Research Paper

Effect of alternate furrow irrigation with different irrigation intervals on tomato (Lycopersicon E.) yield and water use efficiency

Accepted 10th June 2021

ABSTRACT

An experiment was conducted in Eastern Ethiopia of Harari Regional State of Erer Woldiya district, on farmers’ field for two years. The purpose of this study was to evaluate the effect of AFI and EFI with different irrigation intervals on growth component, yield and water use efficiency of tomato for two years, 2018 and 2019. Accordingly, plant height and NFPP were significantly (P<0.05) influenced by IMs, whereas (IIs) had highly significant (P<0.01) effect on plant height and NFPP at both planting season. Total tomato yield was significantly influenced (P<0.05) by furrow IMs, but application frequency was highly significant (p<0.01). Water saved from treatment combination of AFI with 4, 6 and 8 days water IIs were 16, 44 and 58% of total volume of irrigation water applied. Whereas water saved from EFI with 6 and 8 days of application was 33.3 and 50%, respectively. AFI with 4 day water application showed little yield reduction of 4.97%, as compared with no stressed treatment; EFI with the same water application frequency. But AFI with 4 day II saved 16% water from gross water applied for no stressed treatment, EFI with 4 day. Treatment with 6 day II of AFI and EFI showed significant yield reduction of 15.74 and 14.61%, respectively. But total amount of gross volume of irrigation water saved was 44 and 33.3% respectively for AFI and EFI of the same II treatment. Crop water productivity (CWUE, IWUE and EWP) were highly significantly (P<0.01) influenced by both IMs and IIs. The result clearly confirms that, AFI had beneficial advantage over EFI on water saving and, the same consequent occurred in terms of irrigation interval, that is, increasing interval from 4 day followed by 6 to 8 days increases water use efficiency of crop. Hence the result indicates that interaction effect of both factors (IMs and IIs) could save significant amount of irrigation water.

Key words: Irrigation methods, irrigation intervals, tomato, growth, yield parameters, water productivity.

INTRODUCTION

Agriculture is the largest freshwater user on the planet, consuming more than two thirds of total withdrawals (Gan et al., 2013). In many parts of the world, irrigation water has been over-exploited and over-used (Chai et al., 2014a), and freshwater shortage is becoming critical in the arid and semiarid areas of the world (Forouzani and Karami, 2011). About 93% of the available fresh water resources are currently utilized in the agricultural sector (Bhangar and Saima, 2008). The increasing population has resulted in demand for more food and fiber, which is met through increasing irrigated agriculture. It is critical therefore that management and utilization of available water resources is improved at all scales; from catchment, to irrigated district, to farm and field scale.

Traditional surface irrigation methods (basin, border and furrow) are widely used to irrigate crops. Those are
however inefficient irrigation methods and considered one of the main causes of water logging and salinization (Burt et al., 1997). The reason why small holders farmers practiced traditional ones are affordability and capacity on the use of modern, high-tech and efficient micro irrigation methods (drip, bubbler, sprinkler etc.) which are advocated worldwide. Though those modern and efficient irrigations are available in developing countries like Ethiopia, these methods have yet not been widely adopted by farming communities.

Therefore, the need for more efficient irrigation methods that are economical, easy to install and operate, and which are readily acceptable to the farming communities is mandatory; by introducing every furrow irrigation method (EFI) to be transformed into alternate furrow irrigation (AFI), it might be readily accepted by farmers. However, before introducing and advocating this method to local farmers for adoption, the method needs to be evaluated under soil and climatic conditions for representative areas being targeted. According to different finding, AFI method is basically the same as EFI, except that instead of irrigating every furrow, irrigation water is applied to alternate furrows, while the in-between furrows remain dry (Siyal, et al., 2016). This means each ridge receives water from only one side, and the side receiving irrigation water could be changed with each irrigation if the field is set up to facilitate this change. Irrigating just on one side of the ridge means there is significant potential to save irrigation water as compared with EFI, with some yield reduction (Mashori, 2013). Moreover, Nasri et al. (2010) and Kashiani et al. (2011) reported that AFI is considered to be one of the most effective tools to minimize water application and irrigation costs and produce a higher crop yield. The AFI method is a way to save irrigation water, improve irrigation efficiency, and increase corn yield.

