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Evaluation of Onion Response to Deficit Irrigation in Misrak Azernet Woreda, Silte Zone, Rift Valley, Ethiopia

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Abstract

Deficit irrigation improves water productivity and irrigation management practices, resulting in water savings by keeping soil moisture levels below optimal levels during the growing season. This study was conducted to evaluate the response of Onions to deficit irrigation in terms of yield and water productivity in Azernet Berber wore for two years. The experiment had four levels of deficit irrigation (100% ETc, 85% ETc, 70%, 50% ETc and Farmer practice), setted in a three-replication in randomized complete block design (RCBD). Agronomic data were collected and analyzed using SAS 9.0 software. The result of the combined yield shows that the maximum Onion yield of 16.42 ton/ha was observed with 100% ETc and the minimum Onion yield of 12.6 ton/ha with 50% ETc application. The yield of 15.04 ton/ha was obtained by applying 85% ETc has no statistically significant yield difference with 100% ETc application. A water productivity of 2.45 kg/m^3 was obtained from farmer's irrigation practice. The 100% ETc, 85% ETc, and 70% ETc irrigation treatments had acceptable economic returns. Therefore, for maximum Onion yield, 100% ETc/full irrigation/ use was recommended for the study area to produce better Onion yield. When irrigation water was scarce, 85% ETc application was recommended with minimal yield reduction compared to full irrigation as option.

Keywords: ***Deficit irrigation; Etc; Onion; Water productivity***

1. Introduction

Deficit irrigation improves water productivity and irrigation management practices resulting in water saving by maintaining soil moisture content below optimum level throughout growth season. With deficit irrigation, the crop is exposed to a certain level of water stress either during a particular period or throughout the whole growing season [1]. To ensure food security it is must to use the water wisely in order to enhance food production while save water as much possible or in other words to increase water use efficiency of field crops. Besides the increasing demand of water for other purposes (industry and domestic use), degradation of water quality will also limit the water availability for agriculture sector in the coming future [2]. So, the only tool to overcome this phenomenon is the enhancing of water use efficiency, it is also called water productivity. The largest sector of water consumption is agriculture, so increasing water use efficiency will not only increase agriculture production but will also save the water for other purposes.

Onion is one of the important vegetable crops, and it yield, and grade are very responsive to careful irrigation scheduling and maintenance of optimum soil moisture [3]. Therefore, the objective of this study was to identify the level of deficit irrigation effects on yield of Onion with insignificant yield reduction under optimum water use efficiencies in Misrak Azernate Beribere woreda.

2. Methodology

2.1 Description of the study area

The research was conducted at farmers land located in the Misrak Azernet woreda. The study site is located at an altitude 2483 m, longitude 07°51'17"N and latitude 38°02'45". The mean annual temperature ranges from a minimum of 9.3°C to a maximum of 25.7°C.

2.2 Experimental design

The experiment was carried out for two consecutive years (2016/17 and 2017/18). The experiment has five level of treatments (irrigating 100% ETc throughout the season, Irrigating 85% ETc throughout the season, Irrigation of 70% ETc throughout the season, Irrigating 50% ETc throughout the season and farmer practice with three replication arranged in a randomized complete block design (RCBD. Each plot had 14 m^2 (3.5 m × 4.0 m) area. The space between plots and blocks were 1 m and 1.5 m, respectively. The spacing between onion plants and rows kept at 10 cm and 20 cm, respectively.

2.3 Crop establishment and irrigation management

The recommended onion variety called bombe red to the area was selected and used as test crop. Amount of irrigation applied in each irrigation event were measuring by parshall flume. Amount of rain fall during cropping season in the experimental site was measured using plastic rain gauge.

2.4 Soil data

Composite soil samples were collected from experimental site using auger to determine physical properties of soil (soil moisture, texture, Bulk density, field capacity and permanent wilting point) and analyzed in soil laboratory.

