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Validation and Demonstration of Alternate Furrow and Deficit Irrigation on Yield and Water Productivity of Tomato in Farmers Field at Ambo, Western Shoa, Ethiopia

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Abstract: Water is a limiting factor and scarce resource for agricultural production; therefore, it is necessary to adopt different water saving irrigation practices. Alternate furrow irrigation is a water saving irrigation strategies and it is a further development of regular deficit irrigation. The present study was conducted with the aim of validating and demonstrating promising water saving strategies for the farmers. The study was conducted on two farmers field at Ambo district with the selected water saving irrigation practices during 2016/2017 on tomato. The selected promising water saving techniques were alternate furrow irrigation with 100%ETc and conventional furrow irrigation with 75 % ETc level, while conventional furrow irrigation with 100 % ETc level considered as a control. In addition, farmers' perception towards water saving irrigation practices were assessed based on different treats. The analysis result revealed that application of alternate furrow with 100 % ETc level results a higher water productivity as compared to conventional furrow irrigation with 100% ETc and 75% ETc level without a significant yield reduction. Farmers perceive that application of alternate furrow irrigation100 % ETc level saves time of application, labour and amount of irrigation water applied wit out significant yield reduction.

Key words: Alternate Furrow Irrigation · Water Productivity and Farmers Perception

INTRODUCTION

Tomato is one of the most widely grown vegetables in the world. Tomato plants are sensitive to water stress and show high correlation between evapotranspiration and crop yield [1]. In many parts of the world, tomato is produced under irrigation [2]. However, due to the global expansion of irrigated areas and the limited availability of irrigation water, there is need to optimize water use in order to maximize crop yield under water deficit conditions [3].

The 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 [4]. 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 [5]. The expectation is that any yield reduction will be insignificant compared with the benefits that gained from the conservation of water. The goal of deficit irrigation is to increase crop water productivity by reducing the amount of water applied or by reducing the number of irrigation events [6].

Another important water saving adaptation of furrow irrigation system 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 arid and semi-arid areas [3, 7] as well as saving irrigation water. According to the findings of Stoll *et al.* [8] on alternate furrow irrigation shown that water can be redistributed from roots in the wet soil into root in dry soil during the night. Plant water status may equilibrate with the wettest part of the root zone which could contribute to maintenance of plant water balance as suggested by Hsiao [9]. With the above justifications this

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study was conducted with the aim of demonstrating, validating and promoting research generated recommendations on alternate furrow and deficit irrigation practices on farmers field in order to analyze farmers perception on water saving irrigation practices that enhance water productivity of agricultural production.

MATERIALSANDMETHODS

Description of the Study Area: The study was conducted at Ambo district on two farmer's field during 2016/17 irrigation season. The site was located near to Ambo Agricultural Research Center which has similar geographical and climatic characteristics with the center. The site is situated on 38° 07'N E longitude and 8° 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 25.4°C and 11.7°C respectively. The soil texture has been classified as clay soil.

Experimental Treatment and Design: The experiment was designed as a single factor factorial experiment in randomized complete block (RCBD) arrangement with three treatments and replicated at two farmers' field. The experiment comprised of two best promising water saving furrow irrigation application as a treatment which are Alternate furrow irrigation (AFI) with 100 % ETc levels and conventional furrow irrigation (CFI) with 75 % ETc level, conventional furrow irrigation (CFI) with 100%ETc level, considered as a control which is the third treatment. The amount of irrigation to satisfy the designed crop water requirement was computed with the aid of CROPWAT software model using necessary primary and secondary data (long term climatic data, soil and crop data). Soil moisture content was monitored using gravimetric method and amount of irrigation water at each irrigation application time were applied by measuring through Parshall flume.

