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Investigating the Effect of Deficit Irrigation on Tomato (*Lycopersicon Esculentum Mill*) Production and Water Productivity: in Case of Mychew SSI Schemes, Tigray, Ethiopia

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Author's contribution

The sole author designed, analysed, interpreted and prepared the manuscript.

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ABSTRACT

There are different methods to wisely utilization of the available irrigation water. From these estimation of crop water requirements and its scheduling is very important. Hence, in Mychew SSI scheme yet not estimated the appropriate irrigation depth and its scheduling for tomatoes. Therefore, this research deals with three different irrigation depths (100% CWR, 75% CWR and 50% CWR) compare with farmer practices. The experiment was conducted in Tigray, Ethiopia, with the objective of this experiment were to verify the FAO CROPWAT software to estimate the CWR of tomatoes, to determine the seasonal irrigation depth, and to schedule irrigation time for optimal tomato production as compared to farmers' irrigation practices. The collected data subjected to two-way analysis of variance (ANOVA), while irrigation water related performance indicators were

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computed using equations. Based on the validated software, the estimated CWR using CROPWAT software was 560.8 mm and this can be saved 35.22% irrigation water from the farmer practices. The irrigation intervals were 3 days, 5 days, 7 days, and 7 days for the initial, development, mid-season, and late-season stages, respectively. The irrigation water saving were 35.22% from the farmer practices and this can be irrigated about 0.35 hectares of irrigable land. Therefore, in the study area, which is dominated by sandy loam soil and its agro ecological classification is Kolla; the CWR should not be less than 75% of the estimated CWR to gain the optimum crop production. The 100% CWR and its irrigation scheduling are recommended for enhancement of tomatoes production and irrigation water saving.

Keywords: *CROPWAT software; irrigation depth; scheduling; farmer practices; CWR.*

1. INTRODUCTION

Ethiopia is a landlocked country, with a land area of 1.13 million km^2 [1]. It is endowed with ample water resources, with 12 river basins with an annual runoff volume of 124 billion m^3 and an essential ranges from 2.6 billion m^3 to 30 billion m^3 of groundwater potential [2]. According to [3], about 80% of Ethiopians live in rural areas, which mainly consist of smallholder households and being rural. They dependent on agriculture with a low level of productivity [4]. Besides, the increment of population from time to time and climate change worsens the problems of food insecurity through land degradation, deforestation and diminishing sources of water. Hence, to overcome these problems, there are different solutions searched by different researchers. Accordingly, water resources (irrigation water) management on farms is a very key solution for enhancement of crop production and productivity to eradication of poverty. This is not only to decrease poverty but also to create jobs for the youth and different community members. Agricultural production through diversification and intensification of crops grown, increase household income because of on/off/non-farm employment, source of animal feed, improving human health due to a balanced diet and easy access and utilization for medication, soil and ecology degradation prevention, and asset ownership are contributions of small-scale irrigation [5].

Irrigation practices can be applied either supplemental or full, designed to permit farming in arid regions and to offset the effect of drought in semi-arid regions [6]. Even in areas where total seasonal rainfall is adequate on average, it may be poorly distributed during the year and variable from year to year [7]. Despite the more advantage of irrigation, majority of population of Ethiopia is dependent on rainfed agricultural production for its livelihood. Based on [5], the government of Ethiopia transforms the rain-fed agricultural system that depends on rainfall into the combined rain-fed and irrigation agricultural system. Since, in many decades, Ethiopian government introduced and implemented the small-scale irrigation as an important component enhancing the food security of the community as well as the country development.

Based on different authors [8,9 and 10], these schemes doesn’t achieves its objectives. Because, due to lack of awareness and frequent training about water application, management, operation, and maintenance for the water users and water committee. In addition to this, the expertise of district, development agent, and other body didn’t estimate the CWR, its irrigation scheduling, amount of available irrigation water, and its planned irrigable land.