Eastern part of Ethiopia (Harari Region), is ranked last among region in terms of surface and ground water potential due to the topography and hydro-geological condition (Jema et al., 2010). The source of water for domestic and agricultural use especially for irrigation vegetable production during dry season is groundwater which is availed by constructing traditionally hand-dug wells. Farmers fit their wells with pressurized engine pumps (centrifugal pump) exploit the water for irrigating their farm. Even though irrigation practice virtuous, they do not have knowledge about irrigation management or water productivity. Farmers consider that only water is applied to maximize crop yield (maximizing production per unit of land). So to resolve this ineffective irrigation practice and, to enhance best water saving, as compared to this situation they have to adopt optimum water productivity methods through practicing and promoting water-use efficiency and productivity techniques to optimize yield and cost incurred, like alternate and interval of irrigation as alternative irrigation to achieve on-farm water management and to get better yield with this scare resource and minimize other variable cost. Generally, this experiment aimed to evaluate the effect of AFI and EFI with different irrigation intervals on yield and water use efficiency.

**MATERIALS AND METHODS**

The study was conducted in Harari Regional State of Erere Waldiya district in Erer Dodota kebele. Representative sites was selected purposively based on availability of resources required and willingness of the farmer to buy the experimental land, as well as access for field monitoring and follow up. Accordingly the sites is situated at 42°11' 00" to 42°15' 30" and 9°15'22" to 9°19' 35" East latitude and North longitude, respectively. The site receives a mean annual rainfall of 400 mm. It has erratic and uneven in distribution, with mean minimum and maximum temperatures of 25 and 35°C, respectively. The major soil types which occur in lowlands of the Erer Waldiya districts are Luvisols (Sandy soil) 90% and nitisols (clay) 10% (AGP-II, 2016). The soil in the experimental site 'Erer dodota', being sandy loam.

**Treatments and experimental design**

The experiment has two factors, factorial design arranged in randomized complete block design (RCBD) with three replications. The treatments considered for the experiment were namely two furrow irrigation methods AFI (Alternative furrow irrigation and EFI (every furrow irrigation)) and three irrigation interval or days (4, 6, and 8, interval for successive /next irrigation), hence there are six treatment combinations (Table 1).

### Table 1: Treatment description.

| S/N | Treatment | Treatment Combination |
|-----|-----------|-----------------------|
| 1   | AFI8      | Alternative Furrow Irrigation (AFI) with 8 II |
| 2   | AFI6      | Alternative Furrow Irrigation (AFI) with 6 II |
| 3   | AFI4      | Alternative Furrow Irrigation (AFI) with 4 II |
| 4   | EFI8      | Every Furrow Irrigation (EFI) with 8 II |
| 5   | EFI6      | Every Furrow Irrigation (EFI) with 6 II |
| 6   | EFI4      | Every Furrow Irrigation (EFI) with 4 II |

Note: II = Irrigation interval/day
The experiment was conducted on individual plot size of 3.5 m × 5 m (15 m²) with 18 number of such plot. The spacing between the blocks and plots were kept as 2 and 1 m, respectively. Each plot had 5 furrows and 4 planting ridges (rows) with 0.8 and 0.3 m furrow and between plants spacing, respectively. A test crop tomato (Melka shoal variety) seeds (cultivar: OPV variety) was used which was adapted in the study area with a purity test of 98%, and having germination percentage of 85% collected from Fedis Agricultural Research Center (FARC) of Horticulture Department. Five weeks after germination, seedlings were transplanted on experimental plots.

A common recommended fertilizer rate was applied manually in the experimental plots. All plots received the same amounts of fertilizer consisted of 150 kg ha⁻¹ of urea and 100 kg ha⁻¹ of P₂O₅ (DAP). The irrigation water used in the study was obtained from a well. Crop water requirement was estimated using the CROPWAT computer software program using and climatic, soil and crop data as input.

Soil texture and water holding analysis

Soil samples from the experimental plots were taken to analyze bulk density, texture, moisture content at field capacity and permanent wilting point from the field at three points along the diagonal of the experimental plot at two depth 0-20 cm and 20-40 cm.

Soil texture, organic matter and pH measurement: The particle size distribution in the soil profile was done using hydrometric method following the procedure outlined by Staney and Yerima (1992). For this purpose, disturbed soil samples from the 3 locations on the experimental field was collected from a depth of 0-20 cm and 20-40 cm with the help of soil auger and composite samples were prepared. Organic carbon (%) was determined by potassium dichromate wet combustion producer (Walker and Black, 1934). Organic matter was obtained by multiplying organic carbon by conversion factor of 1.724. The pH of the soil in experimental site was determined by calibrated AD-8000 model (EC, TDS, pH meter) was measuring instrument by preparing soil water solution of 1:2.5 ratio (soil to water) following procedures or guide line given by manufacturer.