Experimental Procedure and Management Practice: Two farmers field at Ambo district were selected in order to implement this experiment. The field was ploughed and well pulverized to break clods. 10 m long by 10 m wide plots were prepared. Seedling of tomato was sown at Ambo Agricultural research center nursery site by preparing suitable bed on which seeds were raised. Six weeks after sowing vigorous and healthy seedlings were selected and transplanted on the selected farmer's experimental site. The seed space on the bed of each plot at 75 cm and 35 cm inter-row and intra-row spacing, respectively. A common irrigation was applied to help establishing the tomato seedlings in all the plots irrespective of different irrigation treatments. Subsequently, the irrigation water was delivered as per the treatment. To meet the nutritional requirement of tomato crop, each plot was received a recommended rate of 92 kg N/ha in the form of urea (about 200 kg/ha) and 18/46 kg N/P2O5 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.

Data Collection: The study employed by both qualitative and quantitative data approach. The qualitative data were collected through focus group discussions using a semi-structured questioner, while the quantitative data were collected from yield and yield component of the experimental plot.

Fruit Yield and Yield Component of Tomato: Tomato growth component data like plant height, number of fruits per plant and number of clusters per plant were collected from 10 plants selected at the central rows. Tomato fruit yield were collected from the whole plot at different period by selecting the ripened fruit and the total fruit weight was obtained by summing up the fruit weight collected at different ripening period.

Water Productivity: Water productivity and effect of water stress on crop performance were quantified from water productivity (WP) and yield response factors (Ky) respectively. Estimation of water productivity was carried out as a ratio of total yield to the total water applied as proposed by Heerman *et al.* [10] (Equation 1).

$$(WP) = \frac{Fruit\ yield}{Growth\ irrigation\ applied} \quad (1)$$

where, WP = Water Productivity

Fruit Yield Reduction or Increment and Yield Response Factor: Tomato Fruit yield reduction or increment and yield response factor used to compare fruit yield obtained from the control with the yield result obtained by applying different treatments. The increase in yield was computed as (2).

$$Increase\ in\ yield\ (\%) = \frac{Y_1 - Y_2}{Y_1} * 100 \quad (2)$$

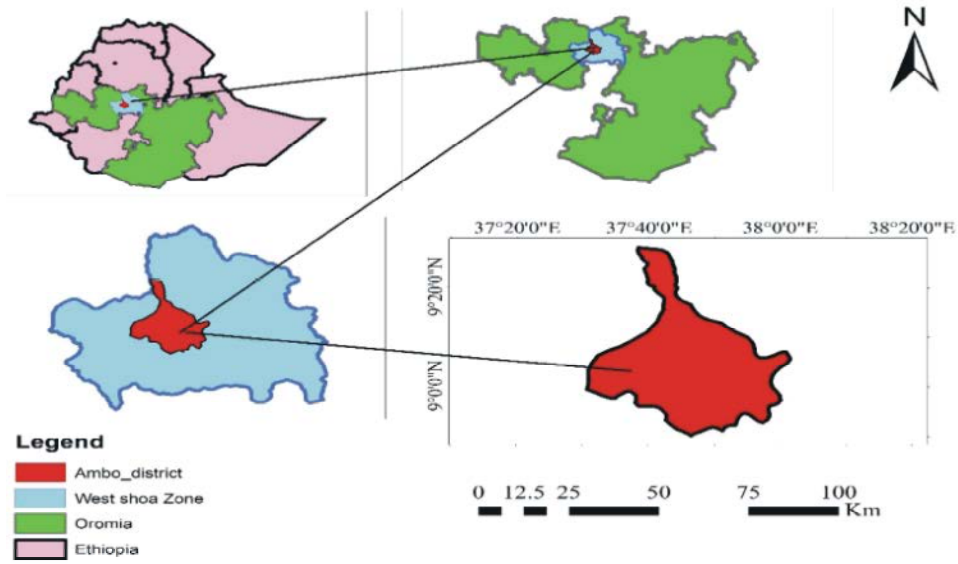

Fig. 1: Study area

Table 1: Combination of experimental treatments

Treatment	Combinations
T1 (AFI100%ETc)	Alternative Furrow Irrigation irrigated at 100% ETc
T2 (CFI 75%ETc)	Conventional Furrow Irrigation irrigated at 75% ETc
T3 (CFI 100%ETc)	Conventional Furrow Irrigation irrigated at 100% Etc

where,

Y1 = Yield obtained from control treatment (conventional furrow irrigation with 100 % ETc) (kg/ha) and