Based on [11 and 12], as with other SSI schemes in Ethiopia, especially Tigray, the Mychew SSI scheme, irrigation water is a critically limiting factor. Furthermore, irrigation water-related conflicts among farmers or irrigation users are becoming a usual problem. This is because the crop's water requirement for different crops that are grown in this scheme is not yet estimated. While the farmers’ want to maximize production and profits through making decisions regard to planting date, crop type, irrigable area, and irrigation water management, which affect the amount of irrigation water available and also all members of the scheme to be irrigated their lands. Tomato crop is the major crop which is grown in the scheme. The objective of this study was to analyze the effect of deficit irrigation on tomato production and water productivity, thereby improving scheme productivity. The study will contribute to bettering tomato fruit productivity and water resource management. Also, it serves as a guide for making choices regarding upcoming planning.

2. METHODOLOGY

2.1 Description of the Study Area

This study was conducted at the Mychew small-scale irrigation scheme, Keih Tekli district, Tigray regional state, Ethiopia (Fig. 1). Keih Tekli district founds 110 km far from Mekelle the capital city of Tigray. The district has altitude ranges from 1218 to 2559 meter above sea level mean annual rainfall is 500 to 800 mm, and temperature is 16 to 29^{0}C [13]. The agro-ecologically the district classified as Weyna Dega (91.79%), Kolla (6.29%), Degua (1.92%) [13]. Geographically, the study site lies at latitude 13°45”2.06'N and longitude 39°5” 33.04'E and an altitude 1666 meter above sea level. The average annual temperature of the study area range between 27 and 30°C, and the rainfall is a uni-modal pattern and ranged between 350 and 700 mm, with the rainfall normally falling in June and August.

2.2 Experimental Design, Treatment Set Up and Agronomic Management

The experimental design was laid out in randomized complete block design (RCBD) with three replications. As mentioned in the introduction, the irrigation water in the scheme becomes scarce from time to time, so the crop water requirements, which were used in this experiment so as to save the irrigation water and add the irrigated land (including all members in one season of irrigation) estimated through the FAO CROPWAT software, were estimated from 100% to 50%. There were four treatments which composed of different irrigation water levels namely: 1) farmers practices, 2) 100% of ETc, 3) 75% of ETc and 4) 50% of ETC (Table 1).

