Soil conservation benefits of mulching and effects on growth, yield and quality of tomato in a rainforest environment

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ABSTRACT

The effects of mulching materials on soil properties, growth and yield of tomato was evaluated in the rainforest of Nigeria. The experiment was 3 x 5 factorial fitted into randomized complete block design (RCBD) with three replications Mulching materials were black (BP) and transparent polythene sheet (TP), plant residue (PR), paper mulch (PA) and control unmulched. Tomato varieties were Lindo FI, UC82B and Akure Local. Data were collected on soil moisture and temperature regimes and tomato growth and yield variables. Tomato fruits were analysed in the laborartory for proximate and some biochemical constituents. Mulching effects was significant on soil moisture contents and temperature as well as the growth and yield of tomato. Tomato varieties differed in growth, yield and chemical qualities. Compared to the unmulched (bare ground), mulched plots had lower soil temperatures and higher soil moisture contents. Plant residue mulch better conserved soil moisture and temperature compared with polythene sheet mulches. Lindo F1 produced heaviest fruit weight and least by Akure Local, tomato varieties differed in proximate composition and bioactive phytochemical constituents. Fruits of Akure Local had higher fibre, protein, vitamin C, Phenol, FRAP, flavonoid and lycopene while Lindo F1 had highest DPPH and ABTS. Plant residue, paper, transparent and black polythene mulches conserved soil moisture while effects on soil temperature differed. Mulching modifies hydrothermal regimes and created favourable environment for enhancing growth and yield of tomato. The study established the relevance of mulching for soil moisture conservation, amelioration of soil temperatures, growth and yield enhancement of tomato.

Keywords: *Hydrothermal, Phytochemicals, Productivity, Resources, Tomato, Tropics.*

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Highlights of this paper:

- Mulching soil surface via placement of organic or synthetic materials provides multiple benefits to soil, crop and the ecosystem Soil surface was mulched using plant residue, paper, transparent and black polythene (plastics).
- The mulches modified soil hydrothermal regimes and created favourable environment for enhanced growth and yield of tomato.
- The study established the relevance and benefits of mulching for modifying soil hydrothermal status and growth and yield enhancement of tomato.

1. INTRODUCTION

Tomato *Lycopersicum esculentum* L. (Synonymous *Solanum lycopersicum)*, belongs to the family Solanaceae. It is one of the most widely consumed fruit vegetable worldwide and a major source of vitamins, minerals and a salad vegetable. Tomato is a valuable source of vitamins A and C, as well as several minerals [1] including calcium, iron, manganese, and particularly potassium [2]. The fruit contains lycopene, which is a carotenoid (a pigment involved in photosynthesis) and that gives red colouring to tomato [3]. *Lycopene is synthesized through the carotenoid metabolic pathway and accumulates in the flesh of toma*toes as they ripen, is useful for prevention of prostrate cancer. Tomato is widely used in cannery and made into soups, juice, sauce, ketchup, puree, paste and powder [4]. Tomato is widely cultivated as outdoor (open fields) and indoor (greenhouses, and net houses) crop.

During its growth, crops are subjected to varried environment condiitons manifesting as biotic and abitotic stress factors. Crops' growing environment conditions can be modified through a variety of cultural practices among which is application of mulching on soil surface via placement of organic or synthetic materials around plants [5] to provide a more favourable environment for growth, yield and quality [6, 7]. Mulches serve as protective covering, reduce moisture loss from the soil by preventing evaporation from the sunshine and desiccating winds, regulate soil temperature (cooler in summer and warmer in winter) [5, 7]. Mulch-enhanced temperature regulation and soil moisture conservation promote plant development, control weeds and helps to increase the fruit yield, productivity as well a reduction in production cost [8]. Mulches using organic and inorganic materials such as plant residue, straw, wood shaving, and polyethene sheets/plastic film s, wood shavings etc) are applied in order to regulate soil moisture and temperature regimes [9]. In addition to soil conservation functions, plant residue mulch are known to enhance agronomic traits of crops, soil fertility status enzyme activity, and carbon storage [7, 10]. The enviornmental benefits of plant residue mulch is related to enhanced crop performance without increasing greenhouse gas (N_2O and CO_2) emissions [9, 11]. Mulching provides multiple ecological services in addition to benefits to the environment, soil erosion mitigation constitutes a notable effect [8, 9, 12]. Mulching materials of varying colours determines its energy-radiating behaviour and its influence on the microclimate around plants. Colour determines the surface temperature of mulches and the underlying soil temperatures, moisture retention, and vegetable yields [13]. Plastic mulches are widely used for vegetable production with different impacts on soil temperature, moisture retention, and vegetable yields [10, 14]. Besides modifying the plant's environment, these protective materials provide protection against wind (weathering), rain plash with consequent reduction in fungal and bacterial diseases caused by water splashing while solarisation effects suppress weed growth [7, 14]. In addition to soil conservation functions, plant residue mulch are known to enhance agronomic traits of crops, soil fertility status enzyme activity, and carbon storage [7, 10]. Mulch covering of soil surface can change light availability to soil with consequences on photosynthesis and yields [7, 15]. Mulch-enhanced reduction in soil water evaporation and the resultant conservation of moisture in crop rootzone, thus promoting transpiration, water and nutrient uptake [16].

