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EVALUATION OF IRRIGATION REGIME ON TOMATO IN SHEBEDINO WOREDA, SIDAMA REGION, ETHIOPIA

Department of Irrigation Engineering, Southern Agricultural Research Institute, Hawassa Agricultural Research Center, Hawassa, Ethiopia

Aregash Deboch[*1] Worku Nigussie[*2] Zemede Amado*[3]

aregashdeboch@gmail.com, Workunigussie8@gmail.com, zemedeamado6@gmail.com,

Abstract

Irrigation knowledge that saves water is essential to convince the economic and environmental sustainability of commercial agriculture. Accurate irrigation scheduling is serious to improving irrigation efficiency. A field experiment was conducted to evaluate the responses of tomatoes to irrigation regimes (when and how much) and to identify water productivity under optimal irrigation regimes. The study was conducted for two consecutive years at Hawassa Agricultural Research Center, Ethiopia. Four irrigation scheduling (125% MAD, 100% MAD, 75% MAD, and Farmer practice were used. The design of the experiment was arranged in Randomized Complete Block Design (RCBD) which has four replications. Roma VF variety of tomato was used for this experiment. Results showed that tomato marketable, total yield, and water productivity were significantly affected by irrigation scheduling. The highest marketable tomato yields of 42750kg/ha were obtained from treatment 75%MAD irrigation scheduling. The lowest marketable tomato yield of 25250kg/ha was obtained from treatment Farmer practice.

However, from economic analysis results, 100% MAD irrigation scheduling had a better marginal rate of return (5337.5). Therefore, based on the current findings, the application of irrigation scheduling for tomatoes in the study and similar agro-climatic area and soil type application of irrigation scheduling at 100% MAD gives the highest tomato yield and water use efficiency.

Keywords: Irrigation Scheduling, RBCD, MAD, and Water Use Efficiency.

1. Introduction

The main cause of food insecurity in Ethiopia is due to its dependence on rain-fed agriculture and its incapability to develop irrigation potentials. Ethiopia has almost twelve river basins with a would-be to irrigate an assessed area of 3.5 million ha, out of this only 190,000 ha (4.3%) is actually under irrigation (Makombe et al. 2007; Tesfaye et al. 2008). It is shown that an increase in irrigation development is fundamental for reliable and sustainable food security in the country (Awulachew et al. 2007; Awulachew and Merrey 2007; Angood et al. 2002, 2003).

Determining crop yield response to irrigation is essential for crop selection, economic analysis, and performing active irrigation management strategies. Additionally, this assists to know the time of irrigation as well as optimizing yield, water use efficiency, and ultimate profit (Payero et al. 2009). Under inadequate irrigation water supply, irrigation scheduling is also very suitable in determining irrigation strategies. Irrigation scheduling is one of the most essential tools for developing best management practices for irrigated areas (Pejic et al., 2008). Jensen, M.E., (1980) mentioned irrigation scheduling as "decision making and a planning activity that the farm manager or operator of an irrigated farm is involved in before and during most of the growing season". Irrigation scheduling has been termed as the primary tool to increase crop yields, increase water use efficiency, increase the availability of water resources, and aggravate a positive effect on the quality of soil and groundwater. Irrigation scheduling involves making a decision on when and how much to apply it. Three causes affect the irrigation scheduling decision: water availability, water needs by the crop (evapotranspiration), and water holding capacity of the soil (Mohamed and Makki, 2005).

The modern system of irrigation scheduling practices a combination of weather-, soil- or plant-based approaches. This may contain estimating the earliest date to permit effective irrigation or the latest date to avoid the detrimental effects of water stress on the crop (Ritchie and Johnson, 1991).

Generally in Ethiopia and mainly in the Sidama region, even though irrigation has long been accomplished at different farm levels, there is no efficient and well-managed irrigation water practice. It is very little or no information regarding appropriate managing of irrigation water and crop management practices for the quickly expanding small-scale irrigation farms in the country.

This study is, therefore, objective to find out optimal irrigation water scheduling problems of irrigated agriculture.

2. MATERIALS AND METHODS

2.1 Study Area Description

The experiment site is located in Sidama Region at Shebedino Woreda. The area is located 289 km away from Addis Ababa, the capital city of Ethiopia. Shebedino Woreda geographically located a range of 6°48′0″N to 6°58′40″N latitude and 38°18′40″E to 38°34′40″E longitude and the elevation ranges from 1680 to 3960 a.m.s.l. Shebedino is one of the woredas in the Sidama region of Ethiopia.