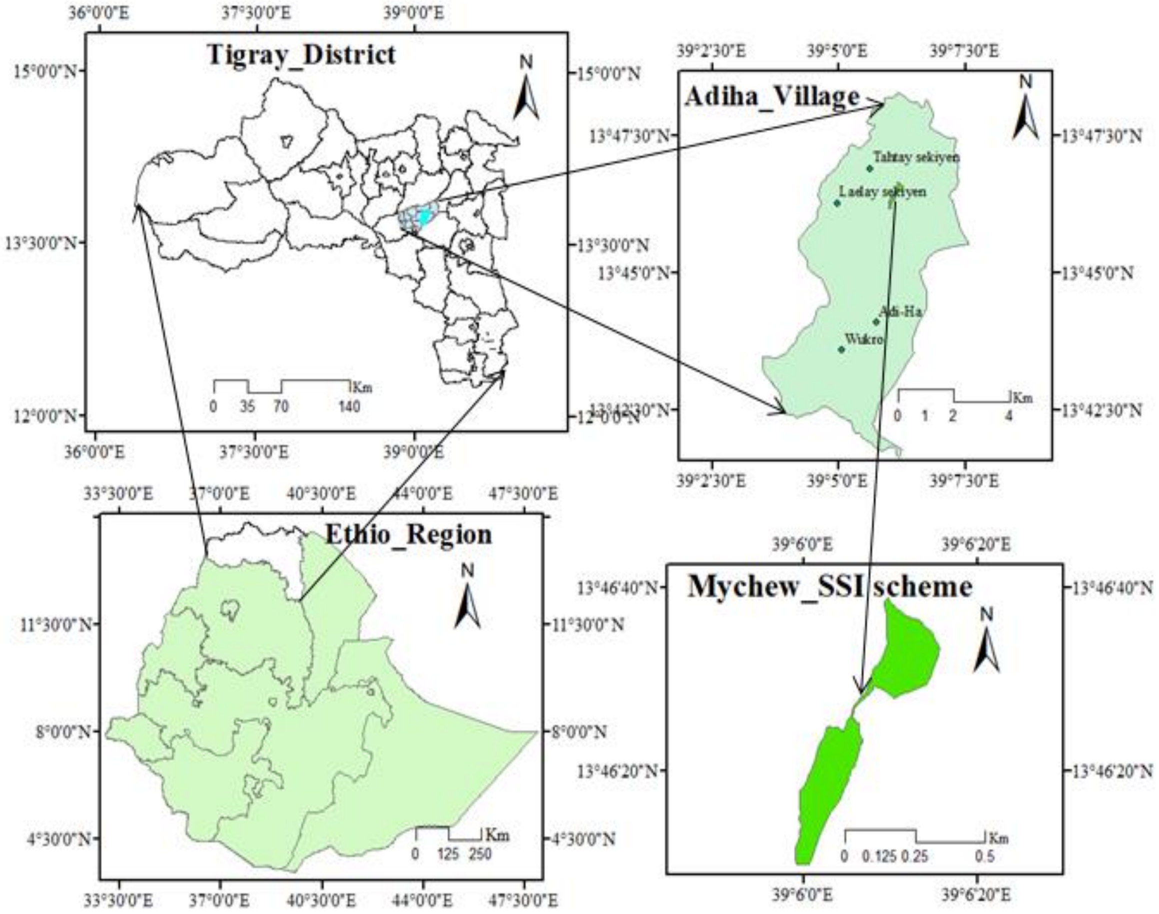

Fig. 1. Map of the study area

Table 1. Treatment settings for field experiment

Treatments	Description
T_1	Watering based on the farmer practices (FP)
T_2	Penman–Monteith methods estimation of Crop water requirement (CWR) 100% (100%CWR)
T_3	Watering 75% of the CWR (75%CWR)
T_4	Watering 50% of the CWR (50%CWR)

The plot size was 3 x 3.5 meters, with 1.5 meter and 1 meter spacing between blocks and plots, respectively. The spacing between furrow and plant were 70cm and 30cm, respectively. The experiment was conducted for two year in 2019 and 2020 in the same site. Tomato crop was identified as the most preferred horticulture crop in the study area. Therefore, based on different verities selection at Abergelle Agricultural Research Center (AbARC) through crop research core process Roma VF tomato variety was highly performed in the study area.

Land preparation for the field experimental site was done properly. The experimental field was irrigated to reach field capacity and seedlings were transplanted to wetted plots. Based on [14], before starting treatment applied on the experimental plots, plants were irrigated to field capacity for three weeks in order to improve root development.

2.3 Determination of Crop Water Requirement (CWR) and its Irrigation Scheduling

Climatic data for this experimental site was collected from Ethiopian national meteorological agency (ENMA). This data includes daily rain fall, minimum and maximum temperature from 1987 to 2017 for the period of 30 years. Whereas, the humidity, wind speed, sunshine hours data were collected from New_LocClim_1.10 software using selection location by coordination (latitude 13°45”2.06'N and longitude 39°5” 33.04'E and altitude 1666) (Table 2). And these were adjusted to a monthly scale for analysis. Likewise, crop characteristics (Kc, critical depletion (fraction), yield response (f), growing period, Kc), the agronomic data (sowing date, length of growing period) and soil data (field capacity, Manageable soil depletion (MAD), PWP) were collected from interviewing of community, district office and related literature [15].

The crop water requirement (CWR) of tomato and its gross irrigation was determined using the Penman-Monteith equation through CROPWAT 8.0 software [16]. Because this software allows the development of irrigation schedules for different management conditions and is easily adopted by the kebele and district expertise. There was no rainfall during in the experimental season in both years. Accordingly, monthly rainfall was taken as zero (0). An irrigation application efficiency of 65 % was considered to determine the gross irrigation water requirement [4]. Based on this, the irrigation intervals were determined through interviews with the farmers.

2.4 Irrigation Water Management and Flow Measurement

The estimated gross irrigation water (Dap) and watering practices of the farmers were conveyed to experimental plots through a two-inch Parshall flume, which was installed at the entrance of the supply ditch. A two-inch Parshall flume was used to measure the amount of irrigation depth for all plots. Based on [17], the water application duration was computed.

