Response of Tomato (Lycopersicon Esculentum), to Deficit Irrigation at Arbaminch Zuria Woreda in SNNPR, Ethiopia

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Abstract:
The experiment was conducted for three consecutive years to find the level of deficit irrigation which allows the maximum yield of tomato without significantly reducing the yield of tomato. The experiment has four levels of treatments (100% ETc, 85% of ETc, and 75% of ETc and 50% of ETc) and laid down in Randomized Completed Block Design (RCBD) with four Replications. Experimental data was analyzed by using Statistix 8.0 software in probability of 5% confidence level. From the result, maximum marketable yield (31.50ton/ha) and total yield (37.65 ton/ha) was obtained from 100%ETc and minimum marketable yield (18.84ton/ha) and total yield (25.02 ton/ha) was obtained from deficit level of 50%ETc. Application of 85% of ETc and 70% of ETc cannot affect both marketable and total yield of tomato significantly. Statistical result shown, there was no significance difference seen in water use efficiency for different deficit levels; 100%ETc (6.79 kg m⁻³), 85%ETc (6.92 kg m⁻³), 75%ETc (7.02 kg m⁻³) and 50%ETc (6.98 kg m³). Even though there was no significant difference among treatments of combined result, the highest water use efficiency (7.02kg m⁻³) was obtained from 70% of ETc compared to other levels of deficit irrigation. Therefore in terms of economic return and water use efficiency; application of 100% ETC is better than the other treatments without decreasing tomato yield.

Key word: Deficit Irrigation, Tomato Yield, Water Use Efficiency.

1. INTRODUCTION

Water is the lifeblood of the planet, and the state of this resource affects all natural, social and economic systems. The ever-increasing world population and the demand for additional water supply by industrial, municipal, and agricultural sectors exert a lot of pressure on renewable water resources [1]. Sustainable use of water in agriculture has become a major concern. The adoption of strategies for saving irrigation water and maintaining acceptable yields may contribute to the preservation of this ever more restricted resource [2]. In areas of water shortage and long summer droughts, maximizing water productivity may be more beneficial to the farmer than maximizing crop yield. A recent innovative approach to save agricultural water is conventional deficit irrigation (DI). It is a water-saving strategy under which crops are exposed to a certain level of water stress either during a particular developmental stage or throughout the whole growing season[3]. In the semi-arid areas of Ethiopia, water is the most limiting factor for crop production. In these areas where the amount and distribution of rainfall is not sufficient to sustain crop growth and development, an alternative approach is to make use of the rivers and underground water for irrigation. Satisfying crop water requirements, although it maximizes production from the land unit, does not necessarily maximize the return per unit volume of water [4]. To quantify the level of deficit irrigation; it is first necessary to define the full crop ETc requirements. Fortunately, the combination approach to calculate ET, research on crop water requirements has produced several reliable methods for its calculation. At present, the Penman-Monteith equation [5] is the established method for determining the ET of the major herbaceous crops with sufficient precision for management purposes. Under conditions of scarce water supply, application of deficit irrigation deficit irrigation could provide greater economic returns than maximizing yields per unit of water. The deficit irrigation has been considered worldwide as a way of maximizing water use efficiency (WUE) by eliminating irrigation that has little impact on yield [6]. Therefore this study was conducted to identify the level of deficit irrigation which allows achieving optimum tomato yield.

2. MATERIALS AND METHODS

2.1. Study Area Description

Arbaminch Zuria woreda is one of the 15th woredas of Gamo-gofa zone. The total area of woreda is 168.172hectare, with 29 rural PAs. The total population is 115,916 among them 54,080 male and 61,836 female with total house hold 26,931 among the total HH 25,987 MHHH and 944 FH HH. This experiment was conducted in chamomile kebelle which locates at longitude of 37°34'59” latitude of 06°75'25” and elevation of 1192 m above sea level.

2.2. Experimental Design

The experiment was laid out in randomized complete block design with four replications of four level treatments. The treatment was conducted under furrow irrigation method. All cultural practices were done in accordance to the recommendation made for the area. The amount of irrigation water to be applied at each irrigation application was measured through the mound.
using Parshall flume. The treatments were 100%ETc, 85%ETc, 70%ETc and 50%ETc. The experimental field was divided into 16 plots and each plot size was 4m by 5m dimension. The space between plots has been 1m and between replication 1.5m. The space between rows 1.0 m and 0.5 m between the plants was used. The experimental plot was pre-irrigated one day before transplanting. Before the commencement of treatment, two to three common light irrigations was supplied to all plots at two to three days interval to ensure better plant establishment.