Y2 = Yield obtained under Alternate furrow irrigation and conventional furrow irrigation system with 75 % ETc (kg/ha)

Yield Response Factor (Ky): Yield response factor indicates a linear relationship between the decrease in relative water consumption and the decrease in relative yield. It shows the response of yield with respect to the decrease in water consumption. In other words, it explains the decrease in yield caused by the per unit decrease in water consumption. Hence the regression analysis was used to find the value of Ky. The yield response factor (Ky) was estimated from the relationship [11] (equation 3).

$$Ky = \left(1 - \left(\frac{Y_a}{Y_m}\right)\right) = Ky = \left(1 - \left(\frac{ET_a}{ET_m}\right)\right) \quad (3)$$

where,
Ya is actual harvested yield,
Ym is maximum harvested yield,
Ky is yield response factor
ETa is actual evapo-transpiration and
ETm is maximum evapo-transpiration

Assessment of Farmer Perception Towards Water Saving Technologies: Farmer's perception on water saving irrigation technologies were assessed by developing a semi- structured questioned or different treat concerning the water saving technics. Focal group discussion on the different treats were collected from the three groups consist of (female group, male group and half of the group female and the other half were male). Finally, the data acquired were analyzed using descriptive statistics techniques.

Data Analysis: The data collected during the experimental period were subjected to statistical analysis using SAS computer program. Whenever treatment effects were significant, Least Significance Differences (LSD) test was used to assess the mean difference among treatments.

RESULT AND DISCUSSION

Irrigation Water Requirement: As per the output of CROPWAT model, the optimal seasonal irrigation water requirement was found to be 697.2 mm/plot (6972 m^3/ha)

Table 2: Analysis Result of Tomato yield and yield component data

Treatments	Fruit yield (Kg/ha)	Plant height (cm)	Fruit number per plant	Cluster number per plant
AFI 100%ETc	43676	58.4	34	11
CFI 75 % ETc	45579	56.2	30	10
CFI 100 % ETc	51286	55.6	28	8
LSD (5%)	NS	NS	NS	NS
CV (%)	5.78	5.7	12.6	6.7

Table 3: Analysis Result of Tomato Water productivity

Treatments	Fruit yield (Kg/ha)	Irrigation water applied (m^3/ha)	Tomato water productivity (kg/m^3)
AFI 100%ETc	43676	3486	12.53[a]
CFI 75 % ETc	45579	5229	8.72[b]
CFI 100 % ETc	51286	6972	7.36[b]
LSD (5%)	NS	-	2.41
CV (%)	5.78	-	5.86

