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Response of Tomato to Deficit Irrigation at Ambo, Ethiopia

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Abstract
Deficit irrigation is a recent innovative approach of water-saving method that cut down irrigation amounts and increase water productivity. The two years research study was conducted to evaluate the effects of deficit irrigation levels and furrow types on fruit yield and water productivity of Tomato at Ambo Plant Protection Research Center. The experiment was laid out in randomized complete block design with a factorial arrangement involving three replications. The treatments comprised of three furrow type (i.e Alternate furrow irrigation, fixed furrow irrigation and conventional furrow irrigation) and three irrigation deficit levels (i.e. 50 % ETc, 75% ETc and 100 % Etc.). From the over year data analysis 100 % ETc irrigation level has a 6.94 % and 15.91 % yield increment as compared to 75 % ETc and 50 % ETc levels respectively. Also a 9.9 % and 18.15 % fruit yield reduction were recorder from alternate furrow and fixed furrow irrigation as compared to treatment receiving conventional furrow irrigation type. Moreover, maximum water productivity of 26.86 kg/m^3 was recorded from 50 % ETc with alternate furrow irrigation and the minimum value 8.82 kg/m^3 was recorded at full irrigation (100% ETc) application with conventional furrow irrigation system. The statistical analysis showed that, there was a significant difference on tomato fruit yield subjected to the furrow system as well as different deficit irrigation levels at ($p<0.05$). Tomato fruit yield obtained from alternate furrow irrigation system was statistically at par with conventional furrow irrigation system and fixed furrow irrigation. But fixed furrow irrigation system has a significant different with that of conventional furrow irrigation system. Also yield obtained with the application of 75 % ETc irrigation level was statistically at par with 100 % ETc level and 50 % ETc but, application of 50 % ETc deficit level was significantly different from 100 % ETc level. Result obtained on water productivity shows a significant difference with furrow system and deficit application levels at ($p<0.05$). Application of 75 % ETc level saved 25 % water applied as compared to 100 % ETc level without a significant fruit yield reduction with a better water productivity value. In the case of furrow irrigation, alternate furrow irrigation system saved about half of the water applied as compared to conventional furrow irrigation or farmers practice without a significant fruit yield difference with better water productivity value. Therefore, 75 % ETc estimated deficit level and alternate furrow irrigation system is recommended for the study area.
Keywords: Deficit irrigation, Alternate furrow, Water productivity and Tomato

1. Introduction

Water is one of the basic natural resources for humanity, but it is often scarce. Mainly spatial and temporal variability in rainfall aggravate water scarcity problem (Rosegrant*et al.,* 2002). Irrigated agriculture is the main user of the available water resources. About 70% of the total water withdrawals and 60-80% of total consumptive water use are consumed in irrigation (Huffaker and Hamilton, 2007). Therefore, water resources should be used with a higher efficiency or productivity. To achieve this goal, improvement in agricultural water productivity is highly imperative.

Many investigations have been conducted to gain experiences in irrigation of crops to maximize performances, efficiency and profitability. However, investigations in water saving irrigation still are continued (Sleper et al., 2007). Nowadays, full irrigation is considered a luxury use of water that can be reduced with minor or no effect on profitable yield (Kang and Zhang, 2004).

A recent innovative approach to save agricultural water is deficit irrigation (DI). Deficit irrigation provides a means of reducing water consumption while minimizing adverse effects on yield (Zhang, et al., 2004) and Mermoud (2005). In this method, the crop is exposed to a certain level of water stress either during a particular period or throughout the whole growing season. The expectation is that any yield reduction (especially in water-limiting situations) will be compensatedby increased production from the additional irrigated area with the water saved by deficit irrigation (Ali et al, 2007).

Tomato (*Solanum lycopersicon* L.) is one of the most important vegetable crops and is one of the most demanding in terms of water use (Peet, 2005). Most of the time tomato is produced through furrow irrigation in smallholder schemes. An important adaptation of furrow irrigation is Alternate Furrow Irrigation (AFI) in which furrows are irrigated alternately rather than consecutively during irrigation water application. This is a form of partial root-zone drying (PRD) system which has been found to increase the production of various vegetables in the ASAL areas (Fereres et al., 2007; Jones, 2004) as well as saving irrigation water.

