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Integrated Effect of Mulching and Furrow Methods on Tomato (Lycopersiumesculentum L) Yield and Water Productivity at West Wellega, Ethiopia

Robel Admasu*[1] Zelalem Tamiru[2]
1.Jimma Agricultural Research Center P. Box 192, Jimma, Ethiopia
2.Haru Agricultural Research Sub-Center, P. Box 192, Jimma, Ethiopia

Abstract
Mulching applications can effectively modify the plant hydrothermal micro-environment.However, the impacts of mulching on potato yield vary with climatic conditions and field managements. Mulching with different furrow irrigation methods is one of the techniques to improve soil and water productivity. A field trial was conducted to study the effect of plastic mulch and different irrigation levels on water productivity and yield attributes of tomato (Lycopersiumesculentum L)based on the objective to select most effective water management techniques and mulching types. A split plot design consists of three furrow irrigation methods (namely conventional, alternate and fixed furrow with 100% ETc) as main plot and three mulch treatments (namely, without mulch, straw mulch and plastic mulch) as sub-plot used with three replications. The irrigation method and mulching types highly significantly ($p<0.01$) affected the studied parameters of tomato at Haru. Maximum tomato yield was recorded from conventional furrow irrigation method which is superior than alternate and fixed furrow irrigation method. However, higher water use efficiency was obtained due to alternate furrow irrigation method. Maximum marketable yield and water use efficiency were obtained due to plastic mulch than no mulch and straw mulch for tomato at Haru. However, there was no interaction effect due to the two factors studied (irrigation type and mulching type) except water productivity. Therefore, for maximizing marketable yield and better water productivity under no water stress condition; irrigation of tomato with conventional furrow irrigation methods coupled with plastic mulch could be used. But for moisture stress scenario it is preferable to use alternate furrow with plastic mulch to achieve highest water productivity with minimum yield loss.
Keywords: plastic mulch, Alternate furrow, Conventional furrow, water productivity
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Introduction
The unproductive evaporation from soil root zone is a major source of moisture loss in the world arid and semiarid regions (Khamraev&Bezborodov, 2016). Consequently, more water is required for plants survival to avoid stress conditions. Minimizing this huge amount of irrecuperable losses of water is therefore very crucial and if achieved can play an important role in contributing soil moisture conservation for optimum crop growth in limited water regions (Kader et al., 2017).In order to reduce the evaporation rate adopting suitable soil management techniques like mulching recommended. Mulch is a protective layer of either organic or inorganic material that is spread on the top soil: to reduce the moisture loss from the soil by preventing evaporation from sunshine and desiccating winds, to prevent weed growth, to improve soil condition, to provide home for earthworms and natural enemies found in the soil and reduce soil compaction from the impact of heavy rains (Lamont, 2000; Ramakrishna et al., 2006; Anonymous, 2008). Mulch helps regulate soil temperature by shading it, thus keeping it cooler and helps insulate it in the winter from chilling winds. This temperature regulating effect helps encourage the root growth of plants, and prevent soil erosion. Agriculture with mulch in the tropics promotes plant health and vigor. Mulching improves nutrient and water retention in the soil, encourages favorable soil microbial activity and worms, and suppresses weed growth. When properly executed, mulching can significantly improve the well-being of plants and reduce maintenance as compared to bare soil culture (Ramakrishna et al., 2006; Anonymous, 2008).

Mulching practices have pronounced effects on enhancing water use efficiency (WUE). Kader et al., (2017) reported that both plastic and straw mulches increased the water use efficiency by 79% and 58%, respectively, compared to bare soil. Based on six years experiments on rice crop in China, Wu et al., (2016)observed that the crop water use efficiency was increased by 70 to 80% and irrigation water use efficiency by 274% when the crop was raised under the plastic film mulch conditions compared to the traditional planting. Alongside the potential benefits of soil water conservation, better yield and higher water use efficiency, mulching also control weed infestation (Matković et al., 2015), improve soil texture (Nawaz et al., 2016), improveaeration, modify soil temperature (Ramakrishna et al.,2006), checking surface sealing and crusting of soil byprotecting the top soil surface from raindrop splashes(Brant et al., 2017), decreasing nutrient losses and increasethe infiltration rate (Lalljee, 2013), and increase sedimentdeposition by enhancing roughness of soil surface(Donjadee&Tingsanchali, 2016).

