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Effect of mulching practice as soil moisture conservation for tomato(*Lycopersicon esculentum* Mill.) production under supplemental irrigation in Yabello district of Borana zone, Ethiopia

Demisachew Tadele Ayana* and Gutama Idossa Olika

Oromia Agricultural Research Institute,Yabello Pastoral Dryland and AgriculturalResearch Center, Yabello,Oromia, Ethiopia

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Corresponding Author: **Demisachew Tadele Ayana** | E-Mail: **(dankoo343@gmail.com)**

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ABSTRACT

The objectives of this study were to evaluate the effect of mulching materials on water retention, tomato yield and yield components, and water productivity. The experiment was laid out in RCBD consisting of four treatments namely:- black polyethylene mulch, white polyethylene mulch, Organic mulch, and no mulch with three replications. The results revealed that the application of mulching materials significantly influences the water retention. From the result, maximum water retention (26.8 %) was recorded under black polyethylene mulch followed by Organic mulchas compared to no mulch plot. The result on fruit yieldshowed that, yield was increased up to 120% in plots mulched with black polyethylene over the no mulched plots. Among the different treatments applied for mulching, the maximum tomato yield (42.02 tonha^{-1}) and (28.11 tonha^{-1}) were recorded under black polyethylene mulch and Organic mulch respectively as compare to no much. The results revealed that the application of polyethylene mulch significantly influenced the tomato yield and yield components. Among the applied treatments, the maximum and minimum plant heights (71.00cm and38.33cm) were recorded under black polyethylene and no mulch respectively. The low mean yield of tomato (19.18 tonha^{-1}) was recorded under no mulch. The study revealed that, themaximum water productivity (4.032 kg/m^3) was obtained from black polythene mulch. Thus, it was concluded that, soil mulching materials have distinct effects on tomato development and yield depending on their color materials. Based on result obtained, the practice of mulching particularly *with black polyethylene mulch can be recommended because of its higher water use efficiency, higher fruit yield, and economically more profitable than the other mulching types for the study area.*

Keywords: *Fruit yield, Mulching, Soil moisture,Polyethylene.*

Introduction

Tomato (*Lycopersicon esculentum* Mill.) is a vegetal of countless economic overgrownworldwide and is commercially cultivated on all over continents(Biswas et al., 2015). Tomato is an essential element in the diet of the world population as it has high levels of lycopene and minerals, resulting in benefits to human health(Hashmi et al., 2015). Yet, the average yield of tomato in Ethiopia is low, ranging from 6.5-24.0 Mg ha^{-1} compared with average yields of 51, 41, 36, and 34 Mg ha^{-1} in America, Europe, Asia and the entire world, respectively–(Iizumi& Sakai, 2020).

The various soil moisture conservation practices have been studied and aim to enhance the yield and quality of tomato production. Among the technologies used in the cultivation of vegetables in recent years, soil mulching with plastic polythene or/and residue material has stood out (Lopes et al., 2011). In some vegetable species, this practice has been important in improving tomato development, yield, and yield quality (Zangoueinejad et al., 2018).Soil mulching is a technique used in crops grown around the world, especially for vegetables, which can have several benefits (Moreno et al., 2016). Mulching improves soil water retention capacity, contributes to early crop development, changes the soil temperature, and reduces weed incidence, and all these factors contribute to increased yield. However, these effects may vary according to soil type, climate, and material used for mulching(Ghosh et al., 2006).

The mulching can be done with organic materials such as straw or with inorganic materials such as plastic films. The choice of mulching material depends on the climate, the cost-benefit ratio, and the crop to be grown '(Wang et al., 2019). Mulching materials have a direct influence on the microclimate near the plant, which can have positive or negative impacts on plant physiological metabolism (Kader et al., 2017). Beneficial effects of soil mulching have been reported for different crops, including tomatoes(Kosterna, 2014), potatoes(Zhao et al., 2014), and maize '(Wang et al., 2019).

Plastic film has become the main material used for soil mulching in recent years, especially in vegetable production. The most popular types of plastic mulching films on the market are black mulch film and white mulch film. Other colors of plastic mulch films that are being studied include silver, red, blue, yellow, and green films (Caruso et al., 2019). However, the effects of these colored mulch films on plant development and production are still inconclusive. In this context, it is evident that information on the use of different plastic mulching films is still incipient. Thus, the study aimed to evaluatedthe effects of different mulchingmaterials on yield and yield components and water productivityof tomato under supplemental irrigation and economic feasibility of the technology.