Bulk density of the soil was calculated using formula:

$$\mathrm{BD} = \frac{\text{Weight of dry soil(gm)}}{\text{Volume of the same soil(cm}^3\text{)}} \qquad 2.1$$

2.5 Determination of Crop Water Requirement (CWR)

Total available Water (TAW) in the root zone was computed as the difference in moisture content between FC and PWP. It is computed as follows:

$$TAW = \frac{(FC-PWP)*BD*Dr}{100} \qquad 2.2$$

Where: TAW= total available water (mm), Fc = Water content at filed capacity (%).

PWP = Water content at permanent willing point (%), BD bulk density (g/cm^3) and Dr = effective depth of root zone (mm).

The optimal crop water requirement (ETc) and irrigation scheduling were computed from models ET Crop = ETo x Kc (FAO Penman Monteith, FAO Irrigation & Drainage paper No.24, 56, 33, new locClim and Crop wat model 8.0). The reference evapotranspiration was calculated from climate data using CROPWAT software. Net and Gross irrigation were computed from cropwat by considering application efficiency 60%.

The net irrigation in each stage was computed from the following expression:
Net irrigation (mm/stage) = ETc(mm) – effective rain fall(mm)

The gross irrigation requirements for each stage were obtained from the expression:

$$\text{Gross irrigation} = \frac{\text{Net irrigation}}{\text{application efficiency}} \qquad 2.3$$

$$\text{Irrigation interval (days)} = \frac{gross\ irrigation}{ETc}\text{, for each stage} \qquad 2.4$$

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

$$T = \frac{L*W*dg}{6Q} \qquad 2.5$$

Where: T = time in minute, dg = gross depth in cm, L = furrow length in meter, Q = flow rate in l/s, W = furrow width in meter

2.6 Crop water productivity

In crop production water productivity is defined as the ratio of the yield produced from crops to the volume of water required to produce those yield.

$$CWP = \frac{Yield(kg)}{ETc(m3)} \qquad 2.6$$

ETc = Seasonal crop water requirement, CWP = Crop water productivity

2.7 Data collection

The field data such as unit bulb weight and bulb yield weight were taken from each plot. Unit bulb weight was taken by random selection of plants from each plot by excluding the border rows and border plants. At the end of the season the amount of bulb yield produced was harvested and weighted. The harvested yield was grouped based on its quality for market according to the size and degree of damage [4].

2.8 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 [5]. 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 [5]. Hence, it is required to calculate marginal costs with the extra marginal net income. The marginal rate of return (MRR) indicates the increase of the net income, which is produced by each additional unit of expenditures, and it is computed as follows:

$$MRR = \frac{\Delta NI}{\Delta VC} \qquad 2.7$$

Where: MRR = marginal rate of return**,** ΔNI = change in net income and ΔVC = change in variable cost

2.9 Statistical analysis

Data was subjected to ANOVA using SAS 9.0 software. Least Significant Difference (LSD at P = 0.05) was employed to identify different level of deficit irrigation that were significantly different.

3. Result and Discussion

3.1 Soil field and laboratory result for experimental field

The composite soil sample from experimental field was analyzed and the results were presented below in (TABLE 1). An average composition of sand, silt and clay percentages were 35.23%, 28.54% and 36.23%, respectively. Thus, according to the USDA textural soil class of experimental site was clay loam. The bulky density of the soil was (1.01 g/cm^3) which is below the critical threshold level (1.4 g/cm^3) and was suitable for crop root growth. The FC, PWP and infiltration rate of soil were 28.93%, 14.02% and 11.4 mm/hr, respectively.

TABLE 1. **Soil laboratory and Infiltration rate results.**

Parameters	**Result**
Moisture content (%)	8.91
Sand (%)	35.23
Clay (%)	36.23

Silt (%)	28.54
Textural class	Clay loam
Bulk density (gm/cm^3)	1.01
Field capacity (%)	28.93
Permanent wilting point (%)	14.02
Infiltration rate (mm/day)	11.4

3.2 Effect of deficit irrigation on onion

The combined yield results were presented in (TABLE 2). The total bulb yield had maximum (16.42 ton/ha) for the full irrigation treatment, and this was not significantly different to treatment receiving 85% of ETc. The minimum bulb yield (12.59 ton/ha) was obtained from treatment receiving 50% of ETc which is significantly different from 100% ETc and 85% of ETc. The result was agreed with Teferi [6] who observed that irrigation water stress throughout the season significantly decreased onion bulb yield.

