Effect of Organic and Inorganic Mulching Materials on Soil Moisture Retention, Growth, and Yield of Two Tomato Varieties in Bungoma, Western Kenya

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Abstract

Mulching materials promote plant growth and yield by preserving soil moisture due to erratic rainfall patterns and distribution. These materials also act as a barrier to the action of rainfall that causes soil compaction and erosion. Therefore, this study was conducted to determine the effect of mulching materials on the retention of soil moisture, growth, and yield of two varieties of tomatoes. The experimental site was Mabanga Agricultural Training Centre in Bungoma, Western Kenya, for two seasons 2015 and 2016. The field experiment was laid out in a Randomized Complete Block Design (RCBD), in a split-plot arrangement replicated four times. Two tomato varieties, namely Cal J (determinate) and Tylka F1 (semi-determinate) were grown on seed beds mulched with different mulching materials. These materials were black polyethylene film, transparent polyethylene film, sugarcane trash, and no-mulch (bare soil). Data collected on growth variables were subjected to ANOVA using GenStat, to determine the effect of mulching on the performance of tomatoes. Significant means were separated using Fischer's protected LSD at $\alpha = 0.05$. In season one, significantly high soil moisture content was conserved from 7.0% under no-mulch to 22.1% under black polyethylene mulch. Similarly, in season two, more soil moisture was retained from 8.4% to 19.3% under white polythene mulch, but this was not significantly different from the black polythene mulch at 18.6%. There was no significant difference between varieties and mulches for shoot weight and total plant weight for both seasons. Significant difference among mulches in fruit yield was observed in season two. Black and white polyethylene mulch retained highest soil moisture content, and they are recommended for adoption in tomato growing.

Keywords: Mulching, tomato varieties, soil moisture content, root microclimate

Introduction

Tomato (*Solanum lycopersicum* L.) is one of the fruit vegetables that are either consumed fresh or in processed forms. Processed products include tomato preserves, dried tomatoes, and tomato-based foods (Rauf and Shittu, 2015). Tomato plays a significant role as human food — a valuable source of vitamins A and C, as well as several minerals (El-Nahhal, 2018), including calcium, iron, manganese, and particularly potassium (Tegen *et al*., 2016). It contains lycopene, which is a carotenoid — a pigment involved in photosynthesis — that gives red colouring to tomatoes (Kelley and Boyhan, 2010).

Water is essential for plant growth and development, but it is also among the main costs in agricultural enterprises (Verma *et al*., 2015). The success of many agricultural farms relies on the conservative and efficient use of water. Moisture retention is undoubtedly, the most common reason why mulch is applied to cover the soil (El-Khalifa *et al*., 2022). Mulch is used to protect the soil from direct exposure to the sun, which would evaporate moisture from the soil surface and cause desiccation of the soil profile (Torres-Olivar *et al*., 2018).

The protective interface established by the mulch layer minimises raindrop splash by absorbing the impact energy of the rain, hence reducing soil surface crust formation (Verma *et al*., 2015). This mulch also slows down soil surface runoff allowing a longer infiltration time (Niziolomsiki *et al*., 2020). Consequently, these mulch features lead to improved water infiltration rates as well as higher soil moisture retention. An auxiliary benefit of mulch in reducing soil splash is the decreased need for additional cleaning prior to processing of the commodity (Mondal *et al*., 2020) as well as thespread of virulent pathogens.

Organic and inorganic mulches have been shown to improve the moisture retention of soil (Kader *et al*., 2017). This extended water-holding ability enables plants to survive during low rainfall periods. For better outcomes, the use of plastic mulch in the under-mulch irrigation system should be accompanied by regular monitoring of the soil moisture (Han *et al.*, 2015). This is because the effect of rainfall is not as significant when plastic mulch is applied, thus the need for close irrigation checks.

In Western Kenya, soil moisture is generally limited and crop growth is stressed by drought during the growing season, resulting in a decreased and unsustainable yield. Different mulching materials have different effects on enhancing performance because of their varying capacities in absorbing moisture due to their aggregate nature in allowing air circulation (Nwokwu and Aniekwe, 2014), while others have detrimental effects including the higher occurrence of pests and reduced agronomic performance of the crops (Chamo *et al*., 2017). Lima *et al.* (2022) reported that mulching was effective in controlling weeds and emphasized that rice hull mulch was more effective than dry grass mulch.