The experimental plot was watered through the procedure, as the duration of water application for the field was divided by the number of furrows on the plot, and the duration of water application for the furrows was then controlled by the stopwatch for uniform application. Based on [18], the amount of water for each furrow was added until it reached 95% of the average run length on the average of all furrows. Furrows subjected to irrigation were open-ended. However, water does not exceed the edge of the plot, because it flows through the parallel furrows. Whereas other furrows not irrigated were closed-ended. The water in the channel was controlled through a minimum discharge from 5 cm to 10 cm head of the Parshall flume during the irrigation event.

Table 2. Summary of climatic data

Month	Min Temp	Max Temp	*Humidity	*Wind	*Sun	*Rad	*ETo
	°C	°C	%	km/day	hours	MJ/m?/day	mm/day
January	14.1	28.7	66	130	10	20.9	4.1
February	15.5	30.3	64	138	10.3	23	4.76
March	17	31.5	62	147	9.9	24.1	5.31
April	18.5	31.7	59	147	9.9	24.8	5.66
May	17.7	30.2	52	173	9.7	24.3	5.76
June	17.2	30.5	55	156	8.8	22.6	5.41
July	15.3	25.3	85	147	5.5	17.7	3.56
August	15.3	24.6	88	147	4.6	16.5	3.17
September	15.8	26.6	69	147	8.7	22.3	4.49
October	16.2	28.2	72	173	9.9	22.8	4.61
November	15.6	28	78	112	10	21.2	3.98
December	13.8	27.7	67	104	9.8	20	3.75
Average	16	28.6	68	143	8.9	21.7	4.55

*Sources; [15] and *New_LocClim_1.10 software*

2.5 Method of Data Collection

2.5.1 Soil sampling, infiltration rate and crop root depth

The composite soil samples were collected from 0 – 20 cm and 20 – 40 cm depth of the soil using a soil auger to analysis the physiochemical characteristics of the experimental site. The physic-chemical characteristics of the sampled soil were analyzed in Mekelle soil research center laboratory. The soil infiltration rate was measured using the double-ring infiltrometer at the field level before the first watering and land preparation. Soil moisture content for experimental plots was measured through undisturbed soil samples which were collected through a soil core sampler. Its moisture contents were estimated through gravimetrical method at 30 cm soil depth; it is the maximum root hair depth. In these two years experimental season one plot (3 X 3.5m size) was taken to measure the maximum root depth and plant height of tomatoes so as to adjust the root depth and plant height into the FAO software, soil water content characteristics for actual on field, observation and in laboratory test.

2.5.2 Agronomic data collection

The agronomic data, which was very sensitive through different methods of irrigation scheduling such as plant height (cm), fruit number per plant, fruit diameter (cm), and fruit length (cm), marketable yield (kg ha^{-1}), unmarketable yield (kg ha^{-1}) and total fresh yield (kg ha^{-1}) were collected from each experimental plots. These parameters were taken from the middle of the experimental plots (1 m x 1 m) to minimize the boarder effect and change into hectare using Equation 1.

Yield obtain (kg ha^{-1}) = yield obtained per square meter (kg) * 10^4 Equation 1

2.6 Performances Indicators

These performances indicators of the experiment have been analyzed through the following performances indicator measurement using the gross irrigation, marketable yield and its market value as input.

2.6.1 Irrigation water productivity (IWP)

Based on different researchers [19,20 and 21] agricultural water productivity is a measure of the output of a given system in relation to the water it consumes. So it is the net return for a unit of water used. Therefore, this is quantified based on [22].

2.6.2 Economical irrigation water productivity (EIWP) (ETB m^{-3})

As explained in [21], the economic irrigation water productivity (EWP) relates to the economic benefits per unit of water used, so the note was taken in Ethiopian birr so as to understand our farmers.

2.6.3 Amount of irrigation water saved (IWS)

Based on [23], the amount of water saved from the different treatments was evaluated. This is done through the procedure of subtracting the water used by a particular irrigation scheduling method from the farmer's practices. The farmer's watering practice was considered a control for each treatment.

