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Effects of Furrow Irrigation Methods and Mulching on Growth, Yield and Water Use Efficiency of Tomato at Bakotibe, Western Shoa

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Abstract

Sustainable irrigation method is now essential for adaptation and adoption in the areas where water resources are limited. Therefore, a field experiment was conducted to test the combined effect of alternate wetting and drying furrow irrigation, conventional irrigation method and mulches on crop growth, yield and water use efficiency of tomato. The treatments of the experimental area comprised of two irrigation method (conventional and alternate furrow irrigation method) and three mulches (maize, soybean and wheat straw). The yield and yield-component characters in the mulched treatments for two of furrow irrigation method were significantly higher compared to those in the unmulched (bare soil) treatments. The yields of tomato were higher in conventional furrow irrigation method than alternate furrow irrigation method. The highest yield (82267 kg/ha for maize straw, 88004.5 kg/ha for soybean straw and 87074 kg/ha for wheat straw) was obtained at conventional furrow irrigation method. Soybean and wheat straw mulched treatment produced higher yield than the maize straw-mulched treatment. The highest water use efficiency of 16.221A kg/ha/m^3 15.978 kg/ha/m^3 was obtained with alternate furrow irrigation method under soybean and wheat straw mulch respectively. The study thus reveals that alternate furrow irrigation method with mulch has an explicit role in increasing the water use efficiency of tomato.

Keywords: Dry furrow irrigation • Conventional irrigation • Sustainable irrigation • Wet furrow irrigation.

Background and Justification

Tomato is one of the most important and widely grown vegetable in Ethiopia. Fresh, processing and cherry types are produced in the country. Small-scale farmer produces the bulk of fresh market tomatoes. Processing types are mainly produced in large-scale horticultural farms. It is an important cash-generating crop to small scale farmers and provides employment in the production and processing industries. It is also important source of vitamin A and C as well as minerals. Farmers are interested in tomato production more than any other vegetables for its multiple harvests potential of year round production, which results in high profit per unit area. The Production of the tomato crop in most of western Shewa had been limited by several factors among which are irrigation water management and environmental factors that include temperature, humidity and rainfall. Sometimes, many of the farmers can't able to provide irrigation due to unavailability of irrigation facilities and scarcity ofirrigation water. Under this situation mulching and alternate furrow irrigation could be a good substitute means of irrigation to save soil moisture. Proper irrigation managementincreases the water use efficiency; consequently, the production per unit of water will be increased. The degradable mulch has been designed to be incorporated into the soil profile, eliminating the need for polyethylene mulch removal at the end of the growing season [1]. It is one of the agricultural practices that take into account the preservation of the environment compared with polyethylene mulch, which is one of the recognized priorities in the world. Investigations of degradable mulch have proven their favorable impact on crop yields and the ecosystem [2,3]. Benefits of mulch include the enhancement of soil structure, soil fertility [4] and preservation of environmental quality [5]. The development towards optimum utilization of irrigation is to irrigate alternate furrows [6]. It is presumed that irrigating alternative furrows can help to save irrigation water both by minimizing evaporative loss from plant leaf due to reduced stomatal opening with absence of visible leaf water deficit and by reducing deep percolation losses at the same time. Kang et al. applied surge flow to alternate furrows in cotton fields. The performance of alternate furrow irrigation considerably increased and provided the highest water productivity (0.61 kg/m^3) and irrigation application efficiency (85%) as compared to the conventional furrow irrigation. The aim of this study was therefore, to determine the combined effect of cover crop residue and irrigation method practices on water use efficiency of tomato crop.

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Objective

To study the effects of furrow irrigation methods and mulching on the growth, yield and water use efficiency of tomato.

Materials and Methods

Experimental site description

The study was conducted at ganda Oda Haro, Bako Tibe, West Shoa. Bako is located at 9˚ 08' N latitude and 37 ˚ 03' E longitude; 251 km from Addis Ababa. The altitude was ranged from 1670 to 1690 m.a.s.l. The mean annual rainfall is about 1237 mm, with a peak in July.

Experimental design and treatments

The experimental unit arranged in two-way Randomized Complete Block Design and replicated three times. The treatments for the experiment was consist of two levels of furrow irrigation methods (conventional furrow and alternate furrow irrigating methods) and three levels of mulches (maize mulch, soya bean and wheat mulches). The experimental field consisted of 24 plots with a dimension of 5 mx6 m.