Resource-poor farmers in Bungoma County face serious problems with tomato — price fluctuations, inclement weather conditions such as long droughts and moisture shortage, gluts due to poor storage conditions, and pests — all of which affect the production of this crop in Kenya (Council of Governors, 2017–2022). It is, therefore, important to investigate the relative effectiveness of mulch types on environmental and micro-climate conditions in tomato production for possible recommendation and adoption by these farmers.

Materials and Methods

Study Sites

The experiments were conducted at the Mabanga Agriculture Training Centre (ATC) in Bungoma County during September – December 2015, and December – March 2016 under rainfed. Mabanga ATC is situated at latitude 0°26’ N and longitude 34°W at an elevation of 1,360 m above sea level with a mean monthly temperature of 18.2 °C. The average annual rainfall range is 1,800 to 2,000 mm. Rainfall is bimodal, with short rains from October – December and "long rains" from April – July with a mean monthly temperature of 22.5 °C (Jaetzold *et al*., 2012). Soils are loamy-sand, acidic, and low in both organic matter and available nitrogen, but they are deep, well-drained, and dark red to dark brown in colour.

Experimental design and treatments

The experimental design was split-plot in a randomized complete block design (RCBD) with four replicates. Treatments consisted of two tomato varieties - determinate (Cal-J) and semi-determinate (Tylka F1) for the main plot treatments - and three types of mulching materials. These materials were transparent white polyethylene film, black polyethylene film, sugarcane trash, and no-mulch for the subplot treatments.

Cultural operations
The field was ploughed and harrowed to attain a relatively fine tilth. Planting fertilizer DAP and well-decomposed cattle manure was applied at 200 kg/ha and 2 kg/m^2 respectively, and incorporated within the soil two weeks before raising beds to 20 cm. Dry sugarcane trash was spread out on the subplots at 0.5 kg/m^2, while 25-micron white and black polythene sheets were laid to cover the beds appropriately before transplanting. At the beginning of each season, seedlings were raised in plug trays in the nursery for four weeks until they attained 5 – 7 true leaves. Plugs were filled with a mixture of soil and cattle manure at a ratio of 1:1 on a volume basis. Seedlings were hardened in the screen house for three days before transplanting at a spacing of 90 cm x 60 cm on the raised beds under rainfed conditions. Rainfall was fairly distributed throughout the entire experiment period. Season one received 772 mm with a monthly mean of 193 mm, while season two got 362 mm with a monthly mean of 90.5 mm (Table 1). All other agronomic practices were undertaken as recommended for the optimal growth of these two varieties. Top-dressing of 100kg/ha CAN was done in two equal splits at 14 and 28 DAT. Scouting was undertaken routinely and pests were controlled accordingly. Tylka F1 plants were trained to double-stem by continuous nipping of lateral shoots and staked.

Table 1: Rainfall received during the experiment in 2015 – 2016 at Mabanga ATC

2015				2016		
September	October	November	December	January	February	March
166	228	260	118	103	72	69

Data collection

Effect of mulching on soil moisture content
Four locations were randomly marked on each subplot where soil samples would be taken to determine their respective moisture content during this study. Approximately 100 g of soil was scooped using an auger to a depth of 10 – 15 cm from each of these four locations per subplot and mixed to form an aggregate sample. These soil samples were immediately weighed using an electronic scale and recorded as 'wet weight of sample'. Samples were also collected before transplanting and sampling was repeated every fortnight until 70 days after transplanting (DAT). Soil moisture was determined on the aggregate samples using the gravimetric method (oven-drying and weighing). This wet sample was oven-dried at a constant temperature of 115 °C for 24 hours. After drying, this sample was allowed to cool and re-weighed to a constant value, and the sample was recorded as the 'dry weight of the sample'. This difference in weight was computed as the soil moisture content.