Determining of FC, PWP moisture content and bulk density: Field capacity (FC), permanent wilting point (PWP) and bulk density (ρb) of the soil in the study area were determined from particle size result by using SPAW version 6.2.0.75 software. After getting soil moisture values, water availability to crops from the soil was calculated. The total available water (TAW) in root zone was then computed as the difference in moisture contents between field capacity (FC) and permanent wilting (PWP) (Allen et al., 1998).

Crop water and irrigation water requirement: Crop coefficient (Kc) for initial, development, mid and late stages, root depth, and allowable depletion level were determined from CROPWAT data base and FAO tables (Allen et al., 1998). Meteorological data were collected from nearest station namely Eautomaticrecemeteorological station, situated in Babile district. The station was established in since 2015. Even though the precision level of the station was high, there was no long-term data records, and no other optional station. Therefore, available data of 4 year were used to determine reference evapotranspiration (ET₀) (Table 2).

Water application and discharge measurement: Water source was from manual hand dug well pumped by using

### Table 2: Average monthly climatic data of ErerAutomatic recording meteorological station and reference evapotranspiration.

| Month   | Minimum Temp (°C) | Maximum Temp (°C) | R.H(%) | Wind (km day⁻¹) | Sunshine (hr) | Ra,(MJ m⁻² day⁻¹) | ETo. (mm day⁻¹) |
|---------|-------------------|-------------------|--------|----------------|--------------|------------------|----------------|
| January | 7.0               | 32.1              | 51     | 111            | 8.5          | 20               | 3.75           |
| February| 14.5              | 32.5              | 68     | 104            | 8.2          | 20.8             | 4.12           |
| March   | 15.4              | 33.6              | 63     | 112            | 7.0          | 20.1             | 4.37           |
| April   | 16.1              | 33.5              | 76     | 104            | 14.5         | 31.9             | 6.14           |
| May     | 18.7              | 29.9              | 85     | 92             | 15.4         | 32.5             | 6.04           |
| June    | 18.2              | 29.7              | 89     | 95             | 16.1         | 32.8             | 5.98           |
| July    | 16.8              | 29.8              | 97     | 92             | 18.7         | 36.8             | 6.55           |
| August  | 13.7              | 30.9              | 87     | 78             | 18.2         | 37.0             | 6.56           |
| September| 11.0             | 32.0              | 78     | 86             | 16.8         | 35.1             | 6.17           |
| October | 7.5               | 30.6              | 63     | 104            | 13.7         | 29.2             | 4.99           |
| November| 13.0              | 23.9              | 49     | 95             | 11.0         | 23.7             | 4.07           |
| December| 12.8              | 23.5              | 52     | 138            | 7.5          | 18.2             | 3.58           |
| Average | 13.7              | 30.2              | 72     | 101            | 13           | 28.2             | 5.19           |

RH = Relative humidity; Ra = Radiation; ETo = Reference Evapotranspiration.
Table 3: Physical properties of experimental soil.

|        | Averaged values of 0-20 and 20-40 cm depth of soil |
|--------|--------------------------------------------------|
|        | Particle size distribution                       |
| Sand (%)| Silt (%)  | Clay (%) | Textural class |
| BD (gcm⁻³) | FC (Vol. %) | PWP (Vol. %) | TAW (mm m⁻³) | OM (%) | pH | Infiltration rate (mm hr⁻¹) |
| 1.6 | 24.5 | 14.3 | 142.6 | 1.2 | 6.5 | 24.0 |

Note: FC = Field capacity volume base; PWP = Permanent wilting point volume base; BD = bulk density; TAW = Total available water; OM = Organic matter; pH = power of Hydrogen.

diesel fuel pump for irrigated vegetable production. The discharge was measured at pump delivery tube before reaching the field and it was directly measured at outlet. Smaller supply channels that were for furrow irrigation and through careful opening and closure of channel banks, the water was supplied into furrows and the flow was measured by parshall flume in the field. Irrigation water was conveyed to the plots through a circular orifice and its quantity was calculated using the equation of immersed orifice as follows (James, 1988):

\[ Q = 0.61 \times 0.334 \times A \sqrt{h} \]

Where: \( Q \) = Quantity of irrigation water in l sec⁻¹, \( A \) = Area of the orifice in cm² and \( h \) = Effective water head over the orifice center in m.