Estimation of crop water requirements

The actual crop evapotranspiration was (ETa) computed by multiplying the reference evapotranspiration (ETo) with crop coefficient (Kc) for different growth stages of the crop. ETo was calculated on a daily basis from daily meteorological data using the CROPWAT 8.0 model. The model uses FAO Penman-Monteith equation, which was accepted as standard method to calculate reference evapotranspiration.

Irrigation water use efficiency

Irrigation water use efficiency (IWUE) was calculated as the ratio between the yields harvested (kg) and the total volume of water applied (m^3)

Water application efficiency(Ea)

It is the ratio of the volume of water stored in the subject region to the volume of water diverted into the subject region.

Ea =Ws/Wf ×100

Where, W_f = water stored in crop root zone, cm

W_f = water delivered at the head end of the furrows, cm.

Laboratory analysis of soil samples

The pH in H_2O under this study area is ranged in optimum value. An electric conductivity of 0.0355 ms/cm lies in the range which is <3 ms/cm, hence the soil samples are non- saline soils as per the rating suggested by Jones (2003). The total nitrogen of study area as suggested by [7] rated as high percent which is suitable for plant growth (Table 1).

Key: FC=Field capacity, PWP=Permanent wilting point, SCL=Sandy clay loam

The soil texture class changed with depth from clay in surface horizon to sandy clay loam in sub-surface at this experimental area. The value of average bulk densities (1.315 g/cm^3) observed in these soils was within the normal range of mineral (Table 2).

Management practice of the tomato crop

The plots were weeded three times and chemicals were sprayed against fungus, fruit worms and pests. Standard Parshall flume was installed near the up-stream of the experimental field to measure irrigation water applied. The time required to apply the desired depth of water controlled by stopwatch. For the conventional furrow method, water was allowed to the end of the furrows with initial stream size maintained. For the alternate furrow method, intervening furrows were irrigated while the others were left dry for an irrigation event.

Table 1. Chemical composition of the soil at Bakotibe experimental field.

No	Chemical properties	0-20 cm	20-40cm
1	Organic carbon (%)	2.305	2.367
2	Available phosphorus (ppm)	8.58	18.78
3	Ph in H_2O	4.91	6.08
4	Ph in 0.01 M $cacl_2$	4.05	5.42
5	Ph in 1M KCL	3.84	4.94
6	Total nitrogen (%)	0.199	0.204
7	Electrical conductivity (ms/cm)	0.0355	0.0348
8	Organic matter (%)	3.974	4.081
9	Av.K (Flame photometry	105.5	167.5
10	Exch. Acidity (cmol(+)/Kg)	3.05	0.03
11	Exch. Mg^{2+}	3.225	6.655
12	Exch.Ca^{2+}	3.605	18.22
13	Exch.K^+	0.217	0.985
14	Exch. Na^+	0.174	0.283

Data management and analysis

All relevant data were recorded, stored and managed in Microsoft excel. The collected data were arranged and organized for the suitability of statistical analysis and finally analysis of variance (ANOVA) was performed using R software. Lest significant difference (LSD) at 5% level significance was used to make mean separation among treatments.

Results and Discussion

The tomato crop was irrigated sixteen times Table 3 (trice in the initial, four times in the development stage, five times in the mid stage and four in the late stage). The highest evapotranspiration values for the irrigated treatments occurred in the mid stage (Figure 1).

*= significant at 95%, **=significant at 99%, ***= significant at 99.9% and NS= non-significant

Number of fruit per plant

Table 4 shows that, conventional furrow irrigation method was highly significant (55.667) in number of fruit per plant than alternate irrigation method (39.833). In Table 5, it was found that all treatments of mulching material were significantly increased the average number of fruit per plant of tomato than bare soil treatment. Highestnumber of branch per fruit was recorded at (59) soybean and (58.3) wheat mulch while the lowest number of fruit per plant was recorded at (29.13) alternate furrow irrigation method without mulch. This agrees with the report of [8] who reported that natural mulches such as leaf, rice straw, dead leaves and compost increase fruit per plant, length, and yield.Similarly reported that mulching with straw produced the highest number of clusters and fruits per plant.

Plant height

Plant height was statistically analyzed as shown in Tables 4. Plant height was highly significantly affected by irrigation method. Conventional irrigation method (88.433 cm) was highly significant in plant height than alternate irrigation method (72.850 cm). Table 5 shows the highest plant height of

Figure 1. Tomato plant at Bakotibe experimental site.

Table 2. Physical properties of soils at various depths at Bako TIbe experimental field.