Furrow irrigation system is a widely used irrigation system by our farmers; yet, the water productivity and technical performance of the systems remains to be very low. Furrow irrigation application performance and water productivity of the system can be enhanced by application of deficit irrigation either by using partial root zone furrow irrigation system or by regular deficit application. Therefore, this research experiment was conducted with an objective of selecting water saving furrow irrigation system and deficit level that enhance water productivity without adverse effect on fruit yield reduction of tomato crop.

2. Materials and Methods

2.1 Description of the Study Area

The experiment was conducted at Ambo Plant Protection Research Center during the growing season of 2013/14 to 2014/15 for two consecutive years. The site is situated on 38º 07' E longitude and 8º 57'N latitude and 2225m.a.s.l altitude. The area experienced bimodal rainfall with a mean annual precipitation of 1115 mm. The mean maximum and minimum temperature of the area is 25.4ºC and 11.7ºC respectively. The soil texture has been classified as clay soil. As the graph show that the ratio between monthly precipitation and monthly evaporation is less than unit starting from January to may and end of September to December therefore irrigation is required during this months for the area.

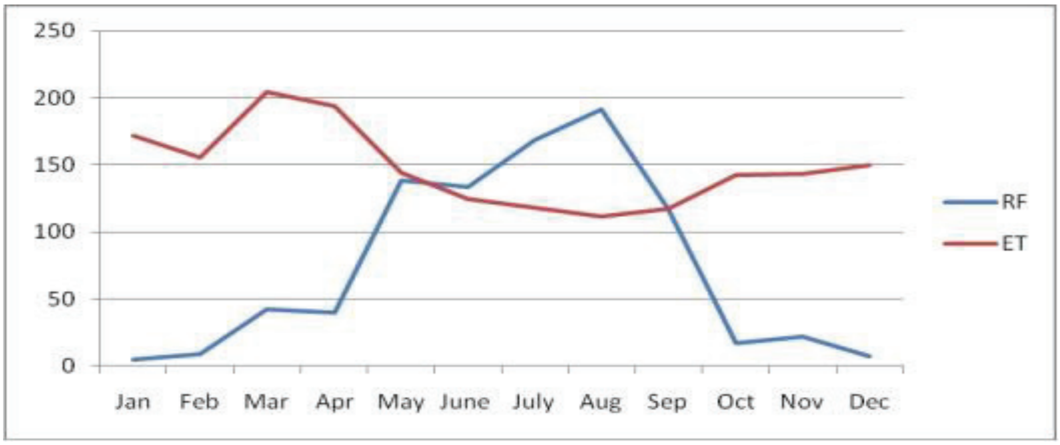

Figure 1. The two consecutive study years Average Monthly Evapotranspiration and rainfall relationship Graph

2.2 Experimental Design and treatment combination

The experiment was designed as a two factor factorial experiment in randomized complete block (RCBD) arrangement. The two factors were furrow irrigation systems and deficit irrigation application levels. The experiment comprised three furrow irrigation systems and three irrigation deficit levels. The three furrow irrigation systems are Alternate furrow irrigation (AFI), fixed furrow (FFI) and Conventional furrow irrigation (CFI) and the three irrigation levels are 50% ETc, 75% ETc, 100% ETc or crop water required by the crop a treatment having 100 % ETc irrigation level and conventional furrow irrigation considered as a control or farmers practice . The experiment has nine treatment combinations and 27 plots. The amount of irrigation to satisfy the crop water requirement was computed with CROPWAT software model using long term climatic data, primary and secondary soil and crop data. The amount of irrigation water to be applied at each irrigation application time measured by Parshall flume and the moisture of the soil was monitored using gravimetric method.

Alternate furrow irrigation (AFI) meant one of the two neighboring furrows was alternately irrigated during consecutive irrigation events. Fixed furrow irrigation (FFI) meant that irrigation fixed to one of the two neighboring furrows. Conventional furrow irrigation (CFI) meant irrigating all furrows during consecutive watering. Where, full irrigation (100% crop water requirement) implies the amount of irrigation water applied as estimated using Penman Monteith with CROPWAT computer program. And 75% (ETc) and 50% (ETc) irrigation level meant 25% and 50% less of full irrigation requirement, respectively.