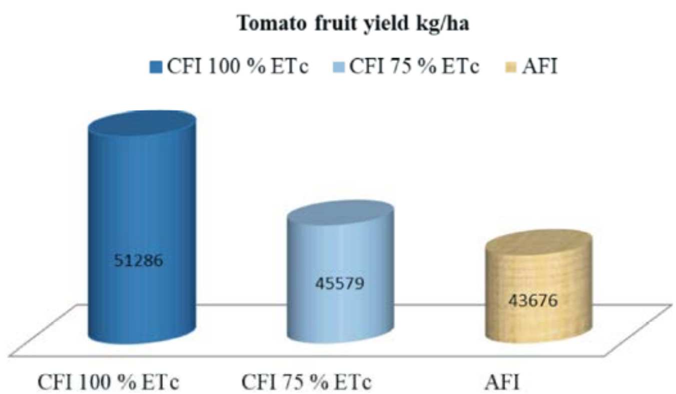

Fig. 2: Tomato fruit yield in Kg/ha as influenced by irrigation treatment

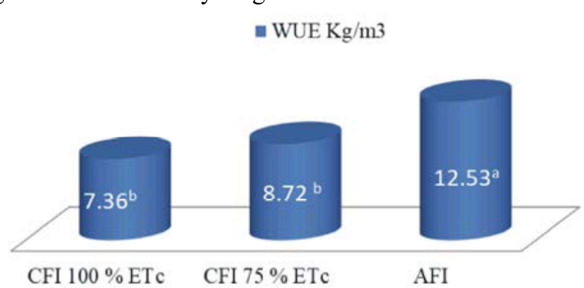

Fig. 3: Water productivity result of tomato as influenced by irrigation treatments

for conventional furrow irrigation (control treatment) method. For the alternate furrow (AFI) 348.6 mm/plot (3486 m^3 /ha) and for conventional furrow irrigation with 25 % deficit application 522.9 mm/plot (5229 m^3 /ha) of water were applied throughout the growing season of tomato crop in respective to the treatments.

Tomato Fruit Yield and Yield Component as Influenced by Alternate Furrow Irrigation and Deficit Irrigation: In order to evaluate the effect of Alternate furrow and regulated deficit irrigation on tomato fruit yield and yield component data were subjected to the statistical analysis and the results are presented in Table 2. The analysis of variance revealed that application of alternate furrow irrigation with 100% ETc and conventional furrow irrigation with 75%ETc had no significant effect on fruit yield and yield component data at ($p < 0.05$) when compared to conventional furrow irrigation with 100%ETc (farmer's practices). The result reviled that there is no significant yield difference between treatments.

Tomato Water Productivity as Influenced by Alternate Furrow Irrigation and Deficit Irrigation: Data on water productivity of tomato production are presented in Table 3. The variability among water productivity of tomato was statistically significant at ($p < 0.05$).

The highest water productivity of (12.53 kg/m^3) corresponds to the plot with the minimum amount of water application (348.6 mm) which was alternate furrow irrigation with 100%ETc.Whereas there is no significant difference between water productivities obtained from conventional furrow irrigation with 75%ETc and conventional furrow irrigation with 100%ETc which. The water productivity obtained consistently increased with the decrease in the amount of water applied. Based on the fact that application of alternate furrow irrigation reduces the amount of water applied by half as compared with conventional furrow irrigation and 25 % as compared with 25 % stressed conventional furrow irrigation method as described in Table 3. Alternate furrow irrigation technique has been fundamentally based on alternatively wetting and drying opposite parts of the ridge of furrows under which the plant root system is thought to be located. Amount of water applied under alternate furrow irrigation was also agrees with conclusion says alternate furrow irrigation is commonly applied as part of deficit irrigation because it does not require the application of more than 50-70% of the water applied under conventional furrow irrigation [12]. On the other hand, alternate furrow irrigation technique recorded lower values of total evapotranspiration as compared with conventional irrigation technique. This may be due to less evaporation from the dry furrow that was reflected on decreasing total evapotranspiration [13]. Also, Shayannejad and Moharrery [14] conclude that alternate furrow irrigation method supply water in a way greatly reduces the amount of wetted surface, which leads to less evapotranspiration and less deep percolation [14].