2.6.4 Additional Irrigable Land (AIL)

Based on [23 and 17], the more irrigable land was estimated using Equation 2.

$$\text{AIL} = \frac{Control\ irrigation\ scheduling - other\ treatments}{Control\ irrigation\ scheduling} * 1\ \text{ha} \quad \text{or}$$

$$\text{AIL} = \text{WS} * 1\text{ha} \qquad \text{Equation 2}$$

2.7 Statistical Analysis

A two-way analysis of variance (ANOVA) was used to analyze the collected two years experimental results/row data. LSD was used for the mean separation ($P < 0.05$) between treatments. All statistics were performed with the program IBM SPSS Statistics 20 [24]. Additionally, the performances analysis was analyzed using Microsoft excel 2010.

3. RESULTS AND DISCUSSION

3.1 Physiochemical Characteristic of the Experimental Site and Root Depth

The infiltration rate of the experimental site was found to be 23 mm/hr. Also, as illustrated in Table 3, the soil texture is dominated by sandy loam. And its pH, electrical conductivity (EC), soil organic matter (OC), cation exchange capacity, available nitrogen (TN), and phosphorus (av. P) were 7.79, 0.16 Ms/Cm, 2.17%, 21.79 meq/100 gm of soil, 4.42 ppm, and 0.109 %, respectively.

Based on Table 4, the maximum average root depth and its height in the experimental site were found to be 69.4 cm and 57 cm, respectively. Since then, these root depths and plant heights were adopted into the CROPWAT 8.0 software to estimate 100% of the CWR. This is similar with the rage of FAO_33 [14].

3.2 Crop (Tomato) Water Requirements (CWR) and Irrigation Scheduling

The CWR tomato of the study area was determined through the software to be 544.6 mm, while the CWR actually measured on the field was 344mm. Hence, the gross irrigation water requirement for 100% of ETc was found to be 560.8 mm. The irrigation water levels for 75% and 50% of ETc were determined accordingly (Table 5). Despite the difference in water level all treatments had similar irrigation intervals. The amount water applied by the farmers practice was found to be higher that 100% ETC which was estimated through the CROPWAT software. This result indicated 9.3% more water applied by farmers. This is similar with [21] result which was found that the farmers watered their farm 10% more than the CWR, [25] also found that the farmers use water 12.2% above the estimated water requirement of tomato.

Hence, the irrigation intervals were set to be 3-days, 5-days, 7-days, and 7-days for the initial, development, mid-season, and late-season stages, respectively. Similar results were reported by [26,25,27 and 28] were gain 495.5mm, 500mm, 488.64 and 433.2mm, respectively, for the 100% CWR of tomatoes using FAO CROPWAT software.

3.3 Correlation Functions of the Growth and Yield Parameters

The correlation functions depending on the different irrigation scheduling of the growth and yield parameters of tomato presented in Table 6. Hence, the relationship between fruit diameter is positive and significantly correlated with plant height and fruit weight. Moreover, marketable yield with plant height, total yield with plant height, and total yield with marketable yields were significant differences at the 0.01 level (2-tailed).

3.4 Effect of Different Irrigation Water Levels

As illustrated in Table 7, the summery of ANOVA results for different watering system during the study years, the treatments were significantly differences for all variables. But, in block or replication there were not significantly differences in all variables.

3.4.1 Yield and yield component

As illustrated in Table 8 (Pooled Analysis), different irrigation scheduling methods had a significant effect on the yield and yield components of tomatoes. Since the 100% CWR have the highest plant height (61.97 cm), marketable yield (39.25 tons/ha), and total yield (39.25 tons/ha). While there are not significant

Table 3. Physicochemical characteristics of the experimental site

Soil sample	Parameters						Texture			
	pH	EC	OC	CEC	AV.P	TN	Sand	Silt	Clay	Class/USDA
		Ms/Cm	%	Meq/100gm soil	ppm	%	%	%	%	
0 – 20	7.97	0.18	2.098	24.208	4.478	0.105	68	12	20	Sandy Loam
20 - 40	7.78	0.16	2.003	24.243	4.391	0.1	84	4	12	Sandy Loam
0 - 20	7.45	0.14	2.193	15.478	5.382	0.11	78	4	18	Sandy Loam
20 - 40	7.97	0.16	2.399	23.249	3.439	0.12	82	6	12	Sandy Loam
Average	7.79	0.16	2.17	21.79	4.42	0.11				

