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Demonstration and Participatory Evaluation of Different Furrow Irrigation under Tomato Production at Sayo District, Kellem Wollega Zone, Western Oromia

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Abstract
Alternate, conventional and fixed furrow irrigation systems are the three furrow irrigation systems demonstrated and participatory evaluated at Sayo District of Western Oromia on the basis of water use efficiency without a significant tradeoff in yield under Tomato production. Randomized Complete Block Design with three replications for one season was used. "Farmers Research Extension Group" had selected alternate furrow irrigation system by setting their observations as the easiness of a system to use by irrigators, can save more water, time and labor. In this study, yield obtained from alternate and conventional furrow irrigation methods show insignificant difference while the alternate furrow method used lesser water input. Time and labor reduced by half under deficits and suits working conditions as technique permits irrigator to move towards the next irrigable area. The substantial amount of water saved under alternate furrow irrigation demonstrates that crop water use efficiency was increased by using the system which may result in substantial benefits, under limited water and labor conditions, improved flexibility in irrigation water management are also expected to be achieved using alternate furrow irrigation. The water thus saved may be used to irrigate additional area that would provide additional crop production. Based on this study, alternate furrow irrigation system appears to be a promising option for water conservation and labor saving without negligible trade-off in yield.
Keywords: Alternate furrow irrigation system, yield, Water-Use-Efficiency
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1. INTRODUCTION

Surface irrigation is the application of water by gravity flow to the surface of the field – the practice of thousands of years old. It collectively represents perhaps as much as 95% of common irrigation activity (FAO, 1989). The popularity of this irrigation type is due to its affordability by their initial investment cost, not by efficiency in maximizing water utilization when compared to sprinkler and drip irrigation methods. Consequently, furrow irrigation technique is commonly used especially for production of row crops.

To enhance crop production under water deficit or overcome toxicity related to over irrigation, it is better to irrigate crops closing the right amount; thereby avoid risk in production with irrigation and cultivate diverse crops in a year – ensures food security.

Productivity of Tomato, the 2nd most important horticultural crop next to potato, is nearly 27 tons per hectare (Doorenbos, J. and W. O. Pruitt, 2001). It has a 90 - 150 days growing period. Optimum mean daily temperature for growth is 18 to 25ºC with night temperatures between 10 and 20ºC. Larger differences between day and night temperatures, however, adversely affect yield. The crop is very sensitive to frost. The crop can be grown on a wide range of soils but a well-drained, light loam soil with pH of 5 to 7 is preferred. Water logging increases the incidence of diseases such as bacterial wilt. The fertilizer requirements, for high producing varieties, are on average 125 kg/ha N, 85 kg/ha P and 200 kg/ha K.

Tomato seedling is generally raised on seed beds with about 10 days of emergency after sowing, from where it is transplanted to a field after 30 days. A spacing of 0.6m by 1m is optional. This crop, being sensitive to salinity, produces well only at ECe below 2.5 mmhos/cm, whereas total loss of the yield is attained at 12.5. Tomato is sensitive to salinity mostly at germination and development stages.

Therefore, this investigation was executed by anticipating determination of water requirement of Tomato at the study site and popularization of more water saving furrow irrigation technique.

2. REVIEW OF LITERATURES

2.1. Role of Irrigation in Feeding the World

Water plays a crucial role in food production. It is estimated that 80% of the additional production required to meet the demands of the future will have to come from intensification and yield increase. Improved moisture control and irrigation are essential to achieve these. The major agricultural water is used for irrigation, which is affected by decreased supply (Czech Republic 2010). Hence, innovations are needed to increase the efficiency of use of the water that is available. Management of agricultural water to increase water productivity and efficiency is very important.

2.2. Concept of Alternate, Fixed and Conventional Furrow Irrigations

2.2.1. Alternate furrow irrigation systems (AFI)

Alternate furrow irrigation system is a water application method that minimizes moist surface which reduces evapotranspiration and deep percolation losses (Jinfeng Wang *et al*., 2007). This system saves substantial amount of water and is incredibly important in areas of water scarcity and salt problems (Majumdar, 2002). Alternate furrow irrigation maintained high grain yield with up to 50% reduction in irrigation amount, while Fixed Furrow Irrigation resulted in a considerable yield decrease (Jinfeng Wang *et al.,* 2007). Therefore, alternate furrow irrigation is an effective water-saving irrigation method in moisture stress areas (Kang *et al*., 2000). AFI tender opportunity for minimizing irrigable area and then shorten irrigation time with a given amount of water; a water saving mechanism which results in improvement of the irrigation water use efficiency.

