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Keywords: *irrigation regime, onion yield, water use efficiency.*

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Abstract- This study was conducted for three consecutive years to find an optimum irrigation regime, which allows the maximum yield of onion at Chano-Mille Kebele of Arbaminch Zuria Woreda. The experiment has four levels of irrigation treatments (125%MAD, 100%MAD, 75%MAD and Farmers practice or irrigating with own practice), laid down in Randomized Completed Block Design (RCBD) with four Replications. The highest marketable yield (24.219ton/ha) was obtained from 100% (MAD) where as the lowest marketable yield (17.292ton/ha) was obtained from 75% of MAD. From the result, the highest total yield (28.347 ton/ha) was observed from 100% (MAD), which was significantly different from other treatments. But, statistically, there was no significant differences in total yield among treatments of 125% of MAD (24.026ton/ha), 75% of MAD (20.555ton/ha), and Farmers' practice (20.703ton/ha). Moreover, the application of irrigation water above MAD and below MAD interval reduced total onion yield in the study area. The highest water use efficiency (5.4092kg m^{-3}) was obtained from treatment of 100% (MAD) while the lowest water use efficiency (3.1029 kg m^{-3}) was observed from Farmer practice. Therefore, the application of irrigation water at 100 %(MAD) was an appropriate irrigation amount and interval to obtain better marketable yield, total yield, and water use efficiency without adversely reducing onion yield in the study area.

Keywords: irrigation regime, onion yield, water use efficiency.

I. Introduction

In Ethiopia, where the amount, timing, and distribution of rain fall is irregular, use of irrigation would significantly improve, and raise the level of production (Haile, 2014). The amount of water required by plants and the timing of irrigation is governed by prevailing climatic conditions, crop and stage of growth, soil moisture-holding capacity and the extent of root development as determined by crop type, stage of growth, and soil (Kirda, 2002). Thus, the amount of water required by plants varies from place to place. Irrigation scheduling has conventionally aimed to achieve an optimum water supply for productivity, with soil water content being maintained close to field capacity. In many ways, irrigation scheduling can be regarded as a mature research field that has moved from innovative science into the realms of use, or at most the refinement, of existing practical applications. Nevertheless, in recent years there has been a wide range of proposed novel approaches to irrigation scheduling, which have not yet been widely adopted; many of these are based on sensing the plant response to water deficits rather than sensing the soil moisture status directly (Jones, 1990a).

The increasing worldwide shortages of water and the costs of irrigation are leading to an emphasis on developing methods of irrigation that minimize water use (maximize the water use efficiency). The advent of precision irrigation methods such as trickle irrigation has played a major role in reducing the water required in agricultural and horticultural crops, but has highlighted the need for new methods of accurate irrigation scheduling and control. In recent years it has become clear that maintenance of a slight plant water deficit can improve the partitioning of carbohydrate to reproductive structures such as fruit and also control excessive vegetative growth (Chalmers et al., 1981), giving rise to what has been termed by Chalmers et al. (1986) as 'regulated deficit irrigation' (RDI). The irrigation scheduling consists of two parts; the first part is to determine the water requirement (the right amount of water). This can be done by different methods, like determination the amount of evapotranspiration of the crop. The second part is to estimate the right time to supply the water to plants. There are several methods that can be used to decide when to irrigate the onion crop. Therefore this study was intended to evaluate optimum irrigation regime for better onion yield.

II. Materials and Methods

a) *Study Area Description*

Arbaminch Zuria woreda is one of the 15[th]woredas of Gamo-Gofa Zone in SNNPR. Gamo-Gofa, one of the fourteen zones and four special woredas in SNNPR, which is 505km and 275 km far from Addis Ababa and Hawassa, respectively. The Zone includes 15 woredas with two colorful reform towns, Arbaminch and Sawla. The district comprises numerous hot springs, beautiful lakes, green mountains, forests, caves, cataracts, rivers, jungles, and a variety of flora and fauna with a pleasant climate. These make the zone

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a beautiful destination for tourists. The total area of the woreda is 168,172 hectares, which is divided in to 29 rural Pas, and its total population is 115,916, among them 54,080 male and 61,836 female with house hold 26,931 among the total HH 25,987 MHHH and 944 FHHH. This experiment was conducted in Chano mile kebele, which is geographically located at the longitude of 37^{0}34'59'', the latitude of 06^{0}75'25" and with an elevation of 1192 m a.s.l. The kebele is categorized under kola agro-ecology with hot temperatures and low annual rainfall. Potential crops grown in the woreda especially in the Chano mille kebele were banana, tomato, onion, maize, hot pepper, cotton, etc. But Onion, tomato, and pepper are highly practiced short-season crops. The study area has a high shortage of irrigation water due to inaccessible topography to use Hare Lake in gravity. There is a high competition of irrigation water among the community.