Table 4. Root depth and crop height

Parameters	Root depth (cm)						Plant height (cm)					
Date	R_1	R_2	R_3	R_4	R_5	Average	H_1	H_2	H_3	H_4	H_5	Average
30/05/2011	27	52	38	38	86	48.2	45	46	47	36	43	43.4
25/06/2011	55	48	43	83	90	63.8	50	36	50	55	65	51.2
23/05/2012	48	29	39	43	68	45.4	52	40	60	63	70	57
24/06/2012	85	42	54	75	91	69.4	41	47	32	62	50	46.4

Table 5. Irrigation scheduling's for different type of irrigation scheduling treatment

Treatment	Average Irrigation depth (mm/season)	Irrigation interval			
		Initial Stage	Development Stage	Mid-Season Stage	Late-Season Stage
T_1	816.5	3	5	7	7
T_2	560.8	3	5	7	7
T_3	420.6	3	5	7	7
T_4	280.4	3	5	7	7

where; T_1 is the CWR recorded based on the watering and irrigation interval system of the farmers, i.e., farmers practice (FP). T_2 is the crop water requirement (CWR) estimated based on actual the Penman-Monteith equation, T_3 and T_4 is 75% and 50% of crop water requirement (CWR) estimated based on actual the Penman-Monteith equation, respectively

Table 6. Correlations for the experimental results

	Plant height (cm)	Fruit diameter (cm)	Fruit weight (g)	Marketable yield (ton/ha)	Unmarketable yield (ton/ha)	Total yield (ton/ha)
PH (cm)	1					
FD (cm)	0.413*	1				
FW (g)	0.378	0.513*	1			
MY ton/ha	0.606**	0.325	0.234	1		
UMY ton/ha	-0.302	-0.283	-0.245	-0.156	1	
TY(ton/ha)	0.572**	0.074	0.224	0.892**	0.030	1

Table 7. ANOVA for different watering system during the study years

Source		SS	df	MS	F	Sig.
Rep	PH (cm)	76.56	2	76.56	4.67	0.05
	FD (cm)	0.25	2	0.25	2.14	0.16
	FW (g)	6.25	2	6.25	3.46	0.08
	MY ton/ha	249.71	2	249.71	2.62	0.13
	UMY ton/ha	2.04	2	2.04	0.30	0.59
	TY(ton/ha)	193.90	2	193.90	1.71	0.21
Trt	PH (cm)	696.13	3	232.04	14.14	0.00
	FD (cm)	6.13	3	2.04	17.50	0.00
	FW (g)	25.79	3	8.60	4.76	0.02
	MY ton/ha	3870.60	3	1290.20	13.55	0.00
	UMY ton/ha	81.49	3	27.16	3.98	0.03
	TY(ton/ha)	7188.09	3	2396.03	21.08	0.00
Year	PH (cm)	3.38	1	3.38	0.21	0.66
	FD (cm)	7.04	1	7.04	60.36	0.00
	FW (g)	18.38	1	18.38	10.18	0.01
	MY ton/ha	301.06	1	301.06	3.16	0.10
	UMY ton/ha	24.15	1	24.15	3.54	0.08
	TY(ton/ha)	2559.43	1	2559.43	22.52	0.00
Trt * Year	PH (cm)	220.46	3	73.49	4.48	0.02
	FD (cm)	2.46	3	0.82	7.02	0.00
	FW (g)	3.46	3	1.15	0.64	0.60
	MY ton/ha	23.36	3	7.79	0.08	0.97
	UMY ton/ha	19.97	3	6.66	0.98	0.43
	TY(ton/ha)	737.44	3	245.81	2.16	0.13

Table 8. Yield and yield component of Tomato for the different irrigation scheduling methods