Materials and Methods

Description of the study area

The study was carried out in Qadalle watershed, which is found in Yabello district of the Borana zone of Oromia National Regional State. Yabello is the capital town of the Borana zone and situated south to Addis Ababa at a distance of 570 km. The Borana lowland is usually known as the southern rangelands. The Qadalle scheme is made from micro earthen dam collecting runoff water. Geographically,it is situated at 4°53′N latitude and 38°5′E longitude with an elevation ranging from 1550m to 1970m above sea level, respectively. The annual average temperature and rainfall is 19 to 24°C and 300 to1000 mm, respectively. The annual precipitation distribution is bimodal with 60% falling from April to May and 30% from October to November. The vegetation comprised in Borana is mainly a mixed savanna which is dominated by perennial grasses (*Cenchrus, Pennisetum, and Chrysopogon species*) and woody plants (Coppock, 2014). The Borana pastoralists traditionally depend mainly on cattle, but also on goat and sheep and nowadays though few on camel for household food security and a few donkeys and camels for transport.

Treatment setup and experimental design

The different moisture conservation materials used for this study wereblack polyethylene mulch, white polyethylene mulch, organic mulch and no mulch. The experiment was laid in a RCBD withthree replications.The experiments were conducted for three consecutiveyears (2012, 2013 and 2014 E.C). Improved and recommended varieties of tomato (Miya) was used as testing crop. Six rows and six plants per row with 70 cm between rows and 30 cm between plants were used for this experiment.The irrigation area waspurposively selected due to the presence of the stored water for supplemental irrigation.The blanket recommendation of fertilizer rate was calculated at the rate of 79kgha^{-1}of Urea and 142kgha^{-1} NPS were applied at transplanting time and 50 kgha^{-1}urea was applied at the early flowering stage.All the agronomic practices were uniformly applied to all treatments as per the recommendation.

Collected data and statistical analysis

The collected data were a number of primary branches, plant height, marketable yield, and total fruit yield (kg/ha).

Number of primary branches: Counted at maturity from 5 randomly selected plants in each plot. Plant height:- Transplanting date to the day on which 50% of the plant height in each plot.

Days to first harvest: The number of days from transplanting to the first picking day.

Fruit yield (kg/ha): The sum of fruit weight per plot from successive harvests (kg) was taken and converted to ton per hectare.

Analysis of variance for the collected parameters was performed as per the methods described by Allison, (2001) using SAS computer software for randomized complete block design, and treatment mean comparison is done by Fisher's list significance difference (LSD) at 5%.

Water productivity

Water productivity was estimated as a ratio of the fruit yield of tomatoes to the total crop water consumption by evapotranspiration (ETc) through the growing season and calculated using the following equation (Zwart & Bastiaanssen, 2004).

$$CWP = Y/\mathrm{ETc}\ (1)$$

Where:- CWP is crop water productivity (kg/m^3), Y is tomato yield (kg/ha) and ETcis the seasonal crop water consumption by evapotranspiration (m^3/ha).

Partial budget analysis

The partial budget analysis of the irrigation system was computed based on investment, operation, and production costs (CIMMYT, 1988). In this research, a partial budget approach based on an economic evaluation of the product was used. To assess the economic viability of the different mulching materials for moisture conservation; costs were calculated (Biswas et al., 2015). The net income for each treatment was computed by subtracting all the production costs from the gross income.

Results and Discussions

Selected soil physicochemical properties of the experimental site

From the result,the soil textural class of the study area is sandy loam (Table 1). The experimental site has 27.7% and 12.1% field capacity (FC) and permanent wilting point (PWP) respectively (Table 1). The average total available water (TAW) by volume percentage is also estimated as 97.1mm/m. Irrigation scheduling of tomato was determined by considering soil type of the experimental site and variable depth (refill to field capacity). But, mostly close supervision was used to add water according to the condition or moisture level of the plot until the plant has established and adapted to the new environment and the irrigation schedule wasstarted measuring of soil water content. The same procedure was also adopted byYaghi et al., (2013).