Effect of mulching on growth and yield of tomato varieties

Shoot fresh weight and total plant weight
One plant was randomly selected from each subplot and tagged for destructive sampling at 60 DAT. Then, these plants were carefully uprooted while keeping the roots intact. The soil was washed off the roots with tap water and wiped dry using a tablecloth. Shoots were cut and separated from the roots using

secateurs. The fresh shoots were weighed using an electronic balance immediately after separating from the roots and their weight was recorded in grams/plant. To obtain total plant weight, the entire uprooted plant (shoot + root) was then weighed immediately using an electronic balance and its weight was recorded.

Fruit weight

Fresh fruits were harvested separately per entire plant from each subplot at 60 DAT. These fruits were graded in the field to remove unmarketable rejects that were rotten or damaged by pests. Their respective weights were measured and recorded as fruit weight in grams per plant. Weight was taken using electronic balance regardless of the fruit size.

Data analysis

Effect of mulching on soil moisture content

Analysis of variance (ANOVA) was carried out to determine the effect of mulching on soil moisture content using GenStat statistical application, version 15.1 at a 5% probability level. Significant means were separated using Fischer's protected LSD at α = 0.05.

Effect of mulching on growth and yield of tomato varieties

The data obtained were subjected to ANOVA to determine the effect of mulching on soil moisture content using Genstat version 15.1 software. Significant means were separated using Fischer's protected LSD at α = 0.05.

Results and Discussion

Effect of mulching on soil moisture content

Significant differences ($p \leq 0.05$) were observed in soil moisture retention due to mulching under these two tomato varieties (Table 2). In the first season between 14 – 70 DAT, black polythene mulch retained the highest moisture content of 14.3 – 22.1%, followed by white polythene at 16.7 – 20.6%, and sugarcane trash at 13.9 – 20.1%. No-mulch treatment conserved the least soil moisture content at 7.0 – 12.3%.

Table 2: Effect of mulching on soil moisture content in the first season trial

Variety	Mulch treatment	14 DAT	28 DAT	42 DAT	56 DAT	70 DAT
	Black polyethylene	17.4a	18.6a	18.3a	21.0a	16.7b
	White polyethylene	17.3a	20.4a	20.6a	20.4a	20.0a
Cal-J	Sugarcane trash	15.5a	15.0b	17.5a	18.9a	15.0b
	No-mulch	8.8b	11.4b	10.2b	11.4a	12.3d
	Black polyethylene	14.3a	19.2a	20.7a	22.1a	20.2a
Tylka F1	White polyethylene	16.7a	19.3a	18.5a	19.1a	17.6a
	Sugarcane trash	14.5a	13.9b	20.1a	19.3a	14.5d
	No-mulch	7.0b	12.6b	9.9b	11.9b	12.1d
LSD		1.849	1.729	2.301	1.780	1.347
P value		<0.001	<0.001	<0.001	<0.001	0.045
V*T		*	*	*	*	*

Means followed by the same letter within the same column are not significantly different at α = 0.05. * Significant at $p \leq 0.05$; DAT (Days after Transplanting); V - Tomato varieties, T - Mulch treatments.

Studies have shown that mulches show significant soil moisture conservation than the no-mulch plots. For instance, Moe (2017) documented that presence of mulch on the soil surface increases soil water content and decreases soil temperature in relation to bare soil, both of which favour healthy plant growth. According to Tesfuhuney *et al*. (2022), mulch affects the absorption of solar energy, and reduces the thermal admittance of this surface compared to the bare soil. Consequently, more of the absorbed heat is reflected to the atmosphere, thus decreasing the available energy to heat the soil.

Meena *et al*. (2022), studied the growth and yield response of groundnut (*Arachis hypogea*) under wheat straw mulch and bare soil and reported that there was higher moisture content in wheat straw mulch plots than bare soil under field conditions. The organic mulches helped to maintain soil moisture content longer than bare soil. Additionally, Rauff and Shittu (2015) reported that mulching conserves water by reducing evaporation and mitigates the negative effects of water stress on plant growth and yield, especially under semi-arid conditions. This finding agrees with Mahmood *et al*. (2011) that mulching conserves and maintains high moisture levels, which in turn results in increased plant growth.
Under-mulch irrigation of vegetable crops has been shown to improve crop yields more than overhead irrigation systems (Rahil, 2022). Mulch conserves and maintains soil moisture levels for longer periods (Nyochembeng and Mangolo, 2021). A study by safari *et al*. (2021) found that plastic mulch conserved 47.08% of water and increased yield by 47.67% in tomatoes when compared to no-mulch. Thakur and Kumar (2021) reported that mulching is a water-saving technique that alters the physicochemical properties of soil, applicable to most field crops, and is a promising alternative to increase the productivity of crops.