No	Depth (cm)	Clay (%)	Silt (%)	Sand (%	Textural class	Bulk density (g/cm^3)	FC (%Vol)	PWP (%Vol)	TAW (mm/m)
1	0-20	44	41	15	Clay	1.2825	34.9	23.1	151.33.5
2	20-40	50	23	27	SCL	1.31475	38.6	24.4	186.69
	Average								169

Table 3. Estimated water requirement for different growth stages of tomato crop.

Month	day	Stage	Kc (coeff)	Etc. (mm/day)	ETc (mm/dec)	Eff rain mm/dec)	Irr. Req (mm/dec)
December	10	Initial	0.6	2.34	2.34	-	2.34
December	20	Initial	0.6	2.32	23.2	-	23.2
December	31	Initial	0.6	2.35	25.9	-	25.9
January	09	Development	0.6	2.41	24.1	-	24.1
January	19	Development	0.70	2.85	28.5	-	28.5
January	30	Development	0.85	3.55	39	-	39
February	09	Development	0.99	4.29	42.9	-	42.9
February	19	Mid	1.12	5.00	50	-	50
February	27	Mid	1.15	5.20	41.6	-	41.6
March	08	Mid	1.15	5.28	52.8	13.2	39.6
43March	18	Mid	1.15	5.36	53.6	18	35.6
March	29	Mid	1.15	5.20	57.2	19.1	38.1
April	08	Late	1.12	4.90	49.0	18.9	30.1
April	18	Late	1.0	4.24	42.4	20	22.4
April	28	Late	0.88	3.62	36.2	25.3	10.9
May	1	Late	0.80	3.19	9.6	9.4	0
Total					578.2	123.9	417.9

Table 4. Growth, yield component and water use efficiencies of tomato for each treatment.

Factor levels	Number of fruit per plant	Plant height (cm)	No. of branch/ plant	Yield per ha (kg)	CWUE (kg/ha/m³)	IWUE (kg/ha/)m³	Application eff. (%)
Furrow method							
Conventional	55.667 A	88.433A	9.7000A	81200A	14.044B	13.601B	69.297B
Alternate	39.833B	72.850B	7.3333B	46952.5B	16.241A	15.724A	73.623A
Significance	***	***	***	***	***	***	***
CV	1.763934	1.869015	5.40202	3.3275	2.145	2.145	1.221634
LSD (5%)	4.218912	1.319717	0.4028	1866.93	0.3778	0.3659	0.764385
Mulch							
Maize mulch	47.700 B	81.967 B	8.600 A	64721C	15.273B	14.789C	72.198C
Soybean mulch	52.433 A	84.867A	9.033 A	70430A	16.752A	16.221A	73.472B
Wheat mulch	51.167 A	83.03AB	9.100 A	69471B	16.500A	15.978A	75.945A
Un mulch	39.700C	72.700 C	7.3333B	51683D	12.044C	11.663D	64.225 D
Significance	***	***	***	***	***	***	***
CV	4.2189	1.86902	5.402	3.327	2.145	2.145	1.221634
LSD (5%)	2.4945	1.86636	0.5697	2640.23	0.5343	0.5174	1.081004

Table 5. Below shows the interaction effect of furrow and mulch on yield, yield component and water use efficiencies of tomato for each treatment.

Interaction effect of Furrow X mulch	Number of fruit per plant	Plant height (cm)	No. of branch/plant	Yield per ha (kg)	CWUE (kg/ha/m³)	IWUE (kg/ha/)m³	Application eff. (%)
Conventional maize mulch	55.133B	88.200B	9.600	82267	14.228	13.780D	69.577
Conventional soybean mulch	59.000A	93.000 A	10.40	88004.5	15.220	14.741C	71.330
Conventional wheat mulch	58.267AB	89.933 B	9.933	87074	15.059	14.585C	73.633
Conventional un mulch	50.267C	82.600 C	8.867	67454	11.666	11.299E	62.647
Alternate maize mulch	40.267 E	75.733 D	7.600	47175	16.318	15.799B	74.820
Alternate soybean mulch	45.867D	76.733 D	7.667	52855.9	18.283	17.701A	75.613
Alternate wheat mulch	44.067D	76.133 D	8.267	51868	17.941	17.370A	78.257
Alternate un mulch	29.133 F	62.800 E	5.800	35911	12.422	12.026E	65.803
Significance	*	**	NS	NS	NS	**	NS
CV	4.21891	1.86902				2.145	
LSD (5%)	3.52787	2.63943	-		-	0.7318	-

84.867cm was obtained with soybean mulch , which agrees with the report of [9] who stated that tomato plants subjected to mulching exhibited the highest plant height when compared with control.For mulching treatments, results are in line with [10] who reported that, leaf area and plant height were significantly affected by the mulching treatments.

