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Weed Control in Tomato (*Solanum lycopersicum*) Through Mulch Types in Kakamega County, Kenya

Anthony Simiyu Mabele*, Millicent Florence Owuor Ndong'a

Department of Biological Sciences, School of Natural Sciences (SONAS), Masinde Muliro University of Science and Technology (MMUST), Kakamega, Kenya

Email address:
mabeleanthony@gmail.com (A. S. Mabele)
*Corresponding author

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Abstract: Tomato (*Solanum lycopersicum*) is the third most important vegetable crop after potato (*Solanum tuberosum*) and onion (*Allium cepa*). Its production heavily involves the use of synthetic pesticides with detrimental impact on humans, insect pollinators, water sources, soil fertility and environment. This study uses different mulch types to mitigate this problem. Mulching is an agricultural technique that protects the roots of plants from heat and cold by use of inorganic and organic mulch types to cover the soil surface around plants. Tomato production in Kakamega County is below 2%. Weeds are ranked high among the yield reducing factors. This study consists of four mulch treatments of white polyethylene (0.18mm thick), maize stalks (18.0cm thick), grass clippings (18.0cm thick), guava leaves (18.0cm thick) and no mulch as control with three popularly grown tomato varieties. The mulch treatments were arranged as factorial in a completely randomized block design replicated three times in the experimental plots, at Masinde Muliro University of Science and Technology (0°17^{1}N, 34°45^{1}E). Tomato variety sub-treatments were completely randomized in the plots to minimize non–experimental bias during sampling weeds incidence. The field project was conducted during the short rains and long rains season of 2016-2017. Data obtained was subjected to analysis of variance (ANOVA) using SAS software, version 9.3 (SAS Institute lnc.) at $p<0.05$ confidence level. Least Significance Difference (LSD) was used to separate the means. Mean weed density was significantly highest in control plots (94.51%) and least in mulched plots (11.41%). The tomato plant growth parameters (leaf length, leaf width, stem height and stem width) were significantly higher in mulched than control plots. Mulches provide clean field sanitation, inhibits weed seed germination, promotes plant growth with high crop yields and reduces synthetic pesticides and herbicides application.

Keywords: Mulching, *Solanum Lycopersicum*, Weeds

1. Introduction

Tomato (*Solanum lycopersicum*) is the second most important vegetable crop next to potato. Tomato (S. *lycopersicum*) is indigenous to Peru and Ecuador regions in South America. It probably evolved from *Lycopersicum esculentum* var. *cerasiforme,* the cherry form belonging to *Solanaceae* family [1]. The fruity vegetable is rich in vitamins A, B, C and E that boosts the immune system of the body from multiple illness and fight against aging. Tomatoes are a source of minerals (K and Fe), antioxidants (lycopenes and carotenoids), phytochemicals (Phenylpropanoids and flavonoids), and phenolic compounds which have a key role in human nutrition. They prevent cardiovascular, prostate, lung, stomach, pancreatic, colorectal, oesophageal, oral, breast, skin and cervical cancers and asthma [2]. Tomato (S. *lycopersicum*) seeds contain proteins, chlorine and sulphur detoxifying agents for the liver. Crushed leaves of tomato (S. *lycopersicum*) contain nicotinic acid which acts as an antiseptic to infected areas of the body [3]. The leading African tomato (S. *lycopersicum)* producing countries include Egypt, Nigeria, Morocco, Tunisia, Algeria, Sudan, South Africa and Cameroon. Tomato (S. *lycopersicum)* is grown all over Kenya with an average yield of 60 tonnes per hectare when managed well, and ranked 6th in Africa with a total production of 559,680 tonnes annually [4]. The major producing Counties are Kirinyaga (14%), Kajiado (9%), Taita Taveta (7%), Meru (5.6%), Bungoma (5.5%), Kiambu (5.2%), Migori (4.6%), Makueni (4.4%), Homabay (3.3%), Nakuru (2.7%) and Machakos (2.6%) [5]. Despite its wide cultivation in Kenya, research findings indicate that the average yield of tomato (S. *lycopersicum*) is still very low in Kakamega County (2.3%) and does not meet the consumers' demand. Tomato (S. *lycopersicum*) production is handicapped by damage from weeds, pests and diseases. Farmers practice intensive spray programmes with herbicides and pesticides to limit losses due to weeds, pests and diseases. These results indicate the necessity to adopt mulching technology to mitigate environmental problems and health issues associated with chemical control.