Table 1: Selected soil physico-chemical properties analysis (0–20 cm)

Soil parameters	Value	Rating	Referance
Sand (%)	65.12		USDA
Silt (%)	17.12		
Clay (%)	17.76		
Texture	Sandy Loam		
Soil pH	7.24	slightly alkaline	Jones, J. Benton (2003)
Electrical conductivity (dS/m)	0.77	non-saline	Hazelton, P. and B. Murphy (2007)
Organic matter (%)	0.9	Low	Tekalign (1991)
Bulk density (g/cm3)	1.38	loose	Clout, J. and Manuel, J. (2015).
Field capacity vol. (%)	27.7	Low	Cong, Z. et al., (2014)
Permanent wilting point vol. (%)	12.1	Ideal	
TAW (mm/m)	97.10	High	

The result on soil moisture content under different mulch materials recorded during the cropping period for 0-20 cm soil depth as shown in Table 2. The result revealed that, the mulching material under study was found effective in conserving soil moisture. The highest moisture (26.8 %) was conserved underblack polyethylene mulch (BPM) as compared to plots with no mulch (Table 2). Whereas, the lowest moisture (18.9%) was recorded under no mulch(Table 2). The higher water retention noted both under BPM and organic mulch (OM) may be due to the formation of an impermeable vapour barrier at the soil surface as compared to white polyethylene mulch(WPM) and no mulch; which being porous allowed diffusion of water under vapour pressure gradient. This result is in line withTeame et al.(2017)who stated significant improvement of soil moisture at the depth of 0-60 cm for sesame as compared with no mulched plot.

Table 2: Effects different mulching materials on soil moisture content at soil sampling depth of 0-20cm

Treatments	Ave. moisture content (%)
Black polyethylene mulch	26.8
Whitepolyethylene mulch	22.5
Organic mulch	24
With no mulch	18.9

Main effect of mulch on the yield and yield components of tomato

The statistical analysis in Table 3 shows that,marketable and unmarketable fruit yields and number of primary branches were significantly affected by the mulch applied during the study season(Table 3). However, the effect of year on plant height was not significant (Table 3). This may be due to supplementary irrigation water used for each year when there is a shortage or absences of rainfall. The resultobtained from this study agreed withBiswas et al.,(2015). Other reports byMishra et al., (2012)stated that water stress caused a significant reduction in stem elongation, leaf expansion (leaf area), number of leaves, and plant heights. Yaghi et al., (2013) also recommended that the decrease in plant height is a form of response shown that; plants have adapted to lower transpiration. But, in this study, there was no time faced water shortage during the trial period as supplementary irrigation was applied to refill the water below field capacity.

Table 3: Mean square value of tomato yield and yield components under different mulching materials at Yabello for three (2012, 2013 and 2014) consecutive years.

Variation	DF	MY (tha^{-1})	UMY(tha^{-1})	NPB	PHT (cm)	Water productivity (Kg/m^3)
Year	2	40.05**	170.40**	2.62**	305.0^{ns}	4.032^{*}
Rep (with in Year)	6	10.54^{ns}	1.5ns	1.17ns	157.00^{ns}	39^{ns}
Treatments	3	932.3**	98.7**	7.72***	1700.89**	195^{**}
Treatments*year	6	43.2**	3.1**	3.66**	11.68^{ns}	75^{**}
Error	22	2.13	8.7	0.32	50.6	3.87
CV (%)		5.22	7.77	18.75	12.9	2.8

*MY = Marketable yield; UMY=Unmarketable yield; NPB=Number of primary branch; PHT=Plant height; cm=Centimeter,tha^{-1}=ton per hectare, ns=non-significant;***= significant at p<0.001; **= significant at p<0.01 and *= significant at p<0.05*

The maximum plant height of the tomato (71.0cm) was recorded with black polyethylene mulch (Table 4). Whereas, the minimum plant height oftomato (38.33cm) was recorded with no mulch(Table 4). This result in lined with the findings ofAshrafuzzaman et al., (2011). The plot mulched with black polyethylene gave the significantly highest yield (42.2 $tonha^{-1}$) and lowest yield (19.18 $tonha^{-1}$) was obtained from no mulch treatment, respectively(Table 4). The highest unmarketable yield (12.66 $tonha^{-1}$) was again recorded from black polyethylene mulch (Table 4). Where as, the lowest unmarketable yield (5.09 $tonha^{-1}$) was recorded from no mulch(Table 4). In this case, the vegetative growth of the crop was vigor in black polyethylene and this high vegetativse growth may favor the occurrence of insect, pest and fruit deterioration that may lead to high unmarketable yield.The comparative evaluation on water productivity showedthat, maximum water productivity (4.032 kg/m^3) was obtained under black polyethylene mulch and the lowest water productivity (3.725 kg/m^3) was obtained under control/without mulch (Table 4). This implies how mulching technology decides irrigation water productivity particularly which is crucial in water-scarce areas like Borana zone as plastic cover protected the underlying soil from incoming solar radiation and kept the soil cooler than it would be without mulch.The result in linedwithOrtiz, (2015) who report thatplastic mulchhas benefits in increasing water productivity as it protects from direct exposure of soil moisture to sunlight.The similar perceptionwas also reported byRobel and Zelalem, (2019) who stated that, plastic mulching helps conserve the available soil moisture through reducing evaporation.