Year _I Analysis

Trt	Plant height (cm)	Fruit diameter (cm)	Fruit weight (g)	Marketable yield (ton/ha)	Unmarketable yield (ton/ha)	Total yield (ton/ha)
T_1	49.8^{c}	5.7	7.577	34.3^{b}	1.55	35.85^{b}
T_2	61.97^{a}	6.213	8.09	38.97^{a}	0.28	39.25^{a}
T_3	55.86^{b}	4.693	7.293	31.29^{b}	2.23	33.52^{b}
T_4	47.41^{c}	4.083	6.207	23.5^{b}	4.25	27.75^{b}

Year_II Analysis

Trt	Plant height (cm)	Fruit diameter (cm)	Fruit weight (g)	Marketable yield (ton/ha)	Unmarketable yield (ton/ha)	Total yield (ton/ha)
T_1	59.81^{ab}	6.36	9.54^{ab}	35.5^{ab}	3.336^{ab}	38.836^{ab}
T_2	62.67^{a}	6.44	10.607^{a}	39.24^{a}	0.12^{c}	39.36^{a}
T_3	49.03^{bc}	6.18	8.513^{ab}	25.95^{bc}	3.213^{b}	29.162^{b}
T_4	46.87^{c}	5.84	7.058^{b}	20.08^{c}	6.77^{a}	26.87^{c}

Pooled Analysis

Trt	Plant height (cm)	Fruit diameter (cm)	Fruit weight (g)	Marketable yield (ton/ha)	Unmarketable yield (ton/ha)	Total yield (ton/ha)
T_1	54.8 ± 8.92^{b}	6.03 ± 0.42^{a}	8.558 ± 1.60^{a}	34.93 ± 3.01^{b}	7.945 ± 1.20	37.343 ± 3.19^{b}
T_2	62.32 ± 2.59^{a}	6.327 ± 0.67^{a}	9.348 ± 2.17^{a}	39.11 ± 0.54^{a}	4.367 ± 0.10	39.305 ± 0.52^{a}
T_3	52.45 ± 6.63^{b}	5.437 ± 0.91^{b}	7.903 ± 1.55^{ab}	28.62 ± 3.40^{bc}	4.224 ± 1.27	31.343 ± 2.96^{bc}
T_4	47.14 ± 4.79^{c}	4.962 ± 1.26^{c}	6.633 ± 2.10^{b}	21.79 ± 2.18^{c}	8.013 ± 2.49	27.31 ± 2.11^{c}

where; T_1 is watering based on the farmer practices, T_2 is 100% of the CWR, T_3 is 75% of the CWR and T_4 is 50% of the CWR, which were estimated using the verified Penman-Monteith methods

Table 9. Irrigation water productivity and its water saving in two experimental years

Trt	Year	Marketable Yield (kg/ha)	Irrigation Depth (mm)	Irrigation Water (m^3)	Irrigation water productivity (kg m^{-3})	Irrigation water saving (%)	Additional irrigable land (ha)
T_1	I	53730	813.9	8139	6.60	0	0
	II	46250	819.1	8191	5.65	0	0
Average		49990	816.5	8165	6.12	0	0
T_2	I	62660	524.5	5245	11.95	35.56	0.36
	II	64910	533.3	5333	12.17	34.89	0.35
Average		63785	528.9	5289	12.06	35.22	0.35
T_3	I	49020	393.4	3934	12.46	51.66	0.52
	II	42110	400	4000	10.53	51.17	0.51
Average		45565	396.7	3967	11.49	51.42	0.51
T_4	I	36810	262.25	2622.5	14.04	67.78	0.68
	II	32600	266.65	2666.5	12.23	67.45	0.67
Average		34705	264.45	2644.5	13.12	67.61	0.68

where; T_1 is watering based on the farmer practices, T_2 is 100% of the CWR, T_3 is 75% of the CWR and T_4 is 50% of the CWR, which were estimated using the verified Penman-Monteith methods

differences between irrigation scheduling by farmers and the 100% CWR in fruit diameter and fruit weight. Even though the unmarketable yield in 100% CWR was less than the other treatments, the 75% and 50% of CWR gain the highest unmarketable yield than other treatments. This is the irrigation water application is very less than its required. Therefore, this indicated the CWR should not be less than 75% of its CWR, in the study area which is estimated by the FAO method. This study agree with the idea of [25], the reduction in fruit yield might be due to unfavorable moisture conditions during tomato growth (extremely water stressed).