Other irrigation water management aspect is deficit irrigation. It has been used as a water saving method in agricultural production to increase benefit and water use efficiency (Mitchell et al., 1991 and Behboudian and Mills, 1997). Deficit irrigation, under furrow irrigation, can be induced via different irrigation techniques such as fixed-furrow. Fixed furrow irrigation (FFI) is a way to save water and showed a small improvement over the alternate furrow irrigation (Slatni et al., 2011). For economic and environmental benefit of using every-other furrow irrigation method is higher than any other irrigation methods, because less water is applied and a greater economic return can be obtained (Nelson and Al-Kaisi, 2011).

Tomato is one of the most widely grown vegetables in the world. Tomato plants are sensitive towater stress and show high correlation between evapotranspiration and crop yield (Nuruddin et al., 2003).However, no work has been done to study the effect of different furrow irrigation methods in combination with mulch in the study area. The present study was planned to evaluate the effect of mulch and amount of water on the yield of tomato under furrow irrigation system and to assess the water productivity in relation to mulch used in tomato production.

Materials and Methods

Description of the experimental area

The experiment was conducted at Haru agricultural research sub-center and found at 28 km from Gimbi town and 466 km from Addis Ababa inwestern Ethiopia. The area is geographically located between latitude of 8°54' 30" North andlongitude of 35°52'0" Eastat an elevation of 1750 m.a.s.l. The rainfall pattern of the area is bimodal. The rainy seasonstarts inMay and extends up to October. The mean maximum and minimum airtemperature are 27.8ºC and 12.4ºC, respectively. The soil type of the center is *Acrisols*andsandy clay loam (Zebene and Wondwosen, 2008).

Treatments and design

The experiment was done in a split plot design with three irrigation water application methods (fixed, alternate and conventional furrow method) in main plot and two mulch types (straw and plastic) and control as no mulch. Each main plot factors (furrow irrigation methods) was assigned randomly within each replication and every subplot factor (mulching) was randomly assigned inside each main plot. Sub plot size of 5m × 5m which consists of 5 ridges spaced at 100 cm was used for mulching factor. Main plot consists of three subplots as furrow irrigation water management method. plastic mulch and vetiver grass (*Chrysopogonzizanioides*) straw mulch with a rate of 6tha^{-1} were used as mulching types in the sub plots. Seed of Tomato variety Melkashola was sown on seed bed for one month.Then seedlings transplanted to prepared ridges in spacing of 30 cmand 100 cm for plants and rows respectively (Lemma, 2002). Recommended agronomic practices such as weeding, cultivation, fertilizer application, staking and disease management were carried out uniformly during the growing season for all plots. Similarly, pre-plant granular, Di-ammonium phosphate at a rate of 200 kg ha^{-1} and urea fertilizer at rate 100 kg ha^{-1} were applied (Lemma, 2002). The amount of irrigation water applied was calculated using CROPWAT 8.0 software by using necessary input data (crop, soil and long-term climatic data). Irrigation water was applied up to field capacity by monitoring soil moisture content using gravimetric method in the conventional furrow plot. the calculated irrigation depth based on the water holding capacity of the soil in the management allowable depletion level was measured using watering cane and applied in to each subplot.