The gross irrigation requirement was obtained from the

\[\text{Inet} = (\text{ETc} - \text{Peff}) \times \text{Bd} \times \text{Dz} \times \frac{100}{\text{FC} - \text{PWP}}\]

(4)

Where, \(\text{Inet}\) is the depth of irrigation supplied at any time, \(\text{ETc}\) is crop evapotranspiration, Kc is crop coefficient, \(\text{Bd}\) is the bulk density, \(\text{Dz}\) is the effective root depth of the plant, \(\text{FC}\) and \(\text{PWP}\) are field capacity and permanent wilting point.

2.3. Climate Data

Climate data like maximum and minimum air temperature, relative humidity, wind speed, sunshine hours, and rainfall were collected from climWat for determination reference evapotranspiration and crop water requirement for tomato crop. The table below shows the monthly average data of temperature (min and max), relative humidity, wind speed, rain fall and evapotranspiration of the study site using climWat model.

<table>
<thead>
<tr>
<th>Month</th>
<th>Min Temp (°C)</th>
<th>Max Temp (°C)</th>
<th>Humidity (%)</th>
<th>Wind (km/day)</th>
<th>rain fall (mm)</th>
<th>ETo (mm/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>16.5</td>
<td>30.7</td>
<td>55</td>
<td>95</td>
<td>35</td>
<td>4.38</td>
</tr>
<tr>
<td>February</td>
<td>17.7</td>
<td>31.7</td>
<td>55</td>
<td>104</td>
<td>31</td>
<td>4.75</td>
</tr>
<tr>
<td>March</td>
<td>19.2</td>
<td>31.5</td>
<td>59</td>
<td>173</td>
<td>64</td>
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<tr>
<td>April</td>
<td>18.5</td>
<td>30.5</td>
<td>67</td>
<td>130</td>
<td>129</td>
<td>4.7</td>
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<tr>
<td>May</td>
<td>18.2</td>
<td>28.6</td>
<td>72</td>
<td>104</td>
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<tr>
<td>June</td>
<td>18.6</td>
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<td>July</td>
<td>18</td>
<td>27.5</td>
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<tr>
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<td>86</td>
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<td>95</td>
<td>105</td>
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<td>60</td>
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<td>4.11</td>
</tr>
</tbody>
</table>

|          | 17.8          | 29.6          | 63           | 102           | 833            | 4.26          |

Average

2.4. Crop Data

Maximum effective root zone depth (RZD) of tomato ranges between 0.7-1.5m and has allowable soil water depletion fraction (P) of 0.4 [7]. Tomato average Kc would be taken after adjustments have been made for initial, development; mid and late season stage to be 0.45, 0.75, 1.15 and 0.85, respectively. Yield data like economical yield, unmarketable yield and total yield was measured in the field.

2.5. Soil Data

Soil physical and chemical properties like textural class, bulk density, field capacity, permanent wilting point and infiltration rate, acidity organic electric conductivity, organic matter and organic carbon content of the soil was measured in laboratory.

2.6. Crop Water Determination

Crop water requirement refers to the amount of water that needs to be supplied, while crop evapotranspiration refers to the amount of water that is lost through evapotranspiration (Allen et al., 1998). For the determination of crop water requirement, the effect of climate on crop water requirement, which is the reference crop evapotranspiration (ETc) and the effect of crop characteristics (Kc) are important [8]. The long term and daily climate data like maximum and minimum air temperature, relative humidity, wind speed, sunshine hours, and rainfall data of the study area were collected to determine reference evapotranspiration, crop data like crop coefficient, growing season and development stage, effective root depth, critical depletion factor of tomato and maximum infiltration rate and total available water of the soil was determined to calculate crop water requirement using cropwat model.

\[\text{ETc} = \text{ETo} \times \text{Kc} - \text{Peff} \times \text{mm} \]

(1)

Where, ETo is crop evapotranspiration, Kc is crop coefficient, ETo is reference evapotranspiration.