**Crop water use efficiency (CWUE) in kg m⁻³:** It is the ratio of crop yield \( Y \) to the amount of water required \( WR \) by the crop in the process of evapo-transpiration, and is formulated as:

\[ CWUE = \frac{Y}{WR} \]

**Irrigation water use efficiency (IWUE) in kg m⁻³:** It is the ratio of crop yield \( Y \) to the total amount of water used in the field determined as:

\[ IWUE = \frac{Y}{TW} \]

**Economical water productivity** in (Birr m⁻³): it is relates the economic benefits per unit of water used and calculated as:

\[ WP = \frac{\text{Yield in chas (value)}}{\text{Total water consumed (m}^3\text{)}} \]

where; \( WP \) is the economic water productivity in birr m⁻³, out-put is the product of marketable yield and market price in birr, and water consumed in m³.

Water saving was calculated as follows (Chapagain and Yamaji, 2010):

\[ \text{Water saved} \% = \frac{\text{Water used in Every FI} - \text{Water used AFI}}{\text{Water used in EFI}} \]

**Data analysis**

All measured variables were subjected to analysis of variance appropriate for RCBD. Significant mean separation was compared using least significant difference (LSD), and Duncan’s Multiple Range Test (DMRT) by Genstat15th version software was used for analysis of variance.

**RESULTS AND DISCUSSION**

**Soil physical properties of experimental field**

Laboratory analysis result indicated that the texture of particle size distribution of the study area was sand clay loam throughout the depths of 0-20 cm and 20-40 cm. The average soil bulk density of 0-40 cm soil depth was 1.6 g cm⁻³. Average available soil moisture content for the top (0-40 cm) soil depths was observed as 15.8% in volume percent and representative value of total available water (TAW) of 142.6 mm m⁻³ was obtained by considering the average of 0 - 40 cm soil depth. The average OM of the soil was found to be 1.2%. Representative value of the soil pH at 1:2.5 soil to water was 6.5. Field level infiltration test indicated that basic infiltration rate of the experimental area soil was 24 mm hr⁻¹ (Table 3).

**Gross irrigation water applied for each growth stages of treatments**

All treatments were conducted according to the initially planned framework and followed the required amount of gross water applied for each stages. Comparison of two irrigation methods (IMs), alternating furrow irrigation (AFI) and every furrow irrigation (EFI) under three irrigation intervals (IIs): (4, 6 and 8 day), is shown in Table 4.
Effect of irrigation methods (IMs) and irrigation intervals (IIs) on growth and yield components

Effect of IMs and IIs on plant height: ANOVA shows that plant height at harvest maturity was significantly (P<0.05) influenced by irrigation methods, and IIs had highly significantly (P<0.01) effect during both planting seasons. The highest mean plant height of both planting seasons, 72.9 and 76.8 cm, was recorded by EFI and every 4 day II, respectively. Whereas the lowest mean plant height was observed at every 8 day water application interval as 64.2 cm in the second year planting season which was not significantly different from 6 day irrigation frequency (Table 5).

The result indicates that furrow water application methods and intervals had significant effect on plant height. Hence, this finding confirms that plant height increased as frequency of application decreases from 8 to 4 day. This is in agreement with the finding of Wakrim et al. (2005) who reported that shoot and pod biomass was significantly decreased in both PRD (partial root drying) and DI (deficit irrigation) as compared with FI of beans. Similarly, Li et al. (2005) reported that leaf area increment, averaged to single leaf, showed that CFI produced significantly larger leaves than the AFI and FFI in the early growth stage of cotton.

Effect of IMs and IIs on number of fruit per plant (NFPP): Number of fruit per plant was counted at fruit set stage or one week after flower drop of the crop. Statistical analysis indicates that NFPP was highly significantly

Table 4: Water applied per growth stage and water saved from each treatments.