Table 1 – climatic data of the study area

Month	Tmax (^{0}C)	Tmin (^{0}C)	Relative humidity (%)	Wind speed (m/sec)	Sunshine hours (hrs)	Effective Rain fall (mm)	Monthly ETo
January	4.3	28.3	73	3.9	8.3	5	4.8
February	3.2	30.1	71	4.3	8.2	38	5.55
March	2.8	30.9	61	4.6	7.2	34	6.33
April	2.4	30.5	66	4.3	8.1	59	6.13
May	1.8	29.3	49	2.8	6.1	234	5.42
June	1.5	26.4	34	2.8	4.2	345	5.12
July	1.8	25.8	28	4.3	3.3	373	6.11
August	1.4	25.9	21	2.8	2.4	396	5.22
September	1.6	26.4	46	2.8	5.4	299	4.95
October	2.6	27.1	57	4.3	6.5	127	5.39
November	3.9	28.2	61	4.3	7.1	38	5.26
December	5.5	29.2	70	4.3	8.1	2	5.03

Data collected

Yield were recorded and the treatments were compared based on marketable and unmarketable yield. Also, water productivity of the crop was estimated.

Fruit yield was calculated by harvesting the total number of plants in the net plot and fruit yield per plot was measured using electronic balance and converted to hectare basis. The water productivity was calculated by the ratio of harvested yield per total water used(Zwartand Bastiaanssen, 2004).

$$Wp = \frac{Harvested\ grain\ yield}{Total\ water\ used} \quad (1)$$

The data were statistically analyzed combined for all years by SAS software. SAS software version 9.2 for windows was used for analysis (SAS Institute, 2011). Whenever the treatment effects were found significant, GLM test at 1 and 5% was performed to assess significant difference among treatments means.

Result and Discussion

Marketable yield

Marketable yield was a highly significantly ($p<0.01$) affected due to different types of irrigation water management methods (Table 2). Maximum marketable yield was recorded from conventional furrow irrigation methods (43617.3K. g ha^{-1}) whereas,the minimum yield (24644.2K. g ha^{-1}) obtained from fixed furrow irrigation method (Table 2).From the result, the maximum marketable yield recorded fromconventional furrow was statistically superior to that of alternative and fixed furrow irrigation method. Concerning the effect of mulches applied, there is a highly significant difference ($P<0.01$) on marketable yield, plastic mulched plants exhibited the highestmarketable yield (37161.3 K. g ha^{-1}) followed by straw mulched plants (34836.7 K. g ha^{-1}) and the lowest values were obtained by non-mulched plants (27919.0 K. g ha^{-1}) (Table 2).From the current findings, the maximum marketable yield obtained from conventional furrow irrigation had a yield advantage of 32% and 43% compared to alternate and fixed furrow irrigation, respectively. In addition, plastic mulch improves marketable yield by 6% and 24% from straw and no mulch, respectively. This might be due to highest soil moisture content in the root zone due to higher irrigation depth application in conventional furrow irrigation method than alternate and fixed furrow methods which leads to moisture stress in the later cases. As the irrigation depth reduced in the case of alternate and fixed furrow, the levels of moisture stress increase. This might be the reduction in irrigation water depth leads to moisture stress which affects photosynthesis capacity of the plant and assimilation of CO_2 to produce food. Guo et al., (2013) reported that moisture stress in plants reduce photosynthesis capacity by reducing chlorophyll content and damage of the reaction center of photosystem. Hence, the lower irrigation depth in case of fixed and alternate furrow method leads to create partial root zone drying and reduce the amount of water needed by the plant for photosynthesis and uptake and transportation nutrient from the soil for production of food.

On the other hand, plastic mulchingleads to conservation of the available soil moisture through reducingevaporation. The increase in marketable fruit yield was owing to less weed growth, higher soil temperature and better soil moisture availability. These results confirm the findings of Chakraborthy and Sandhu (1994). The higher fruit yield under polyethylene mulch may also be ascribed to reduced nutrient loss as a result of less weed density and improved hydrothermal regimes of soil (Rajbir Singh, 2005). Soil mulching not only reduced the soil evaporation and weed growth but also improved the aerial environment around the plants which facilitate plant growth and yield (Ajay and Shashi, 2012). Qin et al., (2015) reported that plastic mulching exerted a much greater effects than straw mulching on the yield of maize, whereas the effects of the two mulching methods were similar for the grain yield of wheat. Wang and Shangguan (2015) studied the effects of five different mulching practices on the grain yield of wheat and reported that plastic mulching was more effective than other mulching methods.