Table 1 Combination of experimental treatments

Treatment	Combinations
T1	Alternative Furrow Irrigation (AFI) irrigated at 100% ETc
T2	Alternative Furrow Irrigation (AFI) irrigated at 75% ETc
T3	Alternative Furrow Irrigation (AFI) irrigated at 50% ETc
T4	Fixed Furrow Irrigation (FFI) irrigated at 100% ETc
T5	Fixed Furrow Irrigation (FFI) irrigated at 75% ETc
T6	Fixed Furrow Irrigation (FFI) irrigated at 50% ETc
T7	Conventional furrow Irrigation (CFI) irrigated at 100% ETc
T8	Conventional furrow Irrigation (CFI) irrigated at 75% ETc
T9	Conventional furrow Irrigation (CFI) irrigated at 50% ETc

2.3 Seedling preparation, transplanting and crop management

Tomato seed of Melkshola variety was sowed at the nursery site. Six weeks after sowing vigorous and healthy seedlings were selected and transplanted on the plot at 0.70 m and 0.35 m inter-row and intra-row spacing, respectively. Treatment applications were started one week after transplanting for well establishment of the seedlings. To meet the nutritional requirement of tomato crop, each plot were received a recommended rate of 92 kg N/ha in the form of urea (about 200 kg/ha) and 18/46 kg N/P_2O_5 in the form of DAP (100 kg/ha). DAP was applied at transplanting time in one application while urea was applied in split application 50% of urea were applied during transplanting and 50 % of the urea applied six weeks after transplanting. Other important agronomic practices were applied uniformly for all experimental plots as often as required.

2.4 Data collection

Yield data were collected from the three central rows out of five plant row per plot to avoid border effect. Plant height, number of fruit per plant and cluster number were collected from selected five plant sample of the three central rows.

2.5 Water Productivity (WP)

Water productivity was estimated as a ratio of grain or fruit yield to the total ETc through the growing season and it was calculated using the following equation (Zwart and Bastiaanssen, 2004).

$$WP = \frac{Y}{ETc}$$

Where, WP is crop water productivity (kg/m^3), Y crop yield (kg/ha) and ETc is the seasonal crop water consumption by evapotranspiration (m^3/ha).

2.6 Data analysis

The two years yield and yield component data collected were subjected to ANOVA test using SAS software. The overall variability and effects of the treatment on yield and yield component parameters were considered as significant when $p \leq 0.05$. Least significant difference (LSD) test was applied for statistically significant parameters to compare means among the treatments.

3.Result and Discussion

Three different deficit irrigation levels and three furrow application types on fruit yield, water productivity and and yield component parameters of tomato was evaluated in this research study.

Analysis of deficit irrigation level and furrow application type on fruit yield of Tomato

In order to evaluate fruit yield tomato data were collected from the three central rows of tomato planted plot and the over year analyzed result of tomato fruit yield subjected to the treatments effect was presented below on Table 2. The over year analysis of tomato fruit yield revealed that there is a statistical significant difference on the use three irrigation deficit level and furrow application type at $P < 0.05$. As showed on the table below a treatment receiving 100 % ETc irrigation level has a 6.94 % and 15.19 % yield increment as compared to 75% ETc irrigation level and 50 % irrigation level respectively, while the statistical analysis showed that application of 100 % ETc level has a significant yield difference with 50% ETc level but it is at par with that of 75 % ETc level. Also conventional furrow irrigation type achieve a higher tomato fruit yield as compared to alternate furrow irrigation and fixed furrow irrigation by 9.9 % and 18.15 % respectively. The analysis result on irrigation type showed that application of conventional furrow irrigation type has a statistical significance difference as compared to fixed furrow. However, there was no significance difference to Alternate furrow.

Table 2.Over Year Analysis Result of Tomato Fruit Yield

Yield (kg/ha)				
Deficit levels	**Furrow type**			
	AFI	**FFI**	**CFI**	**Deficit Mean**
50 % ETc	43722	39563	47082	**43455^{b}**
75 % ETc	48066	42367	52601	**47678^{ba}**
100% ETc	49711	46620	57380	**51237^{a}**
Furrow type mean	**47166^{ba}**	**42850^{b}**	**52354^{a}**	
LSD (5 %)	**5263.7**			
CV (%)	**16.41**			

Analysis of Deficit level and furrow type on Water Productivity

As the over year analysis on Table 3 indicated that application of the three deficit levels and furrow type have a significant difference on water productivity and highest water productivity value of 20.53 kg/m^3 and 20.6 kg/m^3

obtained at the application of 50% ETc irrigation level and alternate furrow irrigation type respectively. While least water productivity value was obtained from 100% ETc irrigation level and conventional furrow irrigation type or farmer practice . The two years over year analysis result on irrigation type indicated that application of alternate furrow irrigation gives a higher water productivity value of 20.6 kg/m^3. There is a 45 % water applied was saved using AFI as compared to CFI or control one without a significant yield reduction. Application of 50 % ETc deficit level has a higher water productivity value with a significant diference to full irrigation application and 75 % ETc deficit level with a significant fruit yield reduction.