Tomato production in Kakamega County is constrained by several abiotic and biotic stresses. Frequent manual cultivation to remove weeds until the crop forms a canopy that minimizes weed competition, is a temporary control measure. Rapid re-growth of weeds occur and the injured roots and stem bases of young and quite mature tomato (S. *lycopersicum*) crops allow penetration of wound pathogens that may kill the crop. The beneficial effects of mulching practice in vegetable and fruit cultivation includes production of better quality fruits, high yield, better economic returns to the farmer and minimal exposure to pesticides [6]. Mulches are cost effective to farmers by reducing over-reliance on active ingredients in synthetic herbicides that kills many annual grasses and broad-leafed weeds. Mulch is a protective layer of either organic or inorganic material that is spread on the topsoil for protection and improvement of the covered area. Mulching is the process the soil surface around the plant is covered with an organic or synthetic material to create congenial conditions for efficient plant growth and development [7]. The well-known effects of mulching are control of weed population, amelioration of soil temperature, improvement of soil aeration, increase in organic matter content (organic mulch), conserve the available soil moisture around the base of plants and increase the activity of soil microorganisms [8]. Mulching prevents weeding tomato fields when the soil is wet enhancing clean field sanitation. This reduces the spread of some bacterial (bacterial wilt) and fungal (Fusarium wilt) diseases [9]. Mulching inhibits the disease triangle pattern in tomato (S. *lycopersicum*) production by reducing weed invasion, prevent weed-seed germination, promote clean field sanitation, stabilize the soil regime through soil moisture amelioration, promote better root development, enhance better anchorage, improve water and nutrient absorption [10], enhance organic matter content (organic mulches) and reduce weeding labor costs. Low yields in tomato (S. *lycopersicum*) farming within Kakamega County is due to weeds infestation [11; 12] among the determinate tomato (S. *lycopersicum*) varieties.

2. Materials and Methods

2.1. Experimental Site

The extensive field experiment was conducted during the short rains season (August to December) of 2016 and long rains season (March to July) of 2017 at the Masinde Muliro University of Science and Technology (MMUST) Agricultural Farm (N00°17.104; E034°45.874'; altitude 1561m above sea level). Soils in this region have been classified as Dystro-Mollic Notisols [13]. The nutrient composition for the soil was total phosphorus (18.9 ppm), total nitrogen (0.26%), organic carbon (2.5%), Potassium (0.41 $cmolcKg^{-1}$), Sodium (0.1 $cmolcKg^{-1}$), Calcium (2.3 $cmolcKg^{-1}$), Magnesium (0.8 $cmolcKg^{-1}$), Zinc (1.9ppm) and iron (0.37ppm), with acidic P^H of 4.2. The experiment was arranged in a Randomized Complete Block Design (RCBD) with three replications of four mulch treatments [white polyethylene (inorganic, 0.18mm thick), maize stalks (organic, 18.0cm thick) grass clippings (organic, 18.0cm thick), guava leaves (organic, 18.0cm thick)] and no mulch as control. The sub-treatments comprised of three determinate tomato varieties (Fortune Maker-F1, Cal-J and Monicah-F1). The four mulch treatments were arranged as factorial in the RCBD replications of 15 experimental plots. Each experimental square plot size of 4m x 4m had a distance of 1m between the plots and 0.5m buffer zones along the edges of each plot. Each experimental plot had 32 plants (n) totaling to 480 plants (N). The tomato (*S. lycopersicum*) transplant spacing used was 0.5m both for intra row and inter row to avoid overcrowding and reduce the confounding influence of the intended objective. The tomato (S. *lycopersicum*) variety sub-treatments were completely randomized in the plots to minimize non–experimental bias during sampling for weeds (Table 1).