Unmarketable yield

The analysis of unmarketable yield showed that different types of irrigation method and mulching types had a high significant($p<0.01$) impact on unmarketable yield (Table 2).The highest unmarketable yield due to irrigation methods obtained from fixed furrow (12735.2K. g ha^{-1}) followed by alternate (12319 K. g ha^{-1}) furrow irrigation whereas, the minimum was obtained from conventional (8760.5 K. g ha^{-1}) furrow irrigation method (Table 2). From the current study, the irrigation methods changed from conventional furrow to alternate and fixed furrow methods the unmarketable potato yield increased significantly. This may be occurred due to the shortage of moisture in the root zone which is a determinant factor for the fruit size. Similarly, the over years data revealed that different types of mulch application affects the unmarketable potato yield (Table 2). From the result in Table 2, the maximum unmarkable potato yield was obtained from no mulch followed by straw mulch whereas, the minimum is from plastic mulch. From the current study, it was observed plastic mulch reduced unmarketable potato yield significantly when compared with straw and no mulch. The reason for this may be due to high moisture conservation in the root zone by reducing surface evaporation and helps the plant to use the moisture for fruit development.More we decrease the level of irrigation further increases the percentage of unmarketable fruits. The amount of water decreased by 50% from the control one (conventional furrow) increases the percentage of unmarketable fruits with 45% and 40% for fixed and alternate furrow application methods, respectively. A study conducted by Mitchell et al., (1991) revealed that a moderate irrigation stresses can significantly improve fruit quality of field-grown processing tomatoes without depressing marketable yields. But several conditions of osmotic or water stress can cause blossom-end rot (Guicharda et al., 2001).Candido et al.,(1999) reported that drought reduces fruit growth and size and excessive fluctuations in soil moisture content may induce physiological disorders such as blossom end rot and this was in agreement with the present study. Ponce et al., (1996) reported plants under any kind of stressed conditions tends to shortened their life span and try to complete their life cycle in hasten which causes the minimum flowering and fruiting of plants.

Water productivity

The mean water productivity analysis revealed a high significant ($p< 0.01$) influence due to different types of irrigation water application method (Table 2).The highest water productivity of tomato was observed from alternative furrow irrigation method which is statistically different with fixed and conventional furrow irrigation method. The maximum water productivity of (12.64 K. g m^{-3}) was recorded from alternate furrow irrigation method.On the other hand, minimum water productivity(7.89 K. g m^{-3}) was recordedfrom conventional furrow irrigation method and this was statistically inferior to both fixed and furrow irrigation method(Table 2). Also, different types of mulching had also high significant ($p<0.01$) influence on tomato water productivity. The study indicated maximum water productivity was observed from plastic mulch than straw and no mulch condition. The maximum water productivity obtained from straw mulch was (11.4 K. g m^{-3}) followed by straw mulching (10.61 K. g m^{-3}) (Table 2). The minimum water productivity (9.77 K. g m^{-3}) observed from no mulch was statistically inferior to both plastic and straw mulching (Table 2) at different irrigation water application method.Higher water use efficiency value recorded with black plastic mulch, was compared to without mulch treatment, which indicate that the plastic mulch distinctly improved the water use efficiency of tomato (Baye, 2011). Black polythene mulch recorded the maximum water use efficiency which was 39 per cent higher over no mulch condition (Mukherjee et al., 2010). Mukherjee et al. (2012) observed that different mulching materials like rice straw, white polythene mulch and black polythene mulch under varied irrigation levels helped tomato to perform better under plastic mulch with rainfed and had highest water use efficiency which agree with the current finding. The relatively low crop water productivity noted for the non-mulching treatments may be due to the uninterrupted supply of solar radiation that reached the earth surface and thus increased the amount of non-beneficial evaporation and ultimately led towards lower water use efficiency as observed by Mukherjee et al., (2010). In contrary, mulch acted as a barrier between soil surface (evaporating site) and microclimate that caused reduction in vapor pressure gradient, and thus minimized the soil moisture loss through evaporation (Sarkar & Singh, 2007).On the other hand, high significant ($p<0.01$) interaction effect between irrigation type and mulch type was observed on water productivity of Tomato. The maximum water productivity was obtained from plastic mulch when combined with alternative furrow irrigation method. The maximum water productivity (13.6 K. g m^{-3}) recorded at plastic mulching with alternative furrow irrigation method followed by alternate furrow with straw mulching (12.8 K. g m^{-3}) (Table 3). The minimum water productivity (7.4 K. g m^{-3}) from no mulch at conventional furrow irrigation water management method was statistically inferior to all treatment combination (Table3).