Mulch enhances soil physical (loose for root development), chemical and biological properties [14, 17]. Soil microbial biodiversity play important role in soil structure stability and water relations in agro ecosystem [14, 17].

Organic mulches are rich sources of carbon required by microbes for growth and multiplication which influence the break down of organic matter for relase of nutrients [18, 19]. In addition to improved physical, chemical and biological properties of soil, rganic mulches following decomposition promote soil organic matter status (improving nutrient avaialibility) [20]. Mulching acts to establish linkage between soil and atmosphere, which resultantantly modifies crop-growing environment [6, 21]. Soil water and heat transfer mechanism under mulch is important to the creation of favourable environment for growth of crops. [21]. Mulching is reported to benefit soil physical proeprties such as structure and macro-porosity, water infiltration and storage and reduction of solar energy to evaporating site and runoff losses from rainfall [16].

Soil surface cover mulches helps keep fruits clean by cutting off fruit contact with the soil and reduce fruit cracking and rot (blossom end rot) [6, 11]. Mulching enhances yield and improved fruit quality of vegetables such as increases in contents of soluble solids, total phenolics (aromatic compounds which serve as anti-microbial protection), flavanols, and antho-cyanins (water-soluble pigments related to flavonoids properties) and carotene and ascorbic acid (water soluble sugar acid with antioxidant properties) [16, 19, 22].

The benefits of mulching has been harnessed to great advantage especially for horticulture practice, mulching has proven to significantly improve the growing conditions and productivity of of vegetable crops [12, 14, 23]. Vegetable crops such as tomato, pepper, eggplant, cucmber and okra respond well to organic and inorganic mulching materials [14, 18, 22]. Responses of warm season vegetables such as cucumbers, muskmelons, watermelons, eggplant, peppers mulching have been expressed as early maturity, higher yields and quality. Mulching acts to maintain favourable hydrothermal regimes during crop growth which had been attributed to the promotion of earliness to maturity [6, 8, 14, 17]. Studies have reported the effects of plant residue (straw return) mulch on performance of staple crops such as corn, soybean, rice, and wheat [19]. Studies have reported the effects of plant residue (straw return) mulch on performance of staple crops and vegetables [6, 19, 22].

The advent of synthetic materials (plastic films/sheets) has altered the methods and promote the practice of mulching to agriculture [24]. Studies have showed that transparent plastic film conserve soil moisture, improve soil temperature, accelerate crop growth, raise crop yield and water use efficiency [11] in addition to meeting crop accumulated temperature requirements in different seasons and agroecologies and climate [24]. Plastics are the most widely used mulching materials, and especially black polythene with reported positive effects on productivity of crops [24]. The use of biodegradable films is increasing due to the benfits of safety when left on the field after harvesting, however, these materials are not very durable and much more expensive than plastics. The utilization of organic and inorganic materials as mulches has played a major role as agrotechnology for increasing growth, yeld and quality of vegetables such as tomato, pepper, eggplant, watermelon, muskmelon, cucumber, and squash [21, 25]. Informed selection of mulching technique and material is important based on crop type, management practice, and climatic conditions to enable realization of the mulching benefits. The efficacy of mulch and ability to deliver its potentials in agriculture is also affected by the characteristics of mulch material, duration of soil cover, application rate,land use, soil type, slope, and environmental factors [26-28]. Therefore, the properly managed mulching strategies could compensate the water requirement of crops in periods of low rainfall or drought. Other factors to be considered in the choice of mulch materials and mulching technique are crop type, management practice and climatic conditions [13, 29, 30] required soil cover age [28, 31], as well as environmental factors e.g. precipitation [26, 27] temperature [12, 28] and soil types [26, 32, 33]. In the era of climate change driven warming and drying (drought and dry spells of frequent episodes and intensities), needed are developments and adoption of eco-friendly agricultural practices such as mulching. Limited information exists on the hydrothermal resource utilization benefits of mulching and on the growth and yield of tomato in a rainforest zone of Nigeria. The aim of the study is to determine the growth, yield and quality of tomato as influenced by variety and mulching materials. Thus, objectives were to determine the effects of mulch material and variety on soil mositure and temperature regimes, the growth, yield and quality of tomato.

2. MATERIALS AND METHODS

2.1. Experimental Site

The study was conducted at the Horicultural Farm of Rufus Giwa Polytechnic, Owo, southwest Nigeria between March and June 2021.

2.2. Experimental Design and Field Layout

The experiment was laid out in 3 x 5 factorial arrangement fitted into a Randomized Complete Block Design (RCBD) replicated three times. Seeds of three (3) varieties of tomato used (namely, LINDO F1, UC82B and Akure Local) were obtained from an Agric Input shop.