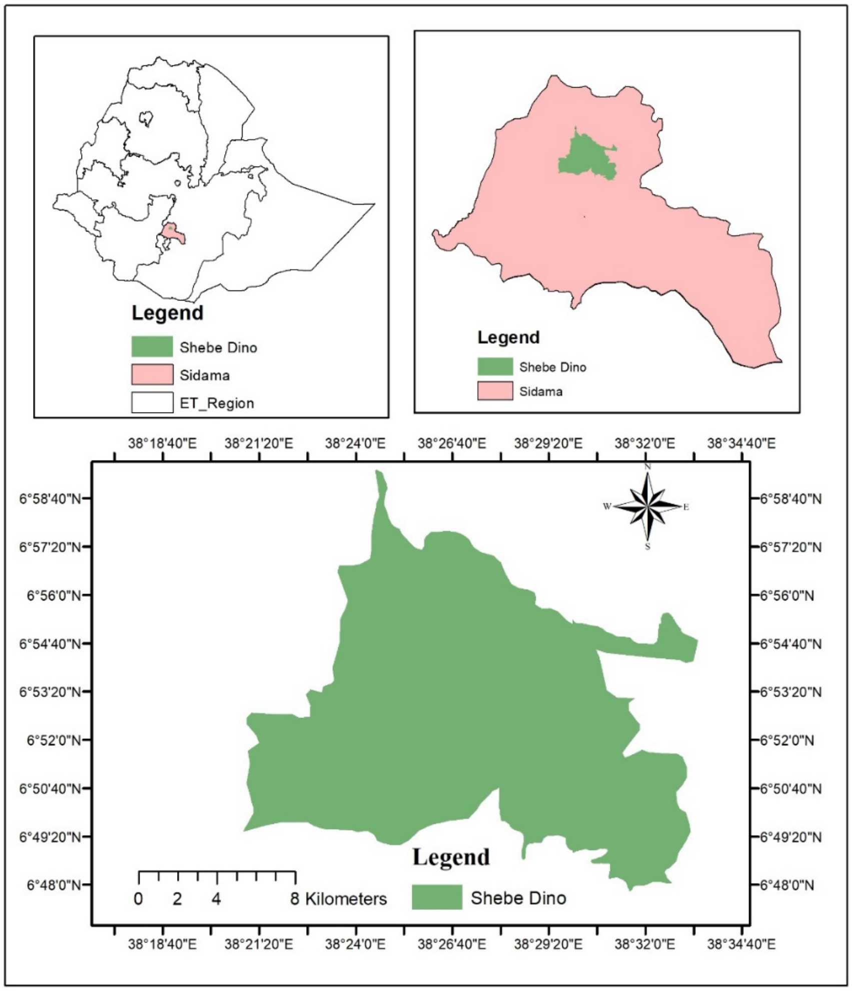

Fig.1. Location map of the study area

2.2 Experimental Design and Treatment

The treatments arrangements were set as completely randomized blocks designed with four-time replications. The depth of applied water to each treatment was measured by Parshall Flume of 3inch throat diameter. The Parshall Flume at the head of 5cm was calibrated and hence the resulting discharge out of the Parshall Flume was 1.705liters per second. Each treatment has a 4 m

× 5 m plot size with 1.5m wide spacing between blocks and 1m free space between plots. The required crop water was calculated by using the CROPWAT version_8 computer program considering the climatic and soil properties of the study area (Allen et al., 1998). Improved tomato variety (Roma VF) which has a total growing period of 45 days after transplanting was grown in seedbeds and transplanted on an experimental plot. This crop variety was selected for its good adaptability, disease resistance, and is most useful in the study area.

The treatment used for the experiment

1. T1= 125%MAD/Management allowable depletion
2. T2 = 100%MAD (based on critical soil moisture depletion level for a particular crop)
3. T3= 75% MAD/ Management allowable depletion
4. T4= Farmer practice (FP)

2.3. Soil Sample Collection and Analysis methods

The disturbed and Undisturbed composite soil sample before planting from each treatment at a depth of 0-20cm, 20-40 cm, and 40-60cm were collected and analyzed for different soil physical properties such as texture, bulk density, permanent wilting point, and field capacity, and also for chemical properties soil pH, at Hawassa Agricultural Research Center Soil Laboratory. Thus, the necessary analyzed soil data were used as input for the CROPWAT model.