Table 1. *Experimental study plots layout.*

	Main Treatments (Mulch types)				
	White Polyethylene (A)	**Maize stalks (B)**	**Control (C)**	**Grass Clippings (D)**	**Guava Leaves (E)**
Sub-Treatments (Tomato varieties)	V1	V3	V2	V1	V2
	V2	V1	V3	V2	V3
	V3	V2	V1	V3	V1

Key: V1 - Fortune Maker-F1 tomato variety; V2 - Cal–J albeit "Kamongo" tomato variety; V3 – Monicah-F1 tomato variety

2.2. Seedbed Management

Certified seeds of the most commonly grown determinate tomato (*S. lycopersicum*) varieties (Fortune Maker-F_1, Cal–J and Monicah-F_1) were purchased from the Kenya Seed Company Limited in Kakamega Municipality. The seedlings were raised on the seedbed situated in a plot adjacent to the experimental plots. The seedbed site had not been planted with a member of the *Solanaceae* family since 2010. Three seedbeds of 1m width and convenient length of 4m were prepared for each variety. Drills of 20cm inter row spacing were made and the seeds thinly sown in the drills then covered lightly with soil. The seedbeds were watered regularly in the morning and evening when the temperatures were cool. Watering frequency was reduced 2 weeks before transplanting to harden the seedlings. Weeds in the seedbed were mechanically uprooted manually.

2.3. Transplanting and On-Farm Management

The experimental field soil was adequately prepared by deep-ploughing, ploughing, re-ploughing and harrowing to remove the existing weeds from the research farm. The soils had been lying fallow since 2012 when tomato crop was last grown in them in a screen house that was relocated. Transplanting was done late in the evening after 45 days of seed sowing. The mulches were set one day to planting, in a loosely well tilted soil devoid of weeds. Fertilizer application using placement method, was done around the planting holes one week after transplanting when the tomato (S. *lycopersicum*) transplants had set, using Di-ammonium Phosphate (DAP) with 2 tea spoonful per hole. Calcium ammonium nitrate (CAN) was applied two months after transplanting during onset of anthesis and flowering.

Crop management involved pruning of side shoots and extreme flowers. Harvesting of mature tomato (*S. lycopersicum*) fruits after 3–4 months of transplanting was done early in the morning when the temperatures were cool. The harvested tomatoes were sorted, graded and packed in clean well ventilated wooden containers for transport to the market.

2.4. Data Analysis

Weed density was scored using a developed mean rating scale of low density = 1-2; moderate density = 3-4 and high density = 5-6. The data obtained on weed density and tomato plant growth parameters of stem height, stem width, leaf width and leaf length was subjected to analysis of variance (ANOVA) using SAS software, version 9.3 (SAS Institute lnc. 2004) [14] at P<0.05 confidence level. Least Significance Difference (LSD) was used to separate the means.

3. Results

Table 2. *Mean weed density.*

Mulch type	Mean	Coefficient of variation (cv)	P-value
Grass	2.8099^{a}	24.21205	0.0052
Maize	1.8575^{b}		
PVC	1.4762^{cb}		
Guava	1.0000^{c}		
Control	5.8000^{d}		
Average mean	2.58872		

Figure 1. *Mulch types efficacy on some sub-treatments: 1: All four mulch types under rain-fed conditions; 2: White PVC mulch type; 3: Grass mulch type; 4: Guava mulch type; 5: Maize stalk mulch type; 6: Control treatment.*

The mean incidence that have a common grouping letter are not significantly different at P < 0.0052. The mean weed density for grass mulch type is statistically higher and different from the mean weed density of maize stalks (*Zea mays*) followed by PVC then guava leaves (*Psidium guajava*). Control experiments had 100% weed incidence that covered the entire plots in all the treatments and sub-treatments (Table 2; Figure 1).

Table 3. *Mean tomato plant height (cm).*

Mulch type	Mean	cv	P-value
Grass	59.10[a]		
Guava	58.05[a]		
Maize	57.95[a]	26.74943	0.5822
PVC	42.48[a]		
Control	8.416[c]		
Average mean	54.9285		

There was no statistical significant difference between the mean tomato plant-height of the different mulch types within the treatments and among the sub-treatments, except a slight difference in PVC and lowest in control (Table 3).