2.2.2. Fixed Furrow Irrigation (FFI)

FFI system supplies water to one side of each furrow ridge. This method of irrigation may be convenient on gentle slopes or on soils with low infiltration rates. Investigation shows that this furrow irrigation method results in yields comparable to those achieved from conventional furrow irrigation. Irrigation water application may be reduced 20% to 30% by employing conventional furrow irrigation. Usually, FFI applies water to more area in a given amount of time than does irrigating every other furrow (Brian L. *et al*., 2000). Generally, Fixed Furrow Irrigation technique is characterized by lower yield and higher WUE (Kang *et al*., 2000)

2.2.3. Conventional Furrow Irrigation (CFI)

CFI option is irrigating every furrow where 51-54% of the total water applied is used to moisten agricultural soil, 20-25% for infiltration, 5-6% for evaporation, and 18-21% for tail water loss. Irrigation water losses through deep percolation and tail water accounts to nearly 40% of total water applied that minimizes the water use efficiency. Besides, this irrigation system accelerates rate of decomposition and leaching of organic elements in the root zone which results in soil fertility losses. Evapotranspiration loss is more from higher amount of wet soil and deep percolation in the CFI system observed (Graterol *et al*. 1993)

A comparative evaluation has been undertaken between conventional and alternative irrigation water management options under maize production on yield and water productivity concepts (Mintesinot *et al*., 2004). Yield-based comparison has shown that conventional furrow generates the highest yield followed by alternate furrows method. The yield increase alternative furrow irrigation over the Conventional furrow system was found to be 54%. Water productivity based comparison has shown that alternate furrows irrigation results in the highest water productivity values followed by conventional furrow irrigation. The increase (by alternate furrow irrigation, scientific scheduling) over the conventional irrigation system was 58%. Economic productivity-based comparison has shown that the highest economic return (by 54%) was obtained from the alternative furrow method over conventional furrow irrigation.

3. MATERIALS AND METHODOLOGY

3.1. Description of the study area

This research was conducted at Sayo District, Kellem Wollega Zone of Oromia National Regional State during 2020. The altitude of the study site is 1582 meter above sea level with latitude and longitude of $8^0$33'N, $34^0$50'E. Soil texture is clay loam. The reference evapotranspiration (ET_o) was calculated from monthly climatic data obtained from the Ethiopian National Meteorological Service Agency.

3.2. Experimental treatments and design

This research was evaluated by social participation and biological approach.

3.2.1. Biological evaluation

Randomized Complete Block Design with three times replication as employed. Three furrow irrigation methods with full ET_c was demonstrated and evaluated. Appropriate soil physico chemical characteristics were tested during the experimentation period. CROPWAT was used to compute Crop Water need; yields were analyzed with SAS tool. Plot areas were 3mx4m each. Parshall flume of 3 inch was used to measure discharge. Irrigation water application efficiency parameters used for computation storage efficiency, water use efficiency and water productivity were collected and analyzed.

3.2.2. Through demonstration and participatory evaluation

Farmers Research Group (FRG) having 20 members was formed around the study area. Three furrow irrigation systems were demonstrated for the established FRG and they participated in the evaluation of the system from starting of the experiment to the end of it for the purpose of selecting which system compatible and valuable depending on available resources for the study area. Group discussion about the objective of the demonstration was done with the FRG members, development agents and farmers representatives of the study area. Supporting guidelines on how to determine; "when" and "how much" to irrigate and how to measure the amount of water passing through the Parshall flume was prepared and distributed for technical assistance and farmers. Irrigation water application efficiency parameters used for computation of storage efficiency, water use efficiency and water productivity were collected and analyzed.

3.3. Flow time measurement

Advance and recession times were the necessary parameters to determine the flow time and were intensively monitored using stopwatch during irrigation. Data on irrigation water depth was recorded at all irrigation events from discharge at Parshall flume and length of irrigation time.

Advance rate

The advance time recorded and the total length that the water travels were the two parameters used to decide the advance rate. Advance rate is the ratio of the length that the waterfront travels to the time required to cover the same length. It is computed using the formula:

$$\text{Ar} = \frac{LT}{AT}$$

Where Ar = advance rate (m/s)
LT = length (m) traveled by waterfront, and
AT = time (s) taken by water to reach the tail end

3.4. Data analyses and computations

The computations were conducted by SAS for biological data analysis and SPSS for social parts. In both cases, LSD at 5% tests was computed for mean comparisons.

3.5. Yield assessments

In order to see the effect of treatments on tomato production, yields were collected from each plot ignoring boarders. All possible calculations including conversion to area were done following standard procedures.