During the second season from 14 – 70 DAT, white polythene mulch had retained the highest moisture content of 14.8 – 19.3%, followed by black polythene at 16.4 – 18.9%. Sugarcane mulch was third at 13.1 – 15.6% while the lowest was no-mulch treatment at 6.2 – 11.4% (Table 3).

Table 3: Effect of mulching on soil moisture content in the second season trial

Variety	Mulch treatment	14 DAT	28 DAT	42 DAT	56 DAT	70 DAT
	Black polyethylene	17.1a	16.7a	17.0a	16.4a	18.6a
	White polyethylene	14.8ab	16.3a	18.7a	16.6a	19.3a
Cal-J	Sugarcane trash	12.9ab	15.6a	12.5b	12.7b	11.4b
	No-mulch	8.4b	11.4b	9.3bc	9.4c	8.9b
	Black polyethylene	16.5a	18.3a	18.9a	14.7b	17.1a
Tylka F1	White polyethylene	15.2a	17.2a	16.9a	18.1a	16.4a
	Sugarcane trash	13.3ab	15.6a	15.0ab	13.1b	13.3ab
	No-mulch	8.4b	6.2b	7.9c	7.4c	8.5b
LSD		1.649	2.679	1.919	1.178	1.841
P value		<0.001	<0.002	<0.001	<0.001	<0.001
V*T		*	*	*	*	*

Means followed by the same letter within the same column are not significantly different at $\alpha = 0.05$. *Significant at $p \leq 0.05$; DAT (Days after Transplanting); V - Tomato varieties, T- Mulch treatments.

According to Singh *et al*. (2017), mulching reduces soil water evaporation. Thus, it enhances more retention of soil moisture. This moisture retention of soil has been shown to be improved by the application of organic mulches. This finding is corroborated by Moe (2017), who reported a higher soil moisture content in Mucuna (*Mucuna pruriens*) mulched plot in comparison with the no-mulch plot. Several studies have shown that mulching with organic materials conserved soil moisture and consequently increased crop production. For instance, Ameyu and Jaleta (2018) documented a higher moisture content of soils under organic mulches — grass straw, rice straw, and rice husks saw dust — than the one under control.

Higher soil moisture was observed in plots with polyethylene mulch when compared with plots with organic mulch and no-mulch (Table 2). This result is in line with the finding of Moe (2017), who reported a superior moisture-conserving property of polyethylene mulches. The same study found that organic mulches — maize straw, palm and fronts, grasses — recorded slightly higher soil moisture than the control. Singh (2017) also reported the ability of organic mulch to conserve soil moisture is appreciably lower than that of polyethylene mulch. The plots without mulch recorded the least moisture content in this experiment. In another study on tomatoes whose result is in agreement with this finding, Ogundare (2015) who reported a higher soil moisture content in no-stick staking plots than stick staking plots. This observation could be due to the indirect effect tomato foliage that spread on the soil and acted as a cover crop, thereby reducing the rate of soil evaporation (Rauff and Shittu, 2015).

Effect of mulching on growth and yield of tomato varieties

Shoot weight and total plant weight

Significant differences ($p \leq 0.05$) between varieties on shoot weight and total plant weight were observed during the first season and not the second season (Table 4). Tylka F1 variety had the highest shoot and total plant weight of 1352.0 and 5006.0, while Cal-J had 954.0 and 3539.0 g/plant respectively. No significant differences ($p > 0.05$) between mulch types were observed during the first and second season. But non-mulched plots recorded the lowest values of shoot and total plant weight compared with the mulched plots. Therefore, the differences in shoot and total plant weight can be attributed to morphological differences among varieties. Shoot weight and total plant weight ranged from 549.0 – 1352.0, and 2071.0 – 5094.0 g/plant respectively, across the two varieties. Researchers have investigated the role of shoot and total plant weights as important yield indicators. These include Pingping *et al*. (2017) and Tang *et al*. (2020) argued that heavier plants would by default be able to bear and carry higher fruit load at the time of dry matter partitioning and plant resource allocation.