The mulching materials evaluates were:black polythene sheet (BP), transparent polythene sheet (TP), plant residue (PR), paper mulch (PA) and control unmulched.

2.3. Nursery Establishment for Tomato Seedlings

The seed of tomatoes sourced were subjected to nuursery practices for a period of four weeks under a well shaded environment.

2.4. Land Preparation

The experimental plot was ploughed and harrowed and laid out into treatment plots (3m x 2 m) with alley-ways between blocks and treatment plots. Four weeks old seedlings of each of the tomato varieties were transplanted using a spacing of 50 by 50cm. Manual weeding was carried out using hand hoe at weekly interval to reduce competition between weeds and plants. Data were obtained on some weather variables of the site of study from The Meteorlogicsl Observatory, Federal University of Technology, Akure, Nigeria.

2.5. Data Collection

Data were collected on soil moisture and temperature,. The ngrowth and yield variables of tomato. The number of leaves and branches per plant were determined by manual counting at fortnight intervals. Stem length was measured from the soil surface to the shoot apex in centimeter (cm) using a meter rule. This activity commenced 3 weeks after seedlings were planted on field plots and at weekly intervals. Plants were carefully uprooted at the end of experiments. Soil around plants were watered for easy uprooting without damage to the root. Root length was measured using a meter rule while major roots were counted manually to determine the number of rootsper plant. Plant biomass was separated into stems, roots and leaves and weighed in the laboratory to determine fresh weights of plant parts. Dry weights of plant parts were also determined after oven-drying at 80 ^{0}C to constant weight using sensitive weighing balance. At the 12th week, tomato fruits were harvested, counted to determine the number of fruits and weighed to determine the fresh weight.

2.6. Fruit Quality Analysis

Harvested fruits of tomato were subjected to chemical, and proximate contents analyses in the laboratory. Fruit samples were randomly selected per plot and analysed for proximate composition   such as crude protein, crude fats, carotene, carbohydrates and moisture content and phytochemicals (lycopene).

2.7. Soil Analysis

The soil samples were taken and subjected to physical (particles size) and chemical analyses, (pH, N, P, K, Ca, mg, Na, organic carbon and organic matter). The determination of particle size was carried out using hydrometer method: soil particles that did not pass through the 2 mm sieve were weighed and reported as a percentage of the whole weight. Soil pH, was measured using a pH meter while total nitrogen was determined following Kjeldahl method [34]. Available phosphorus was analyzed using 0.5 M sodium bicarbonate extraction solution (pH: 8.5) following Olsen and Dean [35]. Exchangeable basic cations (K+, Ca2+, Mg 2+, and Na+) were extracted with 1 M ammonium acetate at pH (7.0). Cation exchange capacity (CEC) was determined from ammonium acetate saturated sample, and excess ammonium acetate was removed by washing with ethanol. Exchangeable cations (Ca^{2+} and Mg^{2+}) in the ammonium acetate leachate were measured by atomic absorption spectrophotometry (AAS), and K^+ and Na^+ were determined by flame photometer [36]. Soil organic carbon determinations was made following the wet oxidation method [37]. Cation exchange capacity (CEC) was by the ammonium saturation method (Jackson, 1958). Organic matter was determined by the wet oxidation method [37] while available phosphorus was determined using Olsen and Mehlich method.

2.8. Determination of Soil Moisture Content and Temperature

Soil moisture contents and soil temperature were measured in dynamics at 3 weeks intervals (from 3 to 15 weeks after transplanting: WAT). Also at increamental depths (10, 25, 40 and 60 depths), soil samples were also collected using augers. Sample moisture contents were measured by oven drying (weighing) method. Soil samples were collected from treatment plots and oven dried for 105 °C for 24 hours until constant weights of samples were obtained. Soil temperature was measured using soil thermometers inserted into the soil at 5 cm. Measurements were taken at 1500 hour (Afternoon).

Free Radical Scavenging Ability of Tomato Fruits: Free radical scavenging ability of the extract against DPPH (1, 1- diphenyl-2-picryhydrazyl) using [38] method for which 1ml of extract was mixed with 1ml of the 0.4mM methanolic solution. The mixture was left in the dark for 30 min before measuring the absorbance at 516nm. The scavenging ability of ABTS (2, 2'-azino-bis (3-ethylbenthiazoline-6-sulphonic acid) was determined according to the method described by Re, et al. [39]. The ABTS was generated by reacting an (7mM) of aqueous solution with $K_2S_2O_8$ (2.45 mM) in the dark for 16 hours and adjusting the absorbance at 734nm to 0.700 with ethanol while appropriate dilution of the extract was added to 2.0 ml and absorbance was read at 732 nm after 15 mins. Total phenol content was determined by Singleton [40]. Exactly 0.2 ml of the extract was mixed with 2.5ml of 10% Folinciocalteau's reagent and 2 ml of 7.5 % Sodium carbonate was added. The reaction mixture was subsequently incubated at 45 °C for 40 mins while absorbance was measure at 700 nm in spectrophotometer. Vitamin C content was determined using the ascorbic acid as the reference compound. Exactly 200 ml of the extract was pipetted and mixed with 300 ml of 13.3 % of TCA using 75 microliter of DNPH. The mixture was incubated at 37°C for 3hrs and 500 ml of H_2SO_4 was added after which absorbance was read at 520nm. Total flavonoid content was determined using a colourimeter assay following the method of Bao, et al. [41]. Exactly 0.2 ml of the extract was added to 0.3 ml of 5 % $NaNO_3$ at zero time, after 5 min, 0.6 ml of 10 % $AlCl_3$ was added while 2 ml of 1M NaOH was added to the mixture in addition to 2.1 ml of distilled water. Absorbance was read at 510 nm against the reagent blank and flavonoid content was expressed as mg equivalent.