3.6. Water use efficiency

Water use efficiency is the yield harvested per unit volume of water (kg/m^3). This term can determine whether the irrigation water application was efficient or not. It has two types:

3.6.1. Total (crop) water use efficiency is the yield harvested per ha-mm of total water used.

$$\text{CWUE} = \frac{Y}{ET}$$

where CWUE = (kg/ha-mm), Y= yield (kg ha^{-1}) and ET= is evapotranspiration in mm

3.6.2. Irrigation water use efficiency is the yield harvested per ha-mm of net depth infiltrated.

$$\text{IWUE} = \frac{Y}{I.gross}$$

where; IWUE= field water use efficiency (kg/ha-mm) Y= yield in (kg/ha).

4. RESULTS AND DISCUSSION

4.1. Soil Analysis

The soil physical (texture, organic carbon, bulk density, water retention at FC and PWP and pH) and chemical characteristics were analyzed at Ethiopian national soil test that the result was presented in table 4.1. The soil in the experimental site, being clay, had moderately low infiltration and moderate organic matter content. Field capacity and permanent wilting point were respectively 34.19 and 23.70 % for the upper 30 cm. The bulk density was 1.09 g/cm^3.

Table 4.1 Soil laboratory analysis result.

Depth (cm)	pH H_2O 1:2.5	O.C (%)	M.C %	FC by % vol.	PWP by % vol.	Sand (%)	Silt (%)	Clay (%)	Class
0-30	6.0	2.92	11	34.19	23.70	27	26	47	Clay

Soil texture was determined using pipette method. Organic carbon content was determined by titration method (Mandare, A.B., 2008). Moisture contents at field capacity and permanent wilting point were measured using a pressure plate apparatus at Ethiopian Construction Design and Supervision Works Corporation Laboratory by applying pressures at 0.33 and 15 bars, respectively. The moisture content of the soil samples on volume basis were determined by multiplying the gravimetric water content on weight basis by the bulk density.

4.2. Water Requirement of Tomato

Crop water need is the quantity of water required by a crop in a given period of time for its normal growth under field conditions at a place. Estimation of the water requirement of a crop is one of the basic needs for crop planning on the farm.

4.2.1. Reference evapotranspiration (ET_o)

Reference evapotranspiration of the study site for each growth stage of the crop was estimated using CROPWAT model. This computer program uses meteorological data (solar radiation, sunshine hours, maximum and minimum temperatures, relative humidity and wind speed) in order to compute ET_o.

Table 4.2 The mean metrological data and ET_o of the study site.

Month	Min. Temp (^0C)	Max. Temp (^0C)	RH (%)	WS (km/d)	Sunshine (hr)	ET_o (mm/day)
January	8.4	28.1	51	1	8.7	3.18
February	9.8	29.8	46	1	8.7	3.5
March	11.6	30.1	47	1	7.4	3.58
April	13.0	29.5	51	1	7.0	3.63
May	13.7	26.6	70	1	6.2	3.45
June	13.7	23.8	83	1	4.4	2.93
July	13.3	22.6	85	1	4.0	2.79
August	13.2	22.7	85	1	5.0	3.06
September	13.0	24.0	82	1	5.9	3.32
October	11.7	24.7	78	1	6.4	3.26
November	9.8	25.7	69	1	7.0	3.06
December	8.7	26.9	59	1	7.5	2.93
Av	**11.7**	**26.2**	**67**	**1**	**6.5**	**3.22**

The values of ET_o estimated by the tool based on climatological parameters need to be adjusted for actual crop ET. The crop water requirement of Tomato is calculated by multiplying the ET_o with crop coefficient (K_c) is presented in Table 4.3.

Table 4.3. Irrigation event and Tomato crop water need.

Date	Day	Kc	ETo (mm/day)	ETc (mm/day)	CWR ETc(mm/dec)	Eff rain (mm/dec)	Irr. req (mm/dec)	Flow (l/s/ha)
12 Feb	0	0.6	3.5	2.1	21.0	0.0	21.0	-
20 Feb	10	0.6	3.5	2.12	16.9	1.0	15.9	0.35
2 March	10	0.66	3.58	2.35	23.5	2.9	20.7	0.34
12March	20	0.83	3.58	2.99	29.9	4.0	25.9	0.39
22March	30	1.02	3.58	3.66	40.2	10.2	30.0	0.49
1April	40	1.12	3.63	4.05	40.5	15.7	24.8	0.52
11 April	50	1.12	3.63	4.08	40.8	20.8	20.0	0.50
21 April	60	1.12	3.63	4.01	40.1	31.5	8.6	0.47
1 May	70	1.04	3.45	3.64	36.4	49.8	0.0	0.33
11 May	80	0.85	3.45	2.94	29.4	63.4	0.0	0.29
21 May	90	0.75	3.45	2.46	2.5	4.1	2.5	-
Total					321.2			

Based on this output, the seasonal irrigation requirement was found to be 321.2 mm.