2.7. Irrigation Water Management

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

\[\text{TAW} = \frac{100}{\text{FC} - \text{PWP}} \times \text{Bd} \times \text{Dz} \times \text{p} \times \text{mm} \]

(2)

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

\[\text{RAW} = \frac{\text{TAW} \times \text{P}}{100} \times \text{mm} \]

(3)

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

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

\[\text{Inet} = (\text{ETc} - \text{Peff} \times \text{mm}) \times \frac{100}{\text{FC} - \text{PWP}} \times \text{Bd} \times \text{Dz} \]

(4)

The gross irrigation requirement was obtained from the

Table 1. Average climatic data of the study area

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</tbody>
</table>

|          | 17.8          | 29.6          | 63           | 102           | 833            | 4.26          |

Average
expression:
\[ GI = \frac{NI}{Ea} \]  
\[ t = \frac{A \cdot dg}{6Q} \]  
\[ - - - - - - - - - - - - - - - - - - - - - (5) \]

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

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

2.9. Economic Analysis
Economic evaluation of deficit irrigation is analyzing the cost that invested during growing season and benefit gained from yield produced by application of water. Marginal Rate of Return (MRR) used for analysis following the CIMMYT method [9]. Economic water productivity was calculated based on the information obtained at the study site: the size of irrigable area, economic data was collected to evaluate the benefits of application of different levels of water in deficit irrigation treatments. Economic analysis includes input cost like cost for water (water pricing), seeds, fertilizers, fuel and labor. However, cost of water pricing and yield sale price were the only cost that varies between treatments. The net income (NI) treatments were calculated by subtracting total cost (TC) from gross income (GI) and were computed as:
\[ NI = (GI − TC) \]  
\[ - - - - - - - - - - - - - - - - - - - - - (7) \]

2.10. Statistical Analysis
Data were analyzed using Statistix 8.0 software at probability of 5% confidence level. The factor of the experiment was considered as single factorial Randomized Complete Block Design (RCBD) during the analysis.

3. RESULT AND DISCUSSION

3.1. Physical and Chemical Properties of Soil
The result of the soil analysis from the experimental site showed that the average composition of sand, silt and clay percentages were 13% 21% and 66%, respectively. Thus, according to the USDA soil textural classification, the percent particle size determination for experimental site revealed that the soil texture could be classified as clay soil. The top soil surface had bulk density of 1.32 g/cm³. In general, the average bulk density of the study area was 1.32g/cm³, which is below the critical threshold level 1.4 g/cm³ and it was suitable for crop root growth. Average moisture content at field capacity of the experimental site soils were 27% and at permanent wilting point had 15% through one meter soil depth. Soil pH was found to be 6.0, which is under the critical range (5.7) for tomato and other crops [7]. The value of EC (1.12ds) was lower considering the standard rates in literature [10]. Generally, according to USDA soil classification, a soil with electrical conductivity of less than 2.0 dS/m at 25°C and pH less than 8.5 are classified as normal soil. Therefore, the soils of the study area are normal soils. The infiltration capacity measured by using double ring infiltrometer and the recorded constant value was 6mm/hours.

<table>
<thead>
<tr>
<th>Soil properties</th>
<th>pH</th>
<th>EC(mv)</th>
<th>%Sand</th>
<th>%Clay</th>
<th>%Silt</th>
<th>Textural class</th>
<th>Bd (gm/cm³)</th>
<th>PWP (%)</th>
<th>FC (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Results</td>
<td>6.0</td>
<td>1.12</td>
<td>13</td>
<td>66</td>
<td>21</td>
<td>Clay</td>
<td>1.32</td>
<td>15</td>
<td>27</td>
</tr>
</tbody>
</table>

3.2 The Response of Onion to Deficit Irrigation
From the result of this experiment there was significant effect for different level of irrigation water application. Analyzed result indicates that there was higher marketable yield (31.504ton/ha) and total yield (37.65ton/ha) obtained from 100% ETc and lowest marketable yield (18.841ton/ha) and total yield (25.02ton/ha) was obtained from deficit level of 50%ETc. Statistically analyzed result indicates that, application of 85% of ETc and 70% of ETc cannot significantly affect both marketable and total yield of tomato. But increase moisture stress level decreases the marketable and total yield of tomato. Even though there was no significant difference among treatments of combined result of experiment, the highest water use efficiency (kg ha⁻¹ m⁻³) obtained from 70% of ETc compared to other levels of deficit irrigation.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>MY (ton/ha)</th>
<th>UNMY (ton/ha)</th>
<th>TY (ton/ha)</th>
<th>WUE (kg m⁻³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100%ETc</td>
<td>31.504a</td>
<td>6.15a</td>
<td>37.65a</td>
<td>6.79a</td>
</tr>
<tr>
<td>85%ETc</td>
<td>25.929b</td>
<td>4.94b</td>
<td>30.87b</td>
<td>6.92a</td>
</tr>
<tr>
<td>70%ETc</td>
<td>24.108b</td>
<td>5.99a</td>
<td>30.10b</td>
<td>7.02a</td>
</tr>
<tr>
<td>50%ETc</td>
<td>18.841c</td>
<td>6.18a</td>
<td>25.02c</td>
<td>6.98a</td>
</tr>
<tr>
<td>CV (%)</td>
<td>24.64</td>
<td>21.27</td>
<td>24.09</td>
<td>29.74</td>
</tr>
<tr>
<td>LSD (5%)</td>
<td>50.97</td>
<td>1.02</td>
<td>50.98</td>
<td>1.70</td>
</tr>
</tbody>
</table>