Results of the analysis of soil sample from site of the experiment before commencement and termination of the experiment are shown in Table 1a and b.

Table 1. Results of laboratory analysis of soil of site of study.

A pre-cropping soil analysis													
Soil properties (Chemical and physical)													
Soil pH	OC (%)	N (%)	P (mg/kg)	K (cmol/kg)	Na (cmol/kg)	Ca (cmol/kg)	Mg (cmol/kg)	CEC (cmol/kg)	EC (µS)	Clay (%)	Sand (%)	Silt (%)	Textural class
5.46	1.02	0.10	12.77	2.25	0.32	1.12	0.14	8.07	48.00	15.62	51.73	32.65	Silt loam

B Post-cropping soil analysis													
Soil properties (chemical and physical)													
SoilpH	OC	N	P	K	Na	Ca	Mg	CEC	EC	Particle sizes			Textural class
	(%)	(%)	(mg/kg)	(cmol/kg)	(cmol/ kg)	(cmol/kg)	(cmol/kg)	(cmol/kg)	(µS)	Clay (%)	Sand (%)	Silt (%)	
4.45	1.07	0.42	13.14	2.55	1.21	0.23	1.02	0.34	7.09	21.3	58.5	20.20	Sandy clay loam

Data obtained following the measurement of soil and tomato plants measurements were subjected to analysis of variance (ANOVA) test wile treatments means were separated using Turkey's Honest Significant Difference (HSD) test at P<0.05.

3. RESULTS

3.1. Site of Study and Conditions

The site of the study is in the forest-savanna transition zone of south west Nigeria and is characterized by wet-dry season transition and bimodal rainfall pattern. The rainy season span the months of March to november of a year and terminates in a short term drought of of 3 to 4 months. The weather conditions are: average monthly rainfall (81.77 mm), minimum temparture (23.4 ^{o}C), maximum temperature (30.88 ^{o}C), minimum relative humidity (89.66 %) and maximum relative humidity (50.72 %) (Figure 1).

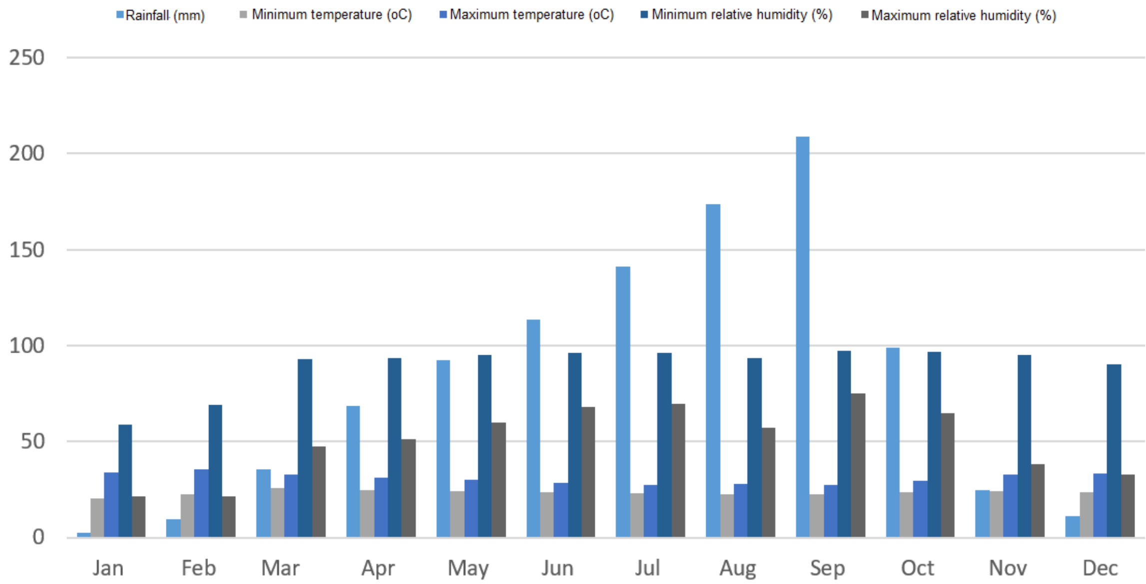

Figure 1. Weather conditions at site of study.