Number of branch per plant

The result of our discussion revealed that (Table 4); conventional furrow irrigation method was highly significant in number of branch per plant than alternate irrigation method. However, numerically the highest number of fruits per plant was found from the treatment (9.10 & 9.033) wheat and soybean mulch respectively. Observed that mulching significantly increased the number of fruits per plant compared to the bare soil.

Fruit yield

There was a significant reduction in yield of over by adopting alternate furrow irrigation as against the conventional furrow irrigation method. The conventional furrow method with mulching of the furrow proved higher yielding. From Table 4 we conclude that, application of soybean, wheat and maize mulch resulted in a yield increase of over that obtained from bare soil. Among all mulching treatments, maximum fruit yield were recorded in treatment soybean (88004.5 kg/ha) and wheat mulch (87074 kg/ha). Significantly lowest (35911 kg/ha) fruit yield was recorded from alternate furrow irrigation method with no mulch (Table 5). Results seem to suggest that there is potential for cover crop residue to increase tomato yields. Incorporating soybean and wheat mulch have improved the tomato crop as well as water content explaining the higher yields obtained in these treatments. It has been observed elsewhere that mulch increased soil nutrients availability to plant roots, leading to higher grain yield [11-13].

Crop water use efficiency

From table 4 we conclude that, Alternate irrigation method (16.241 kg/m^3) was highly significant in crop water use efficiency than conventional furrow method (14.004 kg/m^3). Moreover, tomato crop water use efficiency was highly significant influenced due to different mulch materials (Table 4). The presence of mulching reduce evaporation from the wet soil surface, which supporting the findings by [14]. In contrast to this, table 5shows the interaction effect of the mulchtypeshad no significant effect on crop water use efficiency of tomato.

Irrigation Water use efficiency

Data introduced in Tables 5 showed that, the highest water use efficiency of 17.701 kg/ha/m^3 and 17.37 kg/ha/m^3 was obtained with alternate furrow irrigation method under soybean and wheat straw mulch respectively. So far, alternate furrow irrigation has been investigated in several cereal crops and grapes [15,16]. Compared to conventional furrow irrigation, alternate furrow irrigation saved 20–33% irrigation water shortened the time required for irrigation and substantially improved water use efficiency. No significant differences were observed for the interaction effect among mulch treatments. These results are in agreement with those of [10]. Data introduced in (Table 4) cleared that irrigation water use efficiency of mulched treatments were significantly higher than bare soil treatments. The result is in line with that of [17,18] who reported that irrigation water use efficiency under different mulches treatments are effective in reducing soil evaporation, and increasing plant water use efficiency.

Application efficiency

From our result we observed that (Table 4), Alternate furrow irrigation system (73.623%) were highly significant higher in water application efficiency than conventional furrow irrigation method (69.297%). Mulching materials are highly significant in water application efficiency than bare soil (treatment without mulch). Table 5 shows the highest (78.257%) water application efficiency was resulted from alternate furrow irrigation method with wheat mulch while the lowest (62.647) was recorded undertreatment conventional furrow method with bare soil. In coincidence with this result [19] reported that furrow irrigation application efficiencies range was found to be 65.26%-81.96%. Research shows that use of surface mulch can result in storing more irrigation water in soil by reducing runoff, increasing infiltration and decreasing evaporation [20]. The interaction effect between different mulches and furrow has not significantly different from each other in water application efficiency.

Conclusions and Recommendation

Increasing water use efficiency by planting with mulch could potentially allow year-round planting by farmers. Planting tomatoeswith alternate furrow irrigation method by incorporating mulching material was found to increase water use efficiency significantly during the dry season.Our study confirms that, the most successful tomato production occurs on soybean and wheat mulch. Therefore, based on our findings, we recommend that soybean and wheat mulch are the best for tomato production in our experimental area. Moreover, our study demonstrates that good results can be obtained with maize mulches. The poorest results were obtained for alternate furrow irrigation method those cultivated on bare soil with no mulch. Finally we recommend at scarcity of water; farmers can use alternate furrow irrigation method with wheat or soybean mulch to achieve high water use efficiency. However, if there is excess amount of water farmers can use conventional furrow irrigation method with wheat or soybean mulch. The test crop of our experiment was galila variety tomato; it is better if the test should be extended to other tomato variety and commercial crops.

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