4.3. Yield, water use efficiencies and advance rate

4.3.1. Yield.

Anticipating the yield performance of the three irrigation systems comparison, yield of Tomato was harvested from every treatment avoiding border lines, weighed and converted to hectare basis. The results obtained are presented in table 4.4.

Table 4.4. Effects of irrigation system on yield, CWUE, IWUE and Advance rate

Treatments	Yield	CWUE	IWUE	Advance Rate
CFI	31233^a	97.24^a	98.68^a	0.152^a
AFI	27674 ^{a}	86.16^a	87.44^a	0.12^b
FFI	17155^b	53.41^b	54.2^b	0.152^a
CV	17.69	17.69	17.69	2.34
LSD	9904.4	30.84	31.29	0.38

Explanation: *Different letters indicate significant differences between the means ($P < 0.05$)

The ANOVA showed that the effects of irrigation system significantly ($P < 0.05$) affected the yield of tomato (Table 4.4). The highest yield (31233 kg ha^{-1}) was obtained with the system of traditional furrow irrigation that has no significant difference with the yield obtained under the alternate furrow irrigation (27674 kg ha^{-1}) whereas the lowest yield (17155 kg ha^{-1}) was obtained with the fixed furrow irrigation system.

The above Table (4.4) also shows that there was significant difference between the yields obtained under CFI and FFI treatments. Nevertheless, there was no significant difference between CFI and AFI treatments. But there was a significant reduction (50%) in the volume of water applied to the AFI treatments. The possible reason might be due to AFI has better application efficiency. This result agrees with the result of Graterol *et al*. (1993) that irrigation water significantly lost under CFI. Besides, the plant physiology associated with AFI (Kang *et al*., 2000) and less evapotranspiration associated with AFI (Stone *et al*., 1989) shows similar trend.

4.3.2. Crop water use efficiency

The CWUE was computed by the formula (Section 2.6) and the results were presented in Table 4.4; indicates that insignificant difference for CWUE under both alternate and conventional furrow irrigation methods observed. This shows that the alternate furrow irrigation system is as important as the conventional. The total water used by alternate and fixed furrow irrigation methods reduced by half that contribute to increment of area to be irritated. This also agrees with the significant improvements in CWUE that have been associated with alternate furrow irrigation (Zhang *et al*., 2000).

4.3.3. Irrigation water use efficiency

Alternate and conventional furrow irrigation systems are significantly different ($P<0.05$) from fixed furrow irrigation systems under IWUE (Table 4.4) whereas AFI and CFI are same; they are equally important regardless of other merits.

4.3.4. Advance rate

The results of statistical analysis showed (Table 4.4) alternate furrow irrigation method was different significantly for the advance rate parameter. In alternate furrow, water advanced more slowly compared to fixed and conventional furrow systems. The possible reasons for this result could be due to the difference in soil-water potential between the three systems.

Table 4.5. Pair wise ranking of the irrigation system

System	LS	WS	TS	ET	Frequency	Rank
LS		WS	TS	ET	-	4th
WS			WS	ET	2	2nd
TS				ET	1	3rd
ET					3	1st

Table 4.6. Farmers selection criteria

System	Reasons for its selection	System rank
CFI	Most water lost by evapotranspiration, most labor and time consumed, easier to use than that of alternate and fixed irrigation technology.	3rd
AFI	Best irrigation system to save labor, most water saving, less time consumed to irrigate, somewhat complex to use of technology for the farmers at the beginning	1st
FFI	Medium water saving capacity, optimum for saving labor and time, easier to use than that conventional irrigation system	2nd

5. CONCLUSION

Demonstration and participatory evaluation of conventional, alternative and fixed furrow irrigation methods at Sayo District, Kellem Wollega zone under tomato production was conducted successfully. Their performance evaluation made in terms of yield, water use efficiency and advance rate. Measurements of necessary parameters (field slope, basic infiltration rate of the soil, advance rate, discharge rate, soil moisture before and after irrigation event) were employed on the field. LSD was used to differentiate the means.

Alternate furrow irrigation system was considered as improved irrigation water management technique and its net benefits was evaluated against both fixed and conventional furrow irrigation systems; and saves irrigation water and labor without a significant yield reduction of Tomato.

Since the alternate furrow irrigation required less cost of water and labor, it is recommended as economically feasible technique. In other ways, according to evaluation of the nearby society (FRG), alternate furrow irrigation system was selected based on obtained benefits, hence compatible. This demonstrates that the technique got an acceptance in advance manner that one can promote without repeating the field experiment.

The Tomato water use efficiency was increased under alternate furrow irrigation system which may result in substantial benefits under limited water condition, labor saving and improves flexibility in farm irrigation water management (Mebrahtu Yemane, 2018). This result has of significant importance in areas where irrigation water is limited and irrigate additional land.

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