3.2. Effect on Soil Moisture Contents

Figure 2a shows Soil moisture content under different mulching materials at 10 cm soil depth. Black Polythene (BP) mulch recorded the highest mean value (16.4%), Transparent Polythene (TP) mulch was next (15.8%), Paper (PA) mulch had (15%), followed by Plant Residue (PR) mulch (13.1%) and the least value was obtained from Control (CO) the unmulched treatment (7%). The values were significantly different at P< 0.05, but value of BP (16.4%) and TP (15.9%) were not significantly different at P< 0.05 level. Lindo F1 performed best across mulch materials having higher values of 14.9% moisture which was significant higher than values obtained from UC-82B and AKL varieties. Plant residue mulch was best at soil moisture conservation compare with other mulch materials evaluated for which polythene sheet covers (black and transparent) produced lower soil moisture contents. However, unmulched control produced lowest soil moisture contents (Figure 2b).

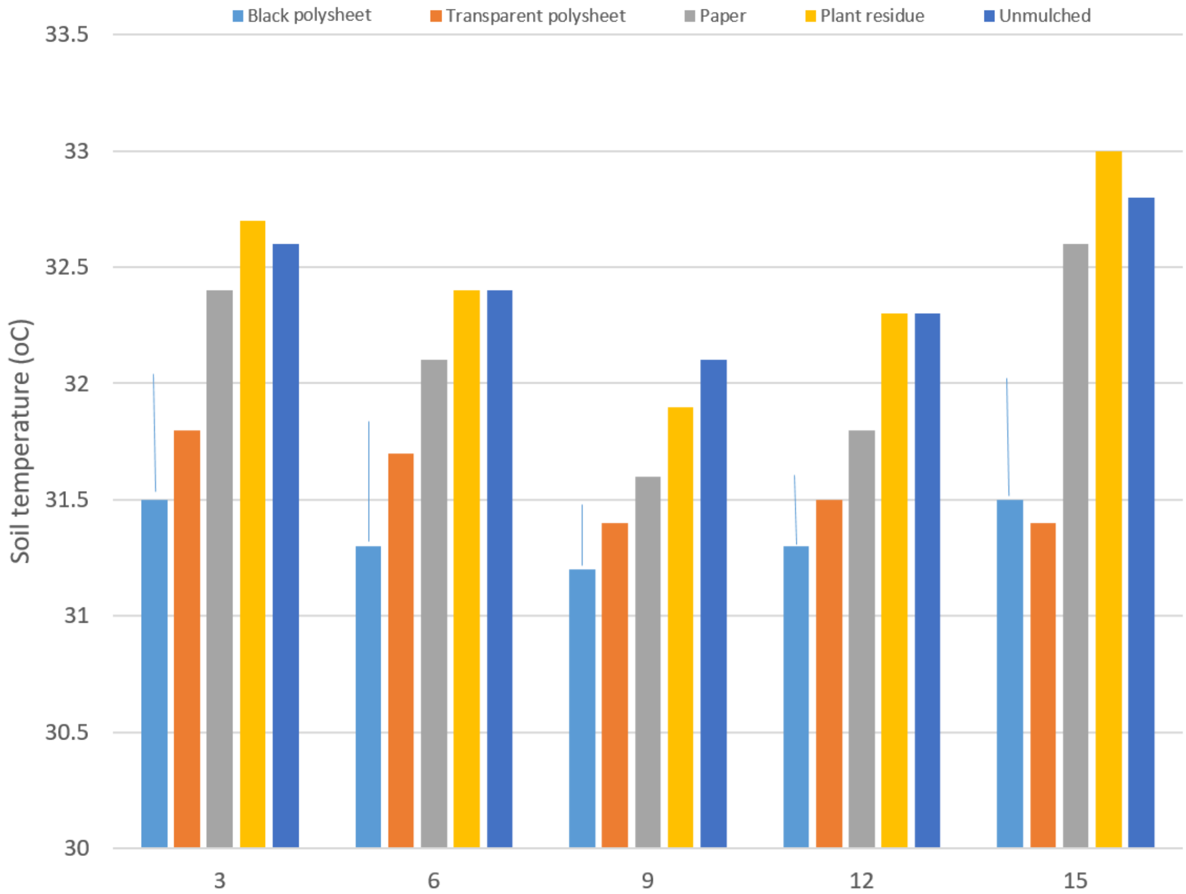