Table 4. *Mean tomato leaf width (cm).*

Mulch type	Mean	cv	P-value
Grass	30.571[a]		
Maize	25.524[ba]		
Guava	22.857[b]	15.70245	0.1551
PVC	19.714[b]		
Control	3.417[c]		
Average mean	24.94285		

The Mean tomato leaf width for the mulch types was statistically significant and different from each other but lowest in control (Table 4).

Table 5. *Mean tomato leaf length (cm).*

Mulch type	Mean	cv	P-value
Grass	40.095[a]		
Maize	34.524[ba]		
Guava	32.857[ba]	21.039	0.3416
PVC	25.190[b]		
Control	4.712[c]		
Average mean	33.16667		

The mean tomato leaf-length for grass mulch type was significantly highest, and different from maize, guava and PVC mulch types that were not significantly different, but lowest in control (Table 5).

Table 6. *Mean tomato stem width.*

Mulch type	Mean	cv	P-value
Grass	1.03333[a]		
Maize	0.9886[ba]		
Guava	0.8000[b]	14.10285	0.1592
PVC	0.7905[b]		
Control	0.0006[c]		
Average mean	0.876767		

The mean tomato stem-width for grass mulch type was statistically highest, and significantly different from the mean stem-width of maize, guava and PVC mulch types that were not statistically different, but lowest in control (Table 6).

4. Discussion

The mean weed density incidence was highest in control plots than grass, maize, PVC and then guava mulch types respectively. The Guava (*Psidium guajava*) leaves allelopathic efficacy inhibited weed seed germination and growth through residue decomposition. Guava leaves contain volatile oil (quercetin, avicularin, guaijaverin, among others) that serve as immediate chemical defence against herbivores and pathogens [15]. Guava (P. *guajava*) leaf aqueous extracts also have antibacterial activity [16]. The guava leaves allelochemicals allelopathic effect inhibits chlorophyll synthesis, cell division and cell elongation in weeds through disruption of membrane permeability, suppressing their growth. The white PVC had slightly higher temperatures by stopping evapotranspiration but not obstructing light. Organic mulches might have carried some weed seeds that germinated when their dormancy was broken. This statistically increased the mean weed incidence in adjacent PVC mulches. The mean tomato plant growth parameters were highest in grass, guava, maize, PVC and control in descending order. Probably the grass mulch type ameliorated the soil with more humus supplement that significantly boosted growth [17]. Appropriate spacing between rows of tomato (*S. lycopersicum*) transplants and minimal DAP application, promoted development of stocky stems with good root system, that enabled the plants absorb sufficient water and sunlight for photosynthesis. The CAN enhanced flowering and fruit formation. Pruning of lateral buds and side-shoots/suckers promoted apical dominance, early maturity and formation of large-sized uniform fruits. Harvesting early in the morning hours minimized heat gain by the fruits retaining their quality taste and high value products. Minimal spraying was done once monthly to prevent tomato early blight and late blight disease.

5. Conclusion

In conclusion, this study used different mulch types to control weeds in three most popular determinate tomato (*Solanum lycopersicum*) varieties. Both organic and inorganic mulch types offered an alternative effective method of controlling weeds. Mulching provided more environmentally benign and durable weed control measures. The mulches blocked weed seed germination, suppressed the existing weeds from thriving, impacted positively on natural biodiversity of soil microorganisms and above ground beneficial pollinators. Mulching minimized weeding costs, promoted greater yields and fetched more income to mitigate poverty levels among small holder farmers.

6. Recommendations

This study recommends the use of mulching as an effective environment friendly method to control weeds for enhancing vegetable crop production. Controlling weeds through different organic and inorganic mulch types is one focal point for sustaining global food and nutrition security for future generations.

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This fieldwork experiment was conducted at Masinde

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Declaration of Interest

The authors have declared that no competing interests exist.

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