| Treatments | Irrigation water in (mm) per each growth stage | I_{gross}(mm) | Water saved in (%) |
|------------|-----------------------------------------------|---------------|--------------------|
|            | Initial | Development | Mid | Late |               |               |
| AFI with 8 day | 33.1    | 45.3    | 64.6 | 49.9 | 321.6 | 58         |
| AFI with 6 day | 44.2    | 60.4    | 86.2 | 66.5 | 428.8 | 44         |
| AFI with 4 day | 66.3    | 90.6    | 129.3 | 99.8 | 643.2 | 16         |
| EFI with 8 day | 39.5    | 53.9    | 76.9 | 59.4 | 382.8 | 50         |
| EFI with 6 day | 52.6    | 71.9    | 102.6 | 79.2 | 510.4 | 33         |
| EFI with 4 day | 78.9    | 107.8   | 153.9 | 118.8 | 765.7 | 0          |
| Total       | 314.6   | 429.8   | 613.6 | 473.6 | 3052.5 |            |

Table 5: Effect of IMs and IIs on growth and yield components of tomato.

| Treatment | Two year data of crop growth and yield component | 2017/18 | | 2018/19 | | |
|-----------|--------------------------------------------------|---------|---|---|---|---|
|           | Treatment                                       | PH | NFPP | TY | PH | NFPP | TY |
|           | EFT                                             | 72.9 | 86.3 | 33.3 | 70.7 | 83.4 | 37.2 |
| Irrigation method (IMs) | AFI                                             | 70.0 | 80.8 | 31.5 | 67.5 | 73.6 | 34.9 |
|           | LSD                                             | 2.2  | 4.9  | 1.4 | 3.0 | 5.9 | 2.0 |
|           | LSD                                             | 2.7  | 6.0  | 1.7 | 3.7 | 7.3 | 2.5 |
| Irrigation intervals (IIs) | 4 day                                           | 77.0<sup>a</sup> | 96.9<sup>a</sup> | 39.6<sup>a</sup> | 76.5<sup>a</sup> | 91.8<sup>a</sup> | 39.2<sup>a</sup> |
|           | 6 day                                           | 70.6<sup>b</sup> | 82.6<sup>b</sup> | 33.1<sup>b</sup> | 66.4<sup>b</sup> | 80.3<sup>b</sup> | 35.3<sup>b</sup> |
|           | 8 day                                           | 66.7<sup>c</sup> | 70.9<sup>c</sup> | 24.5<sup>c</sup> | 64.2<sup>b</sup> | 63.4<sup>c</sup> | 33.7<sup>b</sup> |
|           | LSD                                             | 2.7  | 6.0  | 1.7 | 3.7 | 7.3 | 2.5 |

PH - Plant height (cm); NFPP - Number of fruit per plant in (N_{0}); TY - Total yield in (ton ha^{-1}) and, Note: mean followed by the same letter in the columns are not significantly different.
Effect of IMs and IIs on tomato yield: Analysis of variance indicated that total yield was significantly (p<0.05) influenced by furrow IMs in both planting season, whereas, IIs had highly significant (p<0.01) effect on yield. The highest mean total yield was recorded by EFI as 33.2 and 37.2 t ha⁻¹ in the respective planting seasons, while the lowest mean total yield of 31.5 t ha⁻¹ was recorded by EFI during first year (Table 5). Accordingly, the result under different water application frequency lied in between 39.6 and 24.8 t ha⁻¹ in increasing order from every 4 to 8 days II, respectively.

This shows that water application days or intervals have remarkable effect on tomato yield (Table 5), this may be due to aridity of environment, which increases evapotranspiration in the crop in long day irrigation interval. Similar results was reported by El-Halim (2015), who found that the average two seasons yield of maize irrigated under fixed furrow (FFI) and every furrow (EFI) irrigation method with every 7 day irrigated treatments were higher than that obtained from EFI every 14 days. According to Ibrahim and Kandil (2007), 7 day irrigation frequency or interval using fixed-furrow irrigation produce higher grain yield than less frequent irrigation interval (every 14 day). Stickic et al. (2003) explored that tomato plants grown under PRD had shown 26, 10 and 30% reduction in height, number of leaves and number of fruit, respectively.

Effect of IMs and IIs on water productivity and yield reduction: The result indicated that water saved from treatment combination of AFI with 4, 6 and 8 days water application were 16, 44 and 58% of total volume of irrigation water applied. Whereas EFI with 6 and 8 day application obtained 33.3 and 50%, respectively (Table 6).

EFl with 4 day water application produced maximum yield because this treatment received maximum amount of water of all treatment, as a result no yield reduction was observed or was used as control for comparison purpose. Whereas EFI with 4 day II showed little yield reduction which was 4.97% as compared with no stressed (EFI with the same II). But AFI with 4 day II was obtained as 16% water from gross water applied when compared with no stressed treatment EFI with 4 day (Table 6).