2.4. Soil Physical and Chemical Properties

Soil texture was determined using the pipette method. This is done based on a direct sample of the density of the solution. As per Stoke’s law at a depth 'L' below the surface of the suspension and at a time ’t’, all particles whose terminal velocity 'V is greater than that were passed below this level for instance silt passes through but clay remains. The soil PH was measured in a 1:1 soil: water mixture by using a pH meter. The soil bulk density is well-defined as the oven-dry weight of undisturbed soil over in a given volume, as it occurs in the field. It was determined by the core sampler method. We can collect a soil sample from the field and weight the soil sample, then it was placed in an oven-dry at 105oc for 24 hours. After drying the sample, the soil was weighed for a second time for dry mass and the bulk density was calculated by using the following formula.

Pb = Wd/Vv………………………………………………………………… (2.1)

Where

ρb= soil bulk-density, (g/cm3)

Wd = weight of dry soil, (g)

Vc = volume of core sampler, (cm3)

The double ring infiltrometers were used in order to measure the infiltration rate of the soil. The experiments were done at seven randomly particular points in the experimental site and the average result was taken at constant intervals of time. The Water content of permanent wilting point (PWP) and field capacity (FC) was determined by using a pressure plate apparatus by applying a suction of 1/3 and 15 bars to a saturated soil sample and when water is no longer leaving the soil sample, the soil moisture was taken as FC and PWP respectively and the PH was measured in a 1:1 soil: water mixture by using a pH meter.

2.5. Crop Data

The effective root zone depth (RZD) of tomato was ranged between 0.7-1.5m and it has an allowable soil water depletion fraction (P) of 0.40(Andreas et al., 2002). Tomato average Kc would be taken after adjustments have been completed for the initial, mid, and late-season stage to be 0.6, 1.15, and 0.8, respectively (Allen et al., 1998).

2.6. Crop Water Determination

Crop evapotranspiration refers to the amount of water that is lost through evapotranspiration whereas Crop water requirement refers to the amount of water that needs to be supplied, (Allen et al., 1998). Based on the determination of crop water requirement, the effect of climate on crop water requirement, which is the reference crop evapotranspiration (ETo), and the effect of crop characteristics (Kc) are very important (Doorenbos and Pruitt, 1977). The long period and daily climate data such as 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, a 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.

$ETc = ETo * Kc$-- (2.2)

Where, ETc = crop evapotranspiration, Kc = crop coefficient and

ETO = reference evapotranspiration

2.7. Irrigation Water Management

Total available water (TAW), stored in a unit volume of soil can be obtained from the equation:

$TEW = (FC - PWP) * BD * Dz)/100$…………………………………………… (2.3)

The depth of irrigation water supplied at any time was determined by the expression

$Inet\ (mm) = ETc(mm) - Peff(mm)$…………………………………………… (2.4)

The gross irrigation requirement will be found from the expression:

$Ig = In/Ea$……………………………………………………………………. (2.5)

Ea =application efficiency of the furrows (60%)

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

$t = (d * l * w)/(6 * Q)$………………………………………………………….. (2.6)

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

2.8. Data Collection

Soil moisture was determined by the gravimetrical method and the Amount of applied water per all irrigation events was measured using an adjusted Parshall flume. During harvesting, the weight of economical yield, fruit number, unmarketable fruit weight, and unmarketable fruit number was measured from the net harvested area of each plot.

Meteorological like: minimum and maximum temperature, relative humidity, wind speed, and daily sunshine hours were collected from the nearby weather stations to determine reference crop evapotranspiration (Table 3). Evapotranspiration was calculated by using the Modified FAO Penman-Monteith method (Allen et al., 1998**).**

Table.3. Mean monthly meteorological data and ETO value of the study area

Month	Min Temp °C	Max Temp °C	Humidity %	Wind km/day	Sun hours	Rad MJ/m²/day	ETo mm/day
January	8.8	28.5	83	104	8.5	20.5	3.87
February	9.5	29	78	104	8	20.9	4.11
March	10.6	29	84	130	7.4	20.8	4.18
April	11.1	27.2	92	104	7.5	21	3.93
May	11.1	26.7	95	104	7.2	19.9	3.67
June	11.1	25.2	97	138	6.6	18.6	3.27
July	12.1	23.7	94	104	4.6	15.8	2.86
August	12.8	24.1	94	104	4.8	16.5	3.01
September	12.1	24.6	98	69	6.1	18.7	3.35
October	11.6	25.7	89	69	7.8	20.7	3.73
November	10.1	26.3	91	86	8.6	20.8	3.66
December	10.1	27.5	79	95	8.3	19.8	3.68
Average	10.9	26.5	90	101	7.1	19.5	3.61