Table 4 : Mean value of tomato yield and yield components under different mulching practices at Yabello.

Treatments	MY (tha^{-1})	UMY(tha^{-1})	NPB	PHT (cm)	Water productivity (Kg/m^3)
Black Polyethylene mulch	42.20^{a}	12.66^{a}	4.43^{a}	71.00^{a}	4.032^{a}
White Polyethylene mulch	22.45^{c}	6.38^{c}	2.68^{b}	50.83^{b}	3.924^{ab}
Organic mulch	28.11^{b}	8.38^{b}	2.93^{b}	59.00^{a}	3.953^{a}
Control	19.18^{d}	5.09^{d}	2.53^{b}	38.33^{c}	3.725^{b}
LSD Value	1.58	0.75	0.612	8.29	*

**Means with the same letter are not significantly different and LSD =least significant difference* MY = Marketable yield; UMY=Non-marketable yield; NPB=Number of primary branch;PHT=Plant height; cm=Centimeter and tha^{-1}= ton per hectare*

Black polyethylene mulch gavemaximum yield attributes compared to no mulch. This increase in the yield was probably associated with the conservation of moisture and improved microclimate above the soil surface which was maintained throughout the life period of the crop. Then, when plants are set out in the warmer soil, they familiarizethemselves more easily, blossom faster, and produce fruit earlier. Increased yield in black polyethylene mulched plots could be largely attributed to the increased soil temperature that resulted in an enhancement of favorable soil environment around the roots of tomato plants, which led to increasing plant growth and hence, increasing nutrient uptake. These results suggested that moisture and temperature have a relationship with soil microbial activity that in turn determines plant growth.

The yield increased due to the applied mulch, which can be attributed to a lower rate of water loss from the soil by evaporation and leading to significant conservation of moisture. Hence, a higher total yield was obtained. Applied mulch increases transpiration, thereby leading to more photosynthetic efficiency that results in increased yield as reported by Liu et al., (2014).Seyfi& Rashidi, (2007)reported that moisture conservation practices with black polyethylene and organic mulch markedly decreased the amount of water applied and increased water use efficiency, and increased crop yield.

Partial budget analysis

The partial budget analysis was done to select the most economically feasible moisture conservation practices. The partial budget for three consecutive years of experiments shows that, the highest net benefit was obtained from black polythene mulch for tomato production (Table 5). Whereas, the lowest net benefit was obtained from no mulch (Table 5). From the partial budget analysis, black polythene mulch was economically the most feasible technology for tomato production in the study area.These results in line with the findings ofCIMMYT, (1988).

Table 5: Partial budget analysis for the different mulching mterials for tomato production per hectare of land

Treatments	Total variable cost (birr)	Tomato sale (birr/kg)	MY (kg-ha)	Gross benefit	Net benefit (birr)	%
Black Polyethylene mulch	112500	60	4220	253200	140,700	-
White Polyethylene mulch	237500	60	2245	134700	102,800	37,900
Organic mulch	63000	60	2811	168660	105,660	35,040
Control	62500	60	1918	115080	52,580	88,120

UMY=Non-marketable yield; MY=marketable yield, and kgha^{-1}= kilogram per hectare

Conclusions and Recommendation

In conclusion, the overall studies revealed that mulchinghad a significant effect on moisture conservation as compared to no mulched plots. The use of black polyethylene mulch recorded 26.8% higher soil moisture content followed by Organic mulch (24%). The soil moisture conservation had reflected on the fruit yield. The highest fruit yield was recorded under black polyethylene mulch with a value of 42.02 tonha^{-1}followed by organic mulchwitha value of 28.11 tonha^{-1}. The maximum water productivity was obtained through the application of black polythene mulch and the minimum water productivity was obtained from no mulch. From this result, it concluded that, the application of mulching improves water productivity.The highest net benefit was obtained from black polythene mulch for tomato production.Under the Lowlands of Borana plateau, the practice of mulching particularly with black polyethylene mulch can be recommended because of its higher water use efficiency, higher fruit yield, and economically more profitable than the other mulching types.

Conflict of interests

The authors declare that there is no conflict of interest.

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