Tomato Yield Reduction and Yield Response Factor as Influenced by Alternate Furrow Irrigation: Application of alternate furrow irrigation and conventional furrow irrigation with 75 %ETc level reduce fruit yield by 14.83 % and 11.13 % as compared to the control treatment with saving of 50 % and 25 % irrigation water applied respectively as described in Table 4. Since relative yield reduction of alternate furrow irrigation statistically had no significant difference with a saving half of the water applied as with respect to the control treatment. In accordance with the experimental results shifting conventional furrow irrigation to alternate furrow irrigation helps to save half of irrigation water applied without a significant yield reduction and with a significant increment in water productivity. Yield response factor for alternate furrow irrigation and conventional furrow with 75 % ETc level were 0.3 and 0.45 respectively. According to FAO [15], only those crops and growth stages with a lower yield response factor (Ky < 1) can generate significant savings in irrigation water through deficit irrigation. A value of Ky greater than 1 shows a yield decrease proportionality more than the evapotranspiration decrease. In other words, this means that the advantages coming from the deficit irrigations are unlikely [6]. Similarly, Doorenbos and Kassam [16] also reported that when Ky is greater than 1, yield loss is more important than evapotranspiration deficit. Since the result of this experiment have a yield response factor (Ky < 1) Table 4, therefore through the application of alternate furrow irrigation as well as 25 % stressed conventional furrow irrigation there is a significant saving of irrigation water applied.

Table 4: Yield reduction and yield response factor result as influenced by deficit application

Treatments	Fruit yield (kg/ha)	Net irrigation applied	Yield Reduction (%)	Water saved (%)	1-ETa/ETm	1-Ya/Ym	Ky
AFI 75%ETc	43676	348.6	14.83	50	0.5	0.48	0.3
CFI 75 % ETc	45579	522.9	11.13	25	0.25	0.11	0.45
CFI 100 % ETc	51286	697.2	0	0	0	0	-

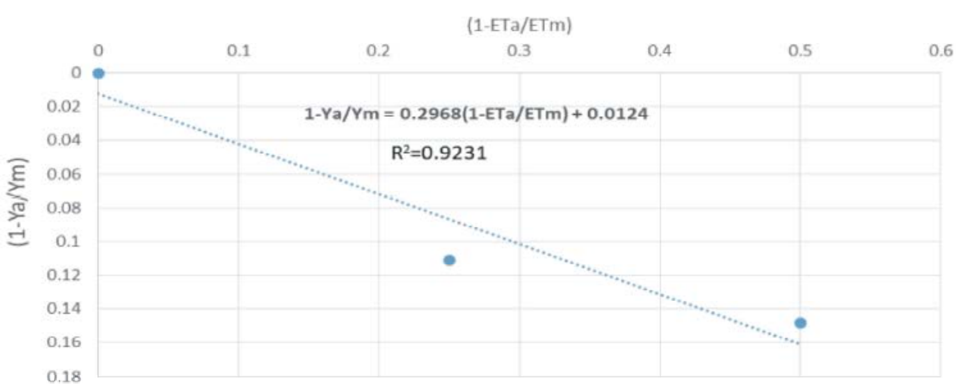

Fig. 4: Water production function of Tomato yield

Table 5: Descriptive analysis of Farmer perception towards water saving techniques (Where 1 – poor 2- Good 3- Very Good)

S.N.	Criteria's/ traits	CFI100 % ETc	CFI75 % ETc	AFI100 % ETc
1	Fruit number per plant	2	1	3
2	Fruit size	3	2	1
3	Yield per plot	3	2	1
4	Maturity	1	2	3
5	Marketability	3	2	1
6	Easiness to apply water	1	2	3
7	In accordance with water saving	1	2	3
8	In accordance with time and labor saving	1	2	3

Fig. 5: Training for Agricultural experts, Development agents and Farm

Assessment of Farmer Perception Towards Water Saving Technologies: The farmers evaluated the experiment with their practices based on different treats as described in Table 5. The farmer perception result on water saving technics indicate that application of alternate furrow irrigation saves more water as compared to their practices or applying irrigation water at every furrow. Therefore, most of the farmer conclude that application of alternate furrow irrigation is better even if it gives smaller fruit size as compared to conventional furrow irrigation and the amount of saved water through the application of alternate furrow irrigation helps to cultivate additional farms.

CONCLUSION

From both quantitative and farmer perception qualitative analysis results alternative furrow irrigation with 100% ETc level gives a promising result on water productivity enhancement. Therefore, shifting conventional furrow irrigation to alternate furrow irrigation is suitable for the study area.

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