Similarly, treatment with 6 day II of AFI and EFI showed significant yield reduction of 15.7 and 14.6%, respectively. But total gross volume of irrigation water saved was 44 and 33.3% for AFI and EFI of the same II treatment (Table 6). Hence water saved from AFI and EFI with 6 day II could irrigate more or additional cultivation land at water limited or scarce environment. Accordingly, Pfeiffer and Lin (2014) concluded that water saved through improved irrigation systems could allow for an expansion of cultivation land and increase crop production in water limited area. Farmers' decisions are often driven by maximizing their return and rarely by environmental concerns; if they pursue efforts to save water, they often use it to expand their irrigated areas or shift to higher value crops, rather than losing water allocation.

The result showed that for tomato performance under different irrigation method with irrigation intervals, as the frequency of water application increases from 4 to 8, the yield reduction also increases. From different point of views, the optimum yield reduction was not more than 15%. In this view the better result lies in for AFI with 4 and 6 day II, and Every furrow irrigation (EFI) with 6 day II. This result is in line with the finding of Shock et al. (2013) who concluded that improper irrigation depth and frequency can substantially reduce yields by increasing the proportion of rough, deformed tubers.

Crop water use efficiency (CWUE): Statistical analysis (ANOVA) indicated that CWUE was highly significantly (P<0.01) influenced by both IMs and IIs. The highest of 11.6 kg m⁻³ and the lowest 7.9 kg m⁻³ were produced by AFI and EFI, respectively from both planting season. Whereas

Table 6: Average water saved and relative yield reduction of season.

| Treatments | I gross (m³) | Water saved (m³) | Water saved (%) | Yield (kg ha⁻¹) | Yield reduced (kg ha⁻¹) | Yield reduced (%) |
|------------|-------------|-----------------|-----------------|-----------------|-------------------------|------------------|
| AFI with 4 day | 6431.6 | 1225.1 | 16.0 | 3839.1 | 13056.9 | 4.9 |
| AFI with 6 day | 4287.7 | 3369.0 | 44.0 | 3404.0 | 6358.4 | 15.7 |
| AFI with 8 day | 3215.8 | 4440.9 | 58.0 | 2734.1 | 2006.5 | 32.3 |
| EFl with 4 day | 7656.7 | 0.0 | 0.0 | 4039.8 | 0.0 | 0.0 |
| EFl with 6 day | 5104.4 | 2552.3 | 33.3 | 3449.8 | 5900.3 | 14.6 |
| EFl with 8 day | 3828.3 | 3828.4 | 50.0 | 3062.8 | 9772.6 | 24.2 |
CWUE, application frequency, was significantly increased when irrigation days or intervals decreased. Hence the result showed that the highest CWUE 11.9 kg m\(^{-3}\) was obtained from 6 day water application intervals followed by 8 day as 11.6 kg m\(^{-3}\), but statistically had no significant difference, and the lowest 9.4 kg m\(^{-3}\) was recorded at 4 day water application interval correspondingly (Table 7) in first year planting. Similarly the highest and lowest mean value 10.7 and 6.2 kg m\(^{-3}\) CWUE was recorded in the second year, respectively. It is also evident that, at each irrigation methods, the CWUE increased with increasing water application day, that is, 4 to 8 day.

### Effect of furrow IMs and IIs on Irrigation water use efficiency (IWUE): The analysis of variance, showed that IWUE was highly significantly (P<0.01) influenced by both furrow IMs and IIs. The result revealed that IWUE was significantly increased from 4.8 to 6.9 kg m\(^{-3}\), of EFI and AFI respectively that computed for both cropping season. Similarly, the highest mean IWUE of 7.1 kg m\(^{-3}\) and the lowest 3.7 kg m\(^{-3}\) was recorded by 6 day and 4 day water application interval, respectively during both planting season (Table 7). This result is in agreement with those of Abdel-Maksoud et al. (2002) who conducted a study on wheat, the result showed that WUE values was improved under AFI as compared with the EFI method. Shahzadari et al. (2007) for field grown potato showed that as compared with FI (full irrigation), PRD (partial root drying) treatment saved 30% of water and increased water use efficiency. Moreover, Awad (2013) reported that both AFI\(_7\) and AFI\(_14\) achieved high WUE of maize as compared with EFI.