b) Soil Data

Soil is a basic parameter to fix the amount of irrigation water, and irrigation interval for irrigating crop onion. Soil physical and chemical properties like textural class, bulk density, field capacity, permanent wilting point and infiltration rate, acidity organic electric conductivity, organic matter and organic carbon content of the soil were measured in the laboratory.

c) Experimental Design

The experiment contained four treatments and was laid out in a randomized complete block design (RCBD) with four replications. The trial was conducted under the furrow irrigation method. All cultural practices and fertilizer application were done in accordance to the recommendation made for the crop. The amount of irrigation water to be applied at each irrigation application was measured using calibrated parshall flume. Time required to irrigate piece of plot and parshall flume head verses was recorded for each treatment. The treatments were 125% MAD, 100% MAD, 75%MAD and Farmer practice. The experimental field was divided into 16 plots and each plot size was 4m by 4m dimension .Space between plots been 1m and between replication 1.5 m. Space between rows 40 cm and 10 cm between the plants was used. The experimental plot was pre-irrigated one day before transplanting. Before the commencement of treatment, to three common light irrigations was supplied to all plots at three days interval to ensure better plant establishment.

d) Climate Data

Climate data like maximum and minimum air temperature, relative humidity, wind speed, sunshine hours, and rainfall were obtained from CLIMWAT for determination of irrigation schedule and crop water requirement for onion crop.

Table 1: Average climatic data of study area

Month	Min Temp (°C)	Max Temp (°C)	Humidity (%)	Wind (km/day)	rain fall (mm)	ETo (mm/day)
January	16.5	30.7	55	95	35	4.38
February	17.7	31.7	55	104	31	4.75
March	19.2	31.5	59	173	64	5.22
April	18.5	30.5	67	130	129	4.7
May	18.2	28.6	72	104	131	4.2
June	18.6	28.2	67	104	55	3.89
July	18	27.5	66	95	47	3.55
August	18.2	28.1	62	104	54	3.9
September	18.2	29.1	67	86	91	4.07
October	17.8	29.2	67	95	105	4.25
November	16.6	29.7	64	69	60	4.1
December	16.5	30.7	54	69	31	4.11
Average	17.8	29.6	63	102	833	4.26

e) Crop Data

The maximum root zone depth (Rz) of onion ranges between 0.3-0.6 m and has allowable soil water depletion fraction (P) of 0.25 (Andreas et al., 2002). Onion average Kc would be taken after adjustments have been made for initial, mid, and late-season stage to be 0.7, 1.05 and 0.95, respectively. Yield data like economic yield, unmarketable yield, and total yield were measured in the field.

f) Crop Water 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 (Allen *et al*., 1998). 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 (Kc) are important (Doorenbos and Pruitt, 1977). 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.

$$ETc = ETo \times Kc \quad ------- (1)$$

Where: ETc- crop evapotranspiration, Kc-crop coefficient, ET_O-reference evapotranspiration.

g) Irrigation water management

The bulk density is also the ratio of the oven-dried mass of soil to its volume for undisturbed soil condition and is expressed on a dry weight basis of the soil as (Blake, 1965):-

$$Bd = \left(\frac{Md}{V_C}\right) - ------- \quad (2)$$

Where: Bd-bulk density, Md- dry mass of the soil, and Vc-volume of core sampling.

The total available water (TAW), stored in a unit volume of soil will be determined by the expression.

$$TAW = \frac{(FC-PWP)*Bd*Dz}{100} \quad ------- (3)$$

Where: TAW-total available water, FC-field capacity, PWP-permanent wilting point, Bd-bulk density, and Dz-root depth.

For maximum crop production, the irrigation schedule should be fixed based on readily available soil water (RAW). The RAW could be computed from the expression:

$$RAW = (TAW * p) -------- (4)$$

Where, RAW in mm, P is in fraction for allowable/permissible soil moisture depletion for no stress and TAW is total available water in mm.