Figure 2a. Soil temperature (@ 1500 hours) under the mulching materials

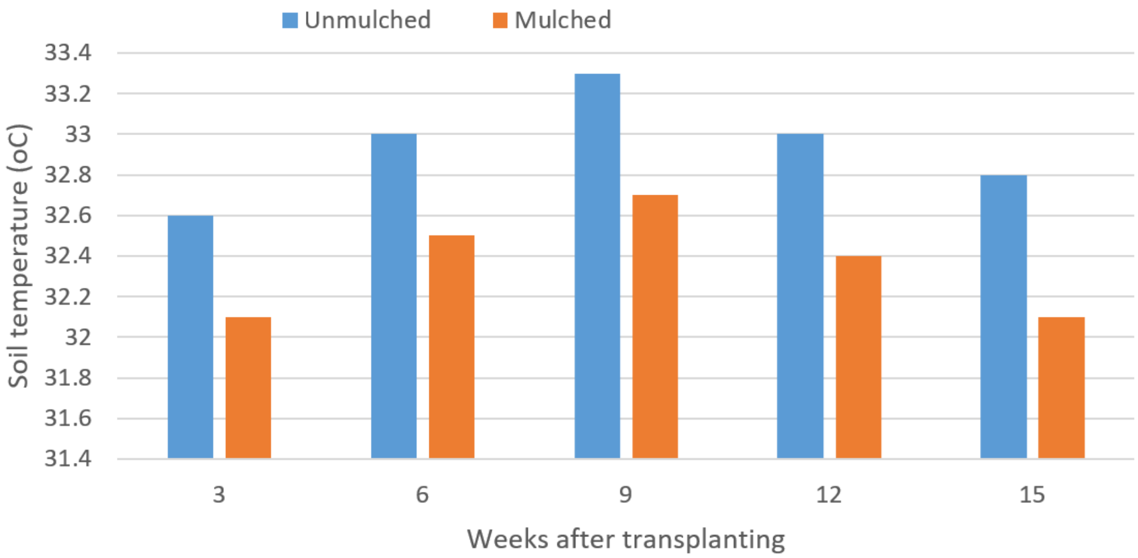

Figure 2b. Soil temperature (@ 1500 hours) under mulched and unmulched treatments.

In Figures 3a to d is presented depth wise (10, 25, 40 and 60 cm) trends in soil moisture contents under the mulch materials evaluated during tomato growth at 3, 6, 9 and 12 weeks after transplanting (WAT). The time course of average soil water content (SWC) at depths (0–10 cm, 10–20 cm, 20–40 cm, 40–60 cm) under the mulch treatments were compared from weekly measurements (Figures 3a to d) At 3 weeks after transplaning (WAT) tomato seedlings average SMC was 0.176 cm^3/ cm^3 . at 10 cm depth while smc values increased 0.27, 0.24 and 0.20 cm^3/cm^3 at 10, 25, 40 and 60 cm depths. The average SWC of 0–60cm soil layer were 0.219, 0.284, 0.216 and 0.167 $cm^3/cm^3$for the respective 3, 6, 9 and 12 WAT.

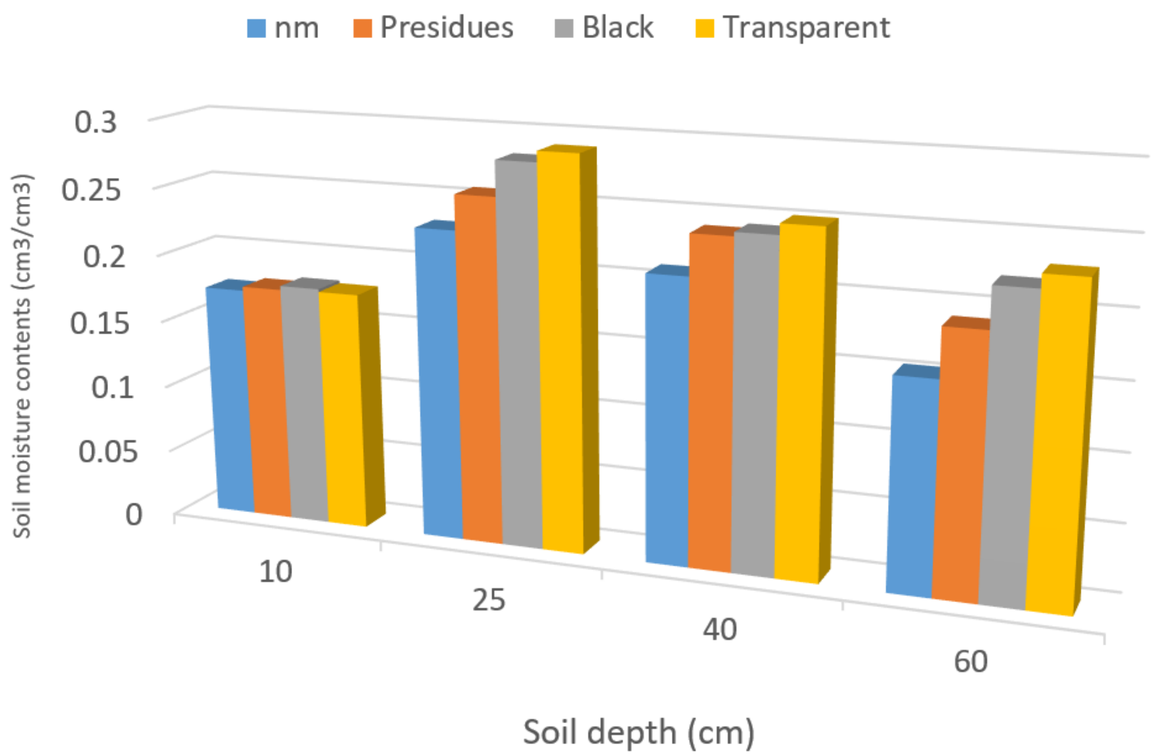

Figure 3a. Effect of mulch materials on soil moisture content at depth (3 weeks after transplanting hart title.