### Effect of furrow IMs and IIs on economic water productivity (EWP): The analysis of variance showed that economic water productivity was highly significantly (P<0.01) influenced by both IMs and IIs. The result indicates that mean maximum economic water productivity value for AFI was obtained as 55.5 ETB m\(^{-3}\), which was significant different from EFI and the mean minimum EWP was recorded by EFI as 38.4 ETB m\(^{-3}\) for both planting season (Table 7). Accordingly, EWP was significantly influenced by different irrigation interval, the result showed maximum value of 56.8 ETB m\(^{-3}\) by every 6 day crop water application which was not significantly different from 8 day and the lowest by 4 day irrigation interval was recorded during first year cropping season. Whereas the second year data indicates that maximum EWP was obtained from 8 day II as 51.1 ETB m\(^{-3}\) followed by 6 day and the lowest as 29.9 ETB m\(^{-3}\) as shown in the Table 7. This result shows that, economic water productivity depends on the ratio of yield obtained in cash to the amount and frequency of water applied in volume (m\(^3\)) basis. Hence every 8 day irrigation interval had least water application frequency and similarly the yield was relatively lower when compared with 6 and 4 day water application interval, this resulted in superior economic water productivity.

Generally, the result of crop water productivity (CWUE, IWUE and EWP) clearly confirmed that, alternate furrow irrigation had beneficial advantage over every furrow irrigation on water saving and the same consequence happened for irrigation interval, that is, increasing irrigation from 4 day followed by 6 to 8 days increases water use efficiency of crop. Hence the result indicates that interaction effect of factors (IMs and IIs) save significant amount of water. Amount of saved water as described in Table 7 from each treatment have advantage of increasing land, time or labor productivity. Some study confirmed the same idea of water productivity, is considerably increased by using APRD (alternative partial root drying) on different crops (Ahmadi et al., 2010b). Guang et al. (2008) also reported that PRD significantly reduced yield by 24%, while WP (water productivity) increased by 52% compared with the FI (full irrigation).

### CONCLUSION AND RECOMMENDATION

Experiment was conducted at Eastern Ethiopia of Harari Regional State of Erer Woldaya district, on farm field for two
years. The purpose of this study was to evaluate the effect of AFI and EFI with different irrigation intervals on growth component, yield and water use efficiency of tomato. Accordingly, the parameters for experimentation include growth component: such as plant height and number fruit per plant and yield parameter total fruit yield and, water productivities.

Plant height at harvest maturity was significantly (P<0.05) influenced by irrigation methods (IMs), but (IIs) had shown highly significantly (P<0.01) effect on plant height on both planting season. Statistical analysis indicates that NFPP was highly significantly (p<0.01) affected by IIs. But NFPP was significantly affected (P<0.05) by irrigation methods at both planting seasons. Total fruit yield was significantly influenced (P<0.05) by furrow irrigation methods in both planting season, but the effect of water application days were highly significant (p<0.01).

Generally, crop water productivity (CWUE, IWUE and EWP) showed that, alternate furrow irrigation had beneficial advantage over every furrow irrigation on water saving and the same consequence perceived for irrigation interval, that is, increasing irrigation interval from the 4th day followed by 6 to 8 days increases water use efficiency of crop. Hence the result indicates that interaction effect of (IMs and IIs) save significant amount of water. Hence water saved from treatment combination of AFI with 4, 6 and 8 IIs were 16, 44 and 58% of total gross volume of irrigation water applied, respectively. While EFI with 6 and 8 application day obtained 33 and 50%. Therefore, the amount of saved water from each treatment has advantage of increasing land, time or labor productivity. AFI with 4 day II shows little yield reduction which was indicated as 4.9%, as compared with no stressed (EFI with the same II).

Accordingly, AFI and EFI showed significant yield reduction of 15.7 and 14.6%, respectively. But total amount of gross volume of irrigation water saved was respectively 44 and 33.3% for AFI and EFI of the same II treatment. Based on this finding, for more popularization for irrigated farmers', optimum yield reduction with equivalent water saving AFI with 4 day II is the best and first option and EFI and AFI with 6 day II was the second if they pursue efforts to save water, farmers often use it to expand their irrigated areas or shift to higher value crops.

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Cite this article as:

Nur J, Ofgea L (2021). Effect of alternate furrow irrigation with different irrigation intervals on tomato (Lycopersicon E.) yield and water use efficiency. Acad. J. Agric. Res. 9(10): 035-043.

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