The depth of irrigation supplied at any time can be obtained from the equation

$$\text{Inet(mm)} = (ETc_{mm} - Peff_{mm}) - --- (5)$$

The gross irrigation requirement was obtained from the expression:

$$GI = \frac{NI}{Ea} -- -------- (6)$$

Where: GI- gross irrigation, NI-net irrigation, and Ea-application efficiency but Ea=application efficiency of the furrows (60%)

The time required to deliver the desired depth of water into each furrow will be calculated using the equation:

$$t = \frac{l*w*dg}{6Q} -- ------- (7)$$

Where: - dg- gross depth of water applied (cm), t-application time (min), l- furrow length in (m), w- furrow width (m), and Q-flow rate (discharge) (l/s).

The amount of irrigation water to be applied at each irrigation application was measured using calibrated Parshall flume.

h) Data Collection

Climate data like maximum and minimum air temperature, relative humidity, wind speed, sunshine hours, and rainfall data were collected to calculate crop water requirement. Soil moisture was determined gravimetrically. The amount of applied water per each irrigation event in four fixed day intervals was measured using calibrated Parshall flume. During harvesting plant height, bulb weight, and bulb diameter were measured from the net harvested area of each plot.

i) Economic Analysis

An economic evaluation of irrigation regime is analyzing the cost that invested during growing season and benefit gained from yield produced by the application of water. Total cost considers variable cost (water cost, labor), and fixed cost (fertilizer cost, seed cost, chemical cost and weed cost) according to seasonal market value. Marginal Rate of Return (MRR) used for analysis following the CIMMYT method (CIMMYT, 1988). Economic water productivity was calculated based on the information obtained at the study site: the size of the 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 were collected to evaluate the benefits of the application of different levels of water in deficit irrigation treatments. Economic data includes input costs like a cost for water (water pricing), seeds, fertilizers, fuel, and labor. However, the cost of water pricing and yield sale price were the only costs that vary between treatments. The net income (NI) treatments were calculated by subtracting total cost (TC) from gross income (GI) and were computed as:

$$NI = (GI - TC) ------- \quad (8)$$

j) Statistical Analysis

Data were analyzed using SAS 9.0 software at the probability of a 5% confidence level. The factor of the experiment was considered a single factorial Randomized Complete Block Design (RCBD) for analysis.

III. Result and Discussion

a) Physical and Chemical Properties of Soil in the Study Area

The soil result of the study area showed that the average composition of sand, silt, and clay percentages was 13% 21% and 66%, respectively. Thus, according to the USDA soil textural classification, the percent particle size determination for the experimental site revealed that the soil texture could be classified as clay soil. The top soil surface had a bulk density of 1.32 g/cm^3. In general, the average bulk density of the study area was 1.32g/cm^3, which is below the critical threshold level 1.4 g/cm^3, and it was suitable for crop root growth. The critical value of bulk density for restricting root growth varies with soil type (Hunt and Gilkes, 1992), but the general bulk density greater than 1.6 g/cm^3 tends to restrict root growth (McKenzie *et al*., 2004). Sandy soils usually have higher bulk densities (1.3–1.7 g/cm^3) than fine silts and clays (1.1–1.6 g/cm^3) because they have larger, but fewer, pore spaces. In clay soils with good soil structure, there is a greater amount of pore space because the particles are very small, and many small pore spaces fit between them. The average moisture content at field capacity of the experimental site soils were 34% and at the permanent wilting point had 16% through one-meter soil depth. Soil pH was found to be at the optimum value (6.0) for onion and other crops. The value of ECe (1.12dS/m) was lower, considering the standard rates in the literature (Landon, 1991). Generally, according to USDA soil classification, a soil with electrical conductivity of less than 2.0 dS/m at 25°C and pH less than 8.5 are classified as normal. Therefore, the soils of the study area are normal soils. The infiltration rate of the study site soil was 6mm/hours.

Table 1: Analyzed soil physical and chemical parameters

Soil data	pH	ECe (dS/m)	%Sand	%clay	%silt	Textural class	Bd (g/cm^3)	PWP (mm/m)	FC (mm/m)
Results	6.0	1.12	13	66	21	Clay	1.32	211.2	448.8