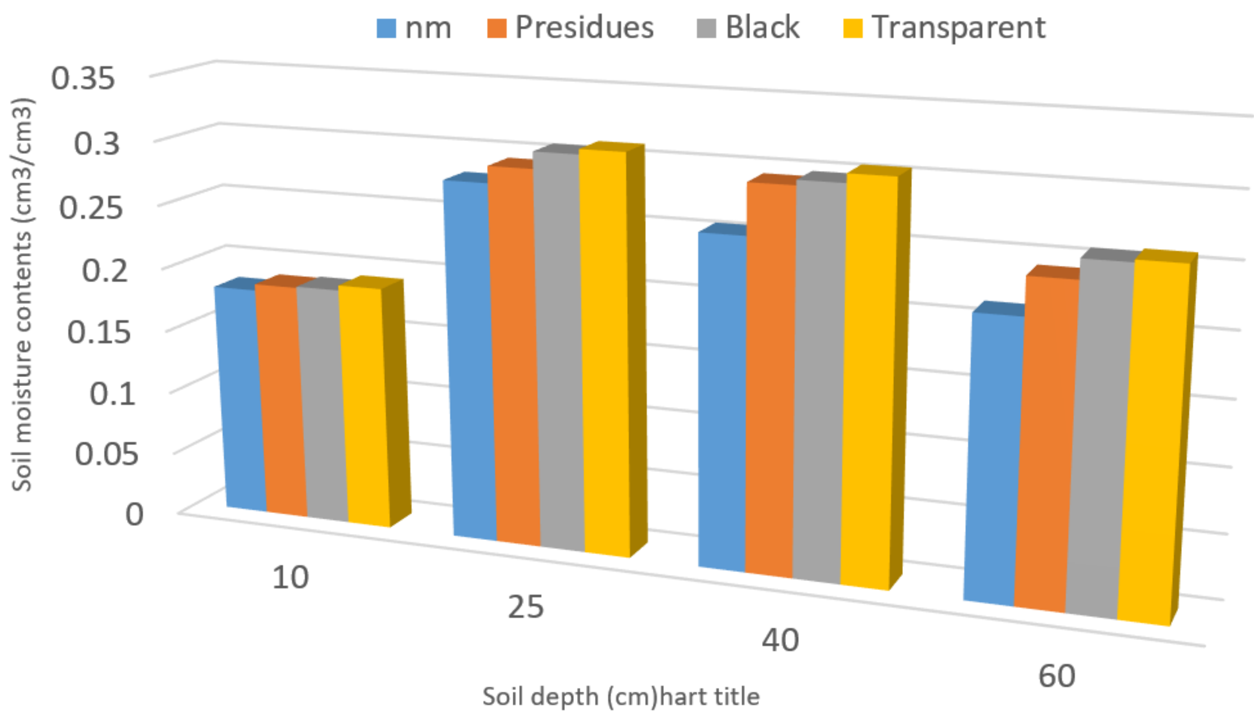

Figure 3b. Effect of mulch materials on soil moisture content at depth (6 weeks after transplanting).