MY=marketable yield, UNMY=unmarketable yield, TY=total yield, WUE=water use efficiency
3.4. Economic Analysis

The cost benefit analysis depicted that the highest net income (251,244Birr/ha) was obtained from treatment level of 100% ETc and the lowest net income (145,777Birr/ha) was incurred from treatment level of 50% of ETc. Benefit cost ratio of all treatments greater than one which was an acceptable approach. But highest benefit cost ratio (7.8) was obtained from treatment level 100% ETc and lowest benefit cost ratio (6.1) was obtained from 50% of ETc. Therefore, application of 100% ETc was economically better and viable for future tomato production in the area.

### Table.4. Average Partial Budget Analysis

<table>
<thead>
<tr>
<th>Treatment</th>
<th>MY (kg/ha)</th>
<th>AY (kg/ha)</th>
<th>GI (Birr/ha)</th>
<th>FC (Birr/ha)</th>
<th>VC (Birr/ha)</th>
<th>TC (Birr/ha)</th>
<th>NIR (Birr/ha)</th>
<th>B/C ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>100%ETc</td>
<td>31,504</td>
<td>28,354</td>
<td>283,536</td>
<td>15,292</td>
<td>17,000</td>
<td>32,292</td>
<td>251,244</td>
<td>7.8</td>
</tr>
<tr>
<td>85% ETc</td>
<td>25,929</td>
<td>23,336</td>
<td>233,361</td>
<td>15,292</td>
<td>14450</td>
<td>29,742</td>
<td>203,619</td>
<td>6.8</td>
</tr>
<tr>
<td>70% ETc</td>
<td>24,108</td>
<td>21,697</td>
<td>216,972</td>
<td>15,292</td>
<td>11,900</td>
<td>27,192</td>
<td>189,780</td>
<td>6.9</td>
</tr>
<tr>
<td>50% ETc</td>
<td>18,841</td>
<td>16,957</td>
<td>169,569</td>
<td>15,292</td>
<td>8,500</td>
<td>23,792</td>
<td>145,777</td>
<td>6.1</td>
</tr>
</tbody>
</table>

MY- marketable yield, AY – adjusted yield(-10% of MY), GI – gross income, FC- fixed cost, VC-variable cost, TC – total cost, NI – net income, B/C-benefit cost ratio

4. CONCLUSION AND RECOMMENDATION

From different deficit level; it was observed that the highest economic and total yield was obtained from the treatment of 100% ETc and lowest was obtained from half of full irrigation level 50% of ETc. As result showed it is concluded that decrease in moisture level decreases tomato production and productivity. There is no significance difference was seen from effects of treatments on water use efficiency. So improving water use efficiency is one important strategy for addressing future water scarcity, which is driven particularly by increasing human population. A deficit irrigation level of 85%ETc has slightly better water use efficiency than 100%ETc full irrigation. Therefore it is recommended that deficit level of 85%ETc was better to increase economic yield, total yield and water use efficiency in irrigation water scarce areas. But in areas where there is enough amount of irrigation water, 100%ETc was recommended to increase tomato yield and water use efficiency. As future direction it is better to further investigation on deficit irrigation level with appropriate irrigation scheduling.

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First of all, I must thank the Almighty God who helped me starting from the earlier to the end of this journey. I feel deeply indebted to express my special gratitude to Dr. Tilahun Hordofa for his heart-full unreserved support. My particular gratitude goes to Southern Agricultural Research Institute (SARI); for funding of research budget on time.

5. REFERENCES