b) The Response of Onion to Different Irrigation Regimes

Analysis of variance revealed that the effects of irrigation amount and irrigation interval resulted in significant variation in marketable yield of onion. The highest marketable yield (24.22ton/ha) was obtained from 100% MAD with using a total of 317.38mm seasonal amount of irrigation water where as the lowest marketable yield (17.29ton/ha) was obtained from treatment of 75% of MAD by using a total of 238.43mm seasonal amount of irrigation water consumed. From analyzed result; highest total yield (28.347 ton/ha) was observed from 100% MAD, but statistically, there was no significant difference among treatments of 125%MAD (24.026ton/ha) with 397.38mm seasonal amount of irrigation water, 75% of MAD (20.555 ton/ha) and Farmer practice (20.703 ton/ha) with 365.59mm amount of irrigation water used. Even though there was no significant difference among the three treatments, the highest total yield was obtained from 125% of MAD (397.38mm amount of irrigation water) next to 100% MAD. Furthermore, from an analyzed result of total yield, the application of irrigation water above MAD and below MAD can reduce onion yield in the study area. Highest water use efficiencies (5.41kg m^{-3}) and (5.22kg m^{-3}) were obtained from treatments of 100% crop water requirement and 75% of MAD respectively while lowest water use efficiencies (3.74 kg m^{-3}) and (3.10 kg m^{-3}) were observed from treatments of 125% of MAD and Farmer practice respectively. From the findings of the experiment, the application of more irrigation water than optimum irrigation water to the field cannot improve water use efficiency with in fixed irrigation intervals.

Table 2: Mean combined values of onion to irrigation amount and interval

Treatments	MY(ton/ha)	UNMY(ton/ha)	TY (ton/ha)	WUE(kg m^{-3})
125% of MAD	20.796^{ab}	3.2295^{ab}	24.026^{b}	3.7362^{b}
MAD	24.219^{a}	4.1278^{a}	28.347^{a}	5.4092^{a}
75% of MAD	17.292^{b}	3.2938^{ab}	20.555^{b}	5.2231^{a}
Farmer Practice	18.839^{b}	1.8634^{b}	20.703^{b}	3.1029^{b}
CV (%)	31.04	77.01	20.90	33.61
LSD (5%)	5.1918	1.9865	4.0336	1.2104

MY–Marketable Yield, TY-Total Yield, WUE-Water Use Efficiency, LSD-Least Significant Difference CV- Coefficient of Variation.

Table 3: The total amount of irrigation water applied in each growing season for each treatment

Growing Stages	Net Irrigation(mm)				Gross irrigation requirement(mm)			
	125% MAD	100% MAD	75% MAD	FP	125% MAD	100% MAD	75% MAD	FP
Initial	27.6	22.1	16.58	25.42	55.13	44.7	33.08	50.72
Dev	85	68.4	51.3	78.66	170.75	136.6	102.6	157.10
Mid	137.25	109.8	82.35	126.3	274.38	219.5	164.63	252.43
End	147	117.6	88.2	135.3	294.13	235.3	176.48	270.60

c) Economic Analysis

The cost-benefit analysis depicted that the highest net income (185,679Birr/ha) was obtained from the treatment level of 100% crop water requirement and the lowest net income (127,586 Birr/ha) was incurred from treatment level of 75% of MAD. The highest benefit-cost ratio, 5.75 was recorded by the full level of water application, and lowest benefit cost ration (4.12) obtained from treatment level of 125% of MAD. Therefore application of full irrigation was economically better and viable for future onion production in the area.

Table 4: Average Partial Budget Analysis

Treatment	MY (kg/ha)	AY (kg/ha)	GI (Birr/ha)	FC (Birr/ha)	VC (Birr/ha)	TC (Birr/ha)	NIR (Birr/ha	B/C ratio
125%MAD	20,796	18,716.4	187,164	15,292	21,250	36542	150,622	4.12
MAD	24,219	21,797.1	217,971	15,292	17,000	32,292	185,679	5.75
75% MAD	17,292	15562.8	155,628	15,292	12,750	28042	127,586	4.55
FP	18,839	16955.1	169,551	15,292	13,223.6	28515.6	141035.4	4.95

MY- Marketable Yield, AY- Adjusted Yield(-10% of MY), GI –Gross Income, FC- Fixed Cost, VC-Variable Cost, TC –Total Cost, NI – net income, B/C – Benefit Cost ratio

IV. Conclusion and Recommendation

Application of the desired amount of irrigation water with appropriate irrigation interval has a significant effect on the yield of onion. From the study, it was observed that the highest marketable yield was obtained from the treatment grown with 100% (MAD) while the lowest highest marketable yield was obtained from 75% of MAD. Application of the amount of irrigation water below and above 100% MAD interval can affect total yield of onion significantly. Maximum water use efficiency was obtained from the treatment level of 100% (MAD). The application of 125% of MAD cannot improve water use efficiency and total yield of Onion. Therefore, it was recommended that the application of 100% (MAD) amount of irrigation water was advisable to improve marketable yield, total yield, and water use efficiency of the Onion crop without affecting yield and water use efficiency in the study area.

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