2.9. Economic Analysis

Economical estimation of deficit irrigation is evaluating the cost spent during the growing season and the benefit gained from yield produced by the application of water. As illustrated in different literature, Marginal Rate of Return (MRR) was used for interpretation by the CYMMYT method (CIMMYT, 1988). Economic water productivity was calculated based on the information acquired at the study site: the size of the irrigable area, the price of water applied, and the income gained from the sale of tomato yield in view of the local market price. Yield and economic data were collected in order 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 cost that varies between treatments. The net income (NI) of the treatments were calculated by subtracting total cost (TC) from gross income (GI) and were computed as

NI= (GI-TC………………………………………………………….……….. (2.7)

The difference between the net income of treatment and its next higher variable cost treatment is termed as a change in net income (ΔNI). Higher net benefits from the economical analysis may very much higher costs (CIMMYT, 1988). Therefore, it is required to calculate marginal costs with the extra marginal net income. The marginal rate of return (MRR) shows the increase of the net income, which is produced by each additional unit of expenditures and it is computed as follows:

MRR= (ΔNI/ΔVC)……………………………………………………………………… (2.8)

Where, MRR= marginal rate of return, ΔVC= change in variable cost and

ΔNI= change in net income

2.9. Statistical Analysis

The collected data were analyzed using Statistical Agricultural Software (SAS 9.0) and the least significant difference (LSD) was employed to see a mean difference between treatments and the data collected was statistically analyzed following the standard procedures applicable for RCBD with a factorial. The treatment means that were different at 5% levels of significance were separated using the LSD test.

3. Results and Discussion

3.1 Physical and Chemical properties of Soil

As indicated in Table 2 the average composition of sand, silt, and clay percentages were 50.75%, 33%, and 16.25%, 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 loam soil. The soil of the trial experimental site is classified as loam and study place soil has an average bulk density of 1.3g/cm3 and the pH of the site is 6.4. The bulk density shows a slight decrease with depth. This could be because of a slight decrease of organic matter with depth and compaction due to the weight of the overlying soil layer (Brady and Weil, 2002).

Table.2. Input soil data for CROPWAT model

Soil property		Soil depth in (cm)				
		0-20	20-40	40-60	60-80	Average
Particle size Distribution	Sand (%)	47	45	55	56	50.75
	Silt (%)	31	32	34	35	33
	Clay (%)	22	23	11	9	16.25
Textural class		Loam	Loam	Sandy loam	Sandy loam	Loam
Bulk density (g/cm3)		1.30	1.27	1.24	1.19	1.3
FC (Vol %)		17	16	13	15	15.3
PWP (Vol %)		9	8	6	7	7.5
PH		6.35	6.4	6.45	6.5	6.4

Where: FC, Bd, and PWP were field capacity, bulk density, and permanent wilting point, respectively. The basic infiltration rate in this experiment was found to be 10 mm/hr.

This means that a water layer of 10 mm on the soil surface will take one hour to infiltrate. In dry season soil, water infiltrates rapidly and as more water replaces the air in the pores, the water from the soil surface infiltrates more slowly and eventually reaches a basic infiltration rate. The Irrigation water that is applied to the experimental plot was done using 3-inch Parshall flume at 5 cm head. The gross amount of water applied to each one plot was gained by multiplying the net irrigation depth of water by application efficiency. The amount of water required by tomatoes was increased from the initial period to the mid-period. From the initial period to the mid-period, the tomato was attained its maximum crop coefficient and there was high reference evapotranspiration. At the late period, the water required was reduced due to the reduction of crop coefficient value.

3.2. Response of Tomato Yield to Irrigation Scheduling

The mean marketable yield of tomato was significant ($P < 0.05$) difference on the different treatments of Management allowable depletion (MAD). The highest marketable tomato yield was obtained from treatments which received 75% MAD with the result of 42750kg/ha and the lowest marketable tomato yield was (25250kg/ha) was recorded from the treatment of Farmer practice. The mean total tomato yield was significant ($P < 0.05$) difference on the different treatments of Management allowable depletion (MAD). The highest total tomato yield (43962.5kg/ ha) was obtained from the treatment of 75% MAD. On the other hand, the lowest value of the total yield of tomato (26362.5kg/ha) was recorded from the treatment of farmer practice.