Treatment receiving 50% of ETc resulted in maximum water productivity with significant difference from all treatments but it has high yield reduction when compared with 100% ETc and 85% of ETc. The control treatment gave minimum water productivity with highly significant difference with all treatments.

TABLE 2. **Combined effect of deficit irrigation levels on total yield, unit bulb weight and water productivity onion crop.**

Treatment	Water Applied (mm)	Water saved (mm)	TY (ton/ha)	UBW (gm)	WP (kg/m^3)
100% ETc	454.8^{b}	-	16.42^{a}	69.53^{ba}	3.60^{c}
85% of ETc	386.6^{c}	68.2	15.04^{ba}	81.60^{a}	3.90^{bc}
70% of ETc	318.4^{d}	136.4	13.96^{bc}	63.78^{b}	4.36^{b}
50% of ETc	227.4^{e}	227.4	12.59^{c}	61.10^{b}	5.52^{a}
Farmers practice	557.7^{a}	-	13.62^{bc}	67.43^{b}	2.43^{d}
CV (%)	9.98		11.75	15.3	12.41
LSD	46.4		2.53	12.9	0.60

CV- coefficient of variance, LSD- least significant difference ($p \leq 0.05$), NS- non- significant, ETc-crop evapotranspiration

3.3 Economic analysis

The cost and benefit of each treatment was analyzed partially, yield and economic data were computed to compare the advantage of different deficit irrigation level of each treatment. The assumption was made for the operating costs (labor, land preparation, seeds, and fertilizers, implement and number of irrigation events costs) were equal for all irrigation treatments. The only unit water price of the study area was considered as variable cost. The cost of drinking water is considered as irrigation water, since farmers in the study area do not pay for irrigation water. Gross revenue has been calculated by multiplying average yield in kg ha^{-1} of onion market price per kilogram. At the time of harvest the market price of onion was 11 birr per kg and the cost of irrigation water was 5 birr/m^3 (by considering cost of drink water as the cost irrigation water).

TABLE 3. **Net income and marginal rate of return from each treatment per hectare of onion crop.**

Treatments	**AW (m^3/ha)**	**OB (kg/ha)**	**Adjusted Yield (10%)**	**GI birr**	**VC birr**	**NI birr**	**MRR %**
50 % of ETc	2274	12595	11336	124694	11370	113324	
70 % of ETc	3184	13964	12568	138246	15920	122326	199
85 % of ETc	3866	15035	13532	148852	19330	129522	211
100 % ETc	4548	16416	14775	162523	22740	139783	301
Farmers practice	5576	13619	12257	134829	27883.5	106945	D

N:B: AW = Applied water, OB = observed yield, GI = gross income, VC = variable cost, NI = net income, MRR = marginal rate of return

4. Conclusions and Recommendations

Maximum yield 16.42 ton/ha was obtained at 100% ETc irrigation water application while minimum yield 12.6 ton/ha was obtained at 50% of ETc irrigation water application. The yield 15.04 ton/ha obtained from 85% of ETc was statistically insignificant difference with the yield obtained at 100% ETc irrigation water application. In terms of water productivity, 50% ETc deficit irrigation level gave the maximum productivity (5.52 kg/m^3) and minimum water productivity of 2.45 kg/m^3 was recorded from farmer practice. 100 % ETc, 85% of ETc and 70% of ETc had acceptable economic return. Therefore, to achieve maximum onion yield, 100 % ETc/full irrigation/ was recommended for study. When irrigation water is scarce, it was recommended to use 85% of ETc application to save scarce water as option.

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