Table 2: Effect of irrigation levelsand mulch type on yield and water productivity of Tomato

Treatment	Marketable yield (K. g ha^{-1})	Un-marketable yield (K. g ha^{-1})	Water productivity (K. g m^{-3})
	Irrigation Methods		
Fixed furrow	24644.2^{c}	12785.2^{a}	11.27^{b}
Alternate furrow	29655.1^{b}	12319.0^{b}	12.64^{a}
Conventional furrow	43617.3^{a}	8760.5^{c}	7.89^{c}
LSD at 0.01	402.6***	463.5***	0.11***
	Mulching Types		
Straw mulch	34836.7^{b}	11261.7^{b}	10.61^{b}
Plastic mulch	37161.3^{a}	9916.0^{c}	11.40^{a}
No mulch	27919.0^{c}	12686.9^{a}	9.77^{c}
LSD at 0.01	402.6***	463.5***	0.11***
CV (%)	6.59	8.55	2.39

Means with the same column followed by the same letters are not significantly different. *significant ($p<0.05$), **significant ($p<0.01$), ***significant ($p<0.001$), ^{ns} not significant ($p<0.05$).

Table 3: Interaction effect of irrigation levels with mulch type on yield and water productivity of Tomato

Treatments	Marketable yield (K. g ha^{-1})	Un-marketable yield (K. g ha^{-1})	Water productivity (K. g m^{-3})
Fixed furrow with plastic mulch	29259.3	11592.6	12.3
Fixed furrow with straw mulch	24472.9	12555.5	11.2
Fixed furrow with No mulch	20201.5	14207.4	10.4
Alternate furrow with plastic mulch	34261.6	10725.9	13.6
Alternate furrow with straw mulch	30185.2	12229.6	12.8
Alternate furrow with No mulch	24518.5	14001.5	11.6
Conventional furrow with plastic mulch	47963.0	7429.6	8.3
Conventional furrow with straw mulch	43851.9	9000.0	8.0
Conventional furrow with No mulch	39037.0	9851.8	7.4
LSD at 0.01	ns	ns	0.107***
CV(%)	1.23	4.02	1.01

*significant ($p<0.05$), **significant ($p<0.01$), ***significant ($p<0.001$), ^{ns} not significant ($p<0.05$).

Conclusion and Recommendation

In view of the objectives of this research and results and discussions presented in earlier sections the following points can be concluded. Generally, mulching showed significant effect on water use efficiency and yield of tomato. According to the findings of this experiment, the highest yield production and crop water use efficiency was obtained using conventional furrow with plastic mulch and alternate furrow with plastic mulch, (43617.3K. g $ha^{-1}$and 13.6 K. g m^{-3}) respectively. In this experiment application ofmulch played a greater role in minimizing evapotranspiration, due to that available water toplants root varied appreciably. Variation between the two mulching material indicates thatdifferent materials have different moisture retention capacity and thus selection of mulchingmaterial need to be an important component of water application.It may, therefore, be concluded that for achieving maximum yield the tomato crop can be conventional furrow irrigated with 100% ETc and higher water productivity and yield can be obtained by application of polythene plastic mulch.

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