Table.3. Effects of optimal irrigation scheduling on yield

No	TRT	MY	UMY	TY
1	T1= 125%MAD	29000.0c	1275.0ab	30275.0c
2	T2 = MAD	34437.5b	1412.5a	35850.0b
3	T3= 75% MAD	42750.0a	1212.5ab	43962.5a
4	T4= Farmer practice	25250.0d	1112.5b	26362.5d
	LSD	2527.2	215.5	2476.6
	CV	7.5	16.7	7.0

*Means followed by different letters in a column differ significantly and those followed by the same letter are not significantly different at $P < 0.05$; LSD= least significant difference; CV = Coefficient of variation.

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3.3. Water Use Efficiency of tomato

The effect of different irrigation scheduling levels was significant ($P < 0.05$) on tomato water productivity. As showed in Table 4, the highest mean value of irrigation water use efficiency was observed to be 20.2kg/m3 on irrigation scheduling with 75% MAD and minimum mean value (11.9kg/m3) for treatments of Farmer practice. The highest mean value of crop water use efficiency was observed to be 7.6kg/m3 on irrigation scheduling with 75% MAD and minimum mean value (4.5kg/m3) for treatments of Farmer practice. Due to the reason of too much water frequently irrigated water and low water productivity.

Table.3. Effects of optimal irrigation scheduling on water productivity

No	TRT	CWUE (kg/m^3)	IWUE (kg/m^3)

1	T1= 125%MAD	5.2c	13.7c
2	T2 =100% MAD	6.1b	16.2b
3	T3= 75% MAD	7.6a	20.2a
4	T4= Farmer practice	4.5d	11.9d
	LSD	0.4	1.2
	CV	7.5	7.4

TRT= Treatment, CWUE= Crop water use efficiency, IWUE Irrigation water use efficiency

3.4. Economic analysis of the interaction effects of irrigation systems and water application levels

The cost-benefit ratio for each treatment was analyzed and income was computed based on the current local market price of tomatoes at Shebedino Woreda. At the time of harvest, the market price of tomato was 10 birr per kg and the cost of irrigation water was 10 birr/m3 (by considering the cost of drink water as the cost of irrigation water). To evaluate by the producer of dominance analysis, the treatments were set in their sort of increasing variable cost, and their equivalent benefits were put aside. Farmer practice and 75% MAD showed the minimum and maximum variable costs respectively. Based on the current prices of tomato yield produced and input costs required for production, the economic analysis was carried out. The highest net income (378500 birr/ha) was obtained at (75% MAD) and the least net income (210000birr/ha) was obtained at (Farmer practice). However, as is indicated in the table the largest MRR (5337.5%) was acquired at 100%MAD.

Table 4: Economic analysis of irrigation scheduling on tomato

No	TRT	AW (m3/ha)	OY (kg/ha)	GI (birr/ha)	FC (birr/ha)	VC (birr/ha)	TC (birr/ha)	NI (birr/ha)	MRR (%)
1	Farmer practice	10000	25250	252500	19500	23000	42500	210000	0
2	125%MAD	7500	29000	290000	19500	25500	45000	245000	1400
3	100%MAD	7500	34437.5	344375	19500	26500	46000	298375	5337.5
4	75% MAD	7500	42750	427500	19500	29500	49000	378500	2670.8

AW= Applied water, Ay = Adjusted yield, GI=Gross income, FC= Fixed cost, TRT= treatment, VC=Variable cost, TC=Total cost, NI=Net income, MRR=Marginal rate of return, D=Domination

Therefore, the highest economic return was observed at (100%MAD of CWR through the growing season) with net income of 298375birr/ha and MRR of 5337.5%. The MRR tells us that the amount of additional income obtained for every 1 birr spent. Hence, (100%MAD) of CWR through the growing season) acquired an additional 53.3birr for every 1birr spent. The minimum acceptable marginal rate of return (MRR) should be between 50 and 100% (CIMMYT, 1988).

4. Conclusion and Recommendation

The experiment was conducted to study the effect of irrigation scheduling on tomato yield and water use efficiency. The result showed that there was a significant difference among the treatments regarding yield, water use efficiency, and irrigation water use efficiency of tomatoes. Based on the obtained results of the effect of different irrigation schedules, the highest marketable tomato yield was obtained from the treatment (100%MAD) which is 34437.5kg/ha. On the other hand, the higher Crop water use efficiency, and IWUE Irrigation water use efficiency of tomato was obtained from the treatment (75% MAD) which is 7.6 kg/m3 and 20.2 kg/m3 respectively.

However, the highest economic return with a net income of 298375birr/ha was obtained under (100%MAD) irrigation scheduling. From economic analysis results, (100%MAD) system is better in the marginal rate of return and is the best technology among the tested technologies to be recommended for the communities of the study area, because of its yield performance, time, labor, and irrigation cost saving.

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