Fruit weight

The total fruit weight per plant showed no significant differences ($p > 0.05$) within varieties in the first and second seasons, as well as among the mulches in season one (Table 5). This observation likely due to the effect of the 772 mm cumulative rainfall that was well-distributed in this season (Table 1) that compensated for moisture deficit in no-mulch plots. However, there was significant difference among mulches in fruit yield in the second season. Unlike season one, this season received half the rainfall of 362 mm during the experiment. It is therefore possible that season two crop encountered higher relative moisture stress. This inference is corroborated by significant variation in yield, whereby the total fruit weight ranged from 2485.0 – 3877.54, and 1522.0 – 1724.87 g/plant in season one and two respectively across these two varieties. Tylka F1 recorded higher total fruit weight per plant while inorganic mulching recorded the highest total fruit weight per plant compared to organic mulching and control in the first and second seasons (Table 5). These results are in agreement with the report by Kumar *et al*. (2012) who documented that inorganic mulching in tomatoes recorded the highest number of fruits, average fruit weight, and yield. Additionally, these results confirm the finding of Khan (2018) who reported that inorganic mulching increased yield by 56% while organic mulching increased by 16% over no-mulch treatment.

Table 4: Shoot weight and total plant weight (g) on plots under different mulches and tomato varieties

Treatments	Season 1		Season 2	
	SW 60 DAT	TPW 60 DAT	SW 60 DAT	TPW 60 DAT
Cal-J	954.0b	3539.0b	549.0a	2071.0a
Tylka F1	1352.0a	5006.0a	560.0a	2135.0a
LSD	266.1	980	62.9	246.6
Black polyethylene	1267.0a	4376.0a	555.5a	2208.0a
White polyethylene	1317.0a	5094.0a	608.3a	2325.0a
Sugarcane trash	1134.0a	3844.0a	506.7b	2130.0a
No-mulch	1092.0a	3777.0a	476.2b	1748.0b
LSD	464.1	1635.0	66.0	210.9
T*V	NS	NS	NS	NS

Means followed by the same letter within the same column are not significantly different at $\alpha = 0.05$. NS - Not Significant at $p > 0.05$; DAT (Days After Transplanting); SW - Shoot Weight; TPW - Total Plant Weight; V - Tomato varieties, T - Mulch treatments.

Table 5: Total fruit weight (g) per plant on plots under different mulches and tomato varieties

Treatments	Season 1	Season 2
	TFW	TFW
Cal-J	2586.0a	1522.0a
Tylka F1	3655.0a	1575.0a
LSD	801.4	190.0
Black polyethylene	3308.17a	1724.87a
White polyethylene	3877.54a	1724.11a
Sugarcane trash	2785.67a	1646.09a
No-mulch	2485.04a	1552.13b
LSD	1210.4	159.4
T*V	NS	*

Means followed by the same letter within the same column are not significantly different at $\alpha = 0.05$. * Significant at $p \leq 0.05$; NS - Not Significant at $p > 0.05$; TFW - Total Fruit Weight; V - Tomato varieties; T - Mulching treatments.

Conclusion

The maximum soil moisture content was recorded in black and white polyethylene mulches and minimum soil moisture was recorded in control. But organic mulch also demonstrated a significant efficacy in soil moisture retention as evidenced by the effect of sugarcane trash mulch in this study. Mulches did not have a statistically significant effect on shoot weight and total plant weight in both seasons. However, significant difference was observed among mulches in fruit yield during the second season.

Recommendation

From the findings of this study, it is recommend that tomato farmers in Bungoma, Western Kenya apply black or white polyethylene, or sugarcane trash mulch as a good agronomic practice for soil moisture retention.

Declaration of conflict of interest

We declare that there is no conflict of interest.

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