET_c \quad (9)$$

Onion seedling was prepared and transplanted to main field after 45 days. The irrigation water had applied using furrow irrigation system. Amount of irrigation water applied in each irrigation event were measured by partial flume.

The time required to deliver the desired depth of water into each plot was calculated as:

$$T = A*d/6Q \quad (10)$$

Where: T=Time in minute; d: Depth in cm; A: Area of plot (m^2); Q: Flow rate in l/s

Agronomic data collection

The field data such as bulb diameter and bulb yield weight were taken from each plot. Bulb diameter was taken by random selected 5 plants from each plot by excluding the border rows and border row. At the end of the season the amount of bulb yield produced was harvested, weighted and converted to into hectare base. The harvested yield was grouped based on its quality for market according to the size and degree of damage [10].

Water productivity

The water productivity was calculated by dividing harvested yield in kg per unit volume of water used in m^3. The crop water use efficiency is the yield harvested in kg per irrigation water used in m^3.

$$CWP = \frac{Yield(kg)}{ETc(m3)} \quad (11)$$

ET_c: Seasonal crop water requirement, CWP: Crop Water Productivity.

Economic analysis

Economical evaluation of deficit irrigation is analyzing the cost that invested during growing season and benefit gained from yield produced by application of water. Marginal Rate of Return (MRR) was used for analysis following the CYMMYT method [11]. Economic water productivity was calculated based on the information obtained at the study site: the size of irrigable area, the price of water applied and the income gained from the sale of onion yield by considering the local market price. Yield and economic data was collected to evaluate the benefits of application of different levels of water in deficit irrigation treatments. Economic data includes input cost like cost for water (water pricing) and other costs. However, cost of water pricing and yield sale price were the only cost that varies between treatments

The difference between net income of a treatment and its next higher variable cost treatment termed as change in net income (ΔNI). Higher net benefits may not be attractive if they require very much higher costs. Hence, it is required to calculate marginal costs with the extra marginal net income. The marginal rate of return (MRR) [11] indicates the increase of the net income, which is produced by each additional unit of expenditures and it is computed as follows:

$$MRR = \frac{\Delta NI}{\Delta VC} \quad (12)$$

$$NI=GI-VC \quad (13)$$

Where: MRR: Marginal rate of return; ΔNI: Change in net income; ΔVC: Change in variable cost; GI: Gross Income; VC: Variable Cost.

Statistical analysis

The field collected data were subjected to SAS 9.0 (statistical Analysis software) based on randomized complete block design. Least Significant Difference (LSD) at p=0.05 was employed to identify different level of deficit irrigation that were significantly different among treatments.

Result and Discussion

Soil result

The average composite soil result of sand, silt and clay percentages were: 18.88%, 36.05% and 45.07%, respectively (Table 2). Based on soil textural classification of USDA, the experimental site soil was silt clay. The soil bulk density was 1.06 g/cm^3 which is below the critical threshold level (1.4 g/cm^3) and suitable for crop root growth [12]. The FC and PWP values were: 23.59% and 12.39%, respectively. All the soil result were presented below in Table 2.

Soil parameters	Results
Sand (%)	18.88
Clay (%)	45.07
Silt (%)	36.05
Textural class	Clay
Bulk density (gm/cm^3)	1.06
Field capacity (%)	23.59
Permanent wilting point (%)	12.39

Table 2: Soil result.

Trts	Yield (t/ha)	BD (cm)	AW (mm)	WP (kg/m^3)
100% ET_c	26.44a	6.04a	479.5b	5.56b
85% of ET_c	25.25a	5.83ab	407.5c	6.24b
70% of ET_c	23.06ab	4.88c	335.5d	6.92ab
50% of ET_c	18.5b	3.87d	239.73e	7.8a
Fp	22.85ab	4.98bc	581.5a	3.87c
CV	15.33	19.37	10.2	24.4
LSD	5.5	0.94	39.8	1.42

NB: The letters a,b & c indicated Treatments with similar letter have no significance difference while Treatments with different letters have significance difference with each other, F_P: Farmers practice.

Table 3: Onion deficit irrigation combined results.

Responses of onion to deficit irrigation

The combined result showed that irrigation water stress throughout the season significantly reduced onion bulb yield and diameter. The maximum yield was obtained from 100% ET_c (26.44 t/ha) and minimum yield was obtained from 50% of ET_c (18.5 t/ha). Among the treatments 100% ET_c, 85% of ET_c, 70% of ET_c and farmers practice, there is insignificant yield difference with minimum yield reduction. But 50% of ET_c had significant yield reduction with 100% ET_c and 85% of ET_c. Maximum and minimum water productivity were obtained from 50% ET_c (7.8 kg/m^3) and farmers practice (3.877.8 kg/m^3), respectively. Water productivity of 85% of ET_c (6.24 kg/m^3) was greater than 100% ET_c (5.56 kg/m^3). The result obtained in this experiment was in agreement with Teferi and Medihn [13] who observed that irrigation water stress throughout the season significantly decreased onion bulb yield. Nazeer and Ali also discussed that different irrigation water depth affects onion yield and biomass (Table 3).

Economic analysis of deficit irrigation with onion

The application of deficit irrigation for improved growth and higher yield could be economically attractive to minimize drought hazards in water shortage areas. Cost benefit ratio for each treatments were analyzed and income was computed based on the current local market price of onion. At the time of harvest the market price of onion was 9 birr per kg and the cost of irrigation water was 8 birr/m^3 (by considering irrigation water cost is half of drinking water cost that is 4 birr/m^3) (Table 4) [14].

Conclusion and Recommendation

The combined yield results showed that maximum yield was obtained from 100% ET_c and minimum yield was obtained from 50% of ET_c. Among the treatments 100% ET_c, 85% of ET_c, 70% of ET_c and farmers practice, there were insignificant yield reduction. But 50% of ET_c had significant yield reduction with 100% ET_c and 85% of ET_c. Maximum and minimum water productivity was obtained from 50% ET_c and farmers practice, respectively. Water productivity of 85% of ET_c was greater than 100% ET_c. The result of economical analysis indicated that Irrigating of 70% of ET_c earns more marginal rate of

Trts ET_c	AW m³/ha (10³)	Y kg/ha (10³)	AY kg/ha (10³)	GI Birr (10³)	VC Birr (10³)	NI Birr (10³)	MRR birr
50% ET_c	2.4	18.5	16	149	95	140	0
70% ET_c	3.3	23	20	186	134	173	8.64
85% ET_c	4.0	25	22	204	163	188	5.15
100% ET_c	4.9	26	23	21	19	194	1.62
F_P	5.8	22	20	18	23	161	D
NB: AW: Applied water, Y: Yield, Gi: Gross Income, VC: Variable Cost, NI: Net Income, MRR: Marginal Rate of Return, FP: Farmers Practice, AY: Adjusted Yield.							

Table 4: Economic analysis.

return. Application of 85% of ET_c provides better marginal rate of return with non-significant yield reduction. Therefore, farmers in this study area should use 85% of ET_c for better yield and water productivity and to earn better incomes.

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