Table 3. Over Year Analysis of Water Productivity

	WP in kg/m^3			
	Furrow type			
Deficit levels	**AFI**	**FFI**	**CFI**	**Deficit Mean**
50 % ETc	26.86	20.26	14.46	**20.53**
75 % ETc	19.69	14.46	10.77	**14.97^b**
100% ETc	15.27	11.93	8.82	**12.01^c**
Furrow type mean	**20.60^a**	**15.55^b**	**11.35^c**	
LSD (5 %)	1.74			
CV (%)	**16.2**			

Other research findings indicated that AFI treatment supplied with cumulative irrigation water which was 60-62% of that supplied to the CFI treatment. This amounted to water savings of 38-40%. The alternate furrow irrigation is a form of partial root drying (PRD), which has shown significant water savings in various crops. Sepashah and Ahmadi, (2010) have indicated in their review on PRD that irrigation water may be reduced by 30-50% with no significant yield reduction.

According to Pataneet *et al.* (2011), the adoption of DI strategies in which a 50% reduction in ETc was applied for the whole or partial growing season to save water helped to minimize fruit losses of tomato and maintain high fruit quality, also Zegbe- Domínguezet *al*. (2006) did not find a reduction in tomato fruits yield of field-grown processing cultivar through the application of deficit irrigation. Although, the effects of DI on tomato fruits yield may be different, many investigators such as Kirdaet *al.* (2004) and Topcu *et al*. (2006) have demonstrated that DI saves substantial amounts of irrigation water and increases in water productivity.

Analysis of Deficit level and furrow type on plant height and number of fruits per plant

Five plant samples from the three central rows of tomato plot were taken to collect plant height and fruit number per plant data. As shown on Table 4, both furrow application system and deficit levels have no significant effect on plant height. Furrow type has no significant effect on fruit number but application of different deficit irrigation levels affect number of fruit per plant. Maximum fruit number was obtained from the application of 100 % ETc level and minimum number of fruit was obtained from the application of 50 % ETc level. However, number of tomato fruit per plant obtained from the application of 75 % ETc level was at par with both 100 % ETc and 50 % ETc levels.

Table 4. Over year Analysis Result of Plant height and Fruit number per plant

Treatments		**plant height (cm)**	**Fruit number per plant**
Furrow type mean	Alternate Furrow Irrigation	**49.54**	**25**
	Fixed Furrow irrigation	**49.38**	**24**
	Conventional Furrow irrigation	**50.66**	**25**
	CV	**6.35**	**21.9**
	LSD (@5 %)	**NS**	**NS**
Deficit level mean	50% ETc Deficit level	**49.64**	**21^b**
	75 % ETc Deficit level	**49.79**	**25^{ab}**
	100 % ETc Deficit level	**50.14**	**28^a**
	CV	**6.35**	**21.9**
	LSD (@5 %)	**NS**	**3.65**

4. Conclusion and Recommendation

Water scarcity is an increasingly important issue in many parts of the world. Therefore, efficient use of water is a key factor for irrigation water management globally, with wide spread efforts being made to increase water productivity and reduce the environmental impacts of irrigation. Deficit irrigation provides a means of reducing water consumption while minimizing adverse effects on yield.

The two years over year analysis result of this study showed that AFI is water saving irrigation method was suited for tomato production without a significant fruit yield loss with maximum water productivity.

Implementation of AFI saved 45 % of the water to be applied for additional irrigate land as compared to conventional irrigation. In addition, application of 75 % ETc level saves 25 % of water without a significant effect on fruit yield of tomato.

Hence, from this experimental findings, application of alternate furrow irrigation is a better water saving furrow application system as compared to conventional furrow irrigation system and application of 75 % ETc level enhance water productivity by reducing the amount of water applied for crop production as compared to 100 % ETc level without adverse effect on yield of tomato. Therefore, 75 % ETc estimated deficit level and alternate furrow irrigation system is recommended for the study area. Further study on integrated effect of deficit level on growing stage is suggested to advance this research findings.

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