Generally, when comparing the marketable tomato yield, it increased by 10.53%, 51.21%, and 95.42% for estimated tomato CWR compared to the farmer practices, 75% CWR and 50% CWR application, respectively. Since the marketable yield in 100% CWR estimated using CROPWAT is more effective than other treatments, like [25] found 29 t/ha in the 100% CWR, [25] also gained 38.53 ton/ha, and [28] statistically highest total yield of fruits per hectare was obtained from normal/estimated/CWR. Based on this, when estimating the optimum CWR at 100% using the adjusting criteria, it is more advantageous to properly manage the irrigation water in scarcity irrigation schemes like the Mychew SSI scheme.

3.4.2 Irrigation Water Productivity (IWP)

As indicated in Table 9, the result of tomato irrigation water productivity was 6.12 kg m^{-3} and 12.06 kg m^{-3} for farmer practices and 100% CWR estimated by CROPWAT, respectively. From this experiment observed as the amount of irrigation water application decreased, the IWP increased (13.12 kg m^{-3} at 50% CWR) but in the study area its soil texture is Sandy loam soil, since, below 75% CWR estimating using FAO CROPWAT is not recommended.

This is similarly results also found in [20] were gain 14.42 kg m^{-3} and 9.01 kg m^{-3} for the FAO CROPWAT and farmer practices, respectively; by [21] as an appropriate estimate of the CWR of the tomato crop; [29] was found 13.7 kg m^{-3}, 16.2 kg m^{-3}, 20.2 kg m^{-3}, for 125% CWR, 100%CWR and 75%CWR, respectively; and [26] found 7.28 kg m^{-3}. Generally, when estimated, the CWR of tomatoes using CROPWAT software for scheduling the irrigation practice and water resource management system can increase irrigation water productivity of crops.

3.4.3 Amount of irrigation water saved (IWS)

Based on Table 9, the IWS were 35.22%, 51.42% and 67.61% through 100% CWR, 50% CWR and 75% CWR, respectively from the farmer practices. When considering the yield redaction through the 50% CWR and 75% CWR watering system, below 75% CWR application was not recommended for the study area. Hence, the estimated crop water requirement of tomatoes through FAO CROPWAT software saved irrigation water compared to farmer practice. Similar results found by [21], i.e. 3127.33 m^{-3}, water from one hectare at the 100% CWR which was estimated using the FAO CROPWAT software.

3.4.4 Additional irrigable land (AIL)

As indicated in Table 9, 0.35ha was can be irrigated through the saved irrigation water when the CWR and its irrigation time was estimated through CROPWAT software and also this software input was adjusted into our site using the climatic data, soil and crop characteristics. As discussed [19], about 0.59 ha additional irrigation land can be irrigated by the save irrigation water.

4. CONCLUSIONS AND RECOMMENDATIONS

This study was conducted to analyze the response of deficit irrigation on tomato (*lycopersicon esculentum mill*) yield and water productivity. The soil texture of the study site was found to be sandy loam. The seasonal CWR, which were estimated using verified CROPWAT software, was determined as 344 mm, and 560.8 mm, respectively. It decreased the application of irrigation water by 9.3% from the farmer practices. The crop water requirement and gross irrigation requirement of tomato yield were also increased by 10.53% compared to the farmer practices. The level of depth of irrigation water application in growing tomatoes significantly affects its marketable yield and total fruit yield. Additionally, the irrigation water savings were 35.22% from the farmer practices. It is concluded that under a furrow irrigation system, appropriate application of estimated tomato CWR through flow measuring devices can allow tomato growers to obtain a higher profitable yield.

The application deficit irrigation at 75% and 50% of CWR penalized the yield significantly and cannot be recommended for the study area because its soil texture is a sandy loam soil (it has low water holding capacity) and the agro-ecological classification are Kola. This recommended result of CWR for tomato can be applied in other areas that have similar agroecology and soil texture to this study area.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

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COMPETING INTERESTS

Author has declared that no competing interests exist.

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