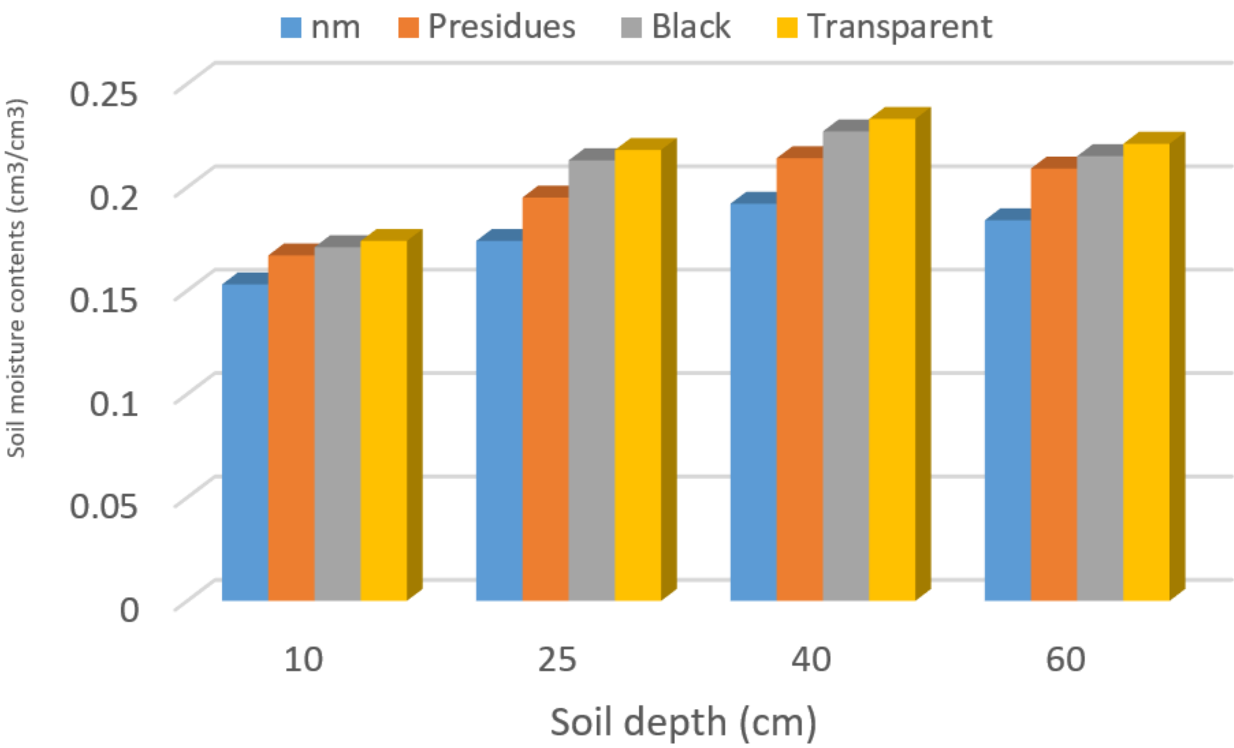

Figure 3c. Effect of mulch materials on soil moisture content at depth (9 weeks after transplanting).

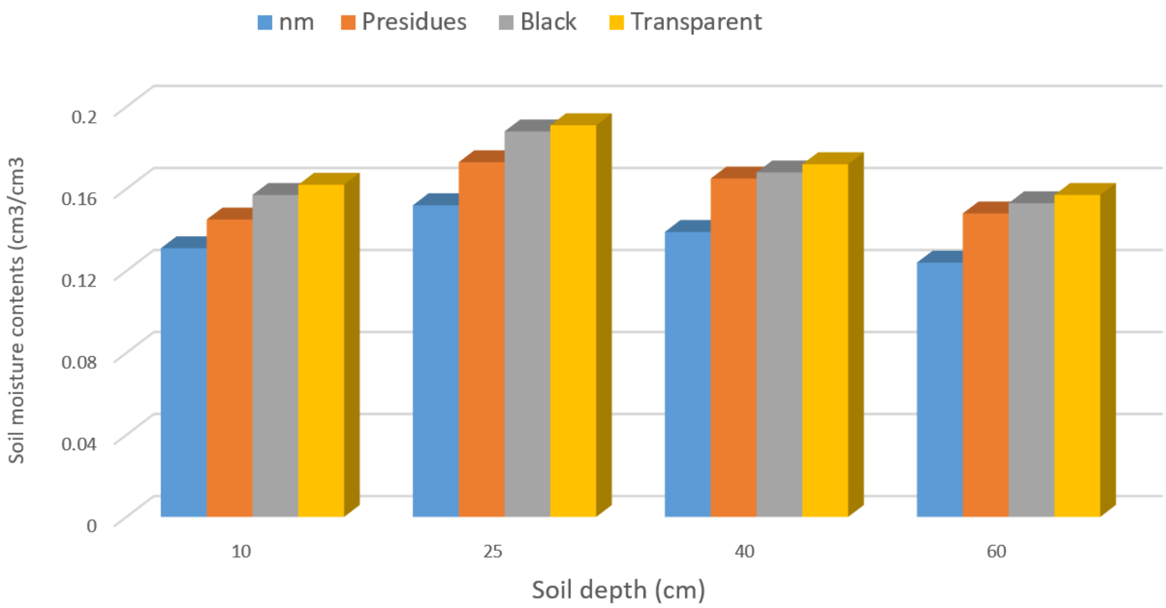

Figure 3d. Effect of mulch materials on soil moisture content at depth (12 weeks after transplanting).

3.3. Effect on Soil Temperature

The mulching materials affected soil temperature regimes during tomato growth (Figure 4a). Polythene sheet covering of soil surface produced higher soil temperature compared with organic (paper and plant residue. Consistently highest soil temperature was recorded for black polythene cover followed by transparent, and paper and plant residue mulch. The unmulched had the lowest soil temperature. In Figure 4b presents measured soil temperatures between mulched and unmulched plots during tomato growth. Soil temperature were ($P<0.05$) most times during the morning hours compared with temperature values measured during the afternoon (1500 h) across measurement periods. In contrast, soil temperatures were most times lower (P<0.05) under mulched treatments compared with the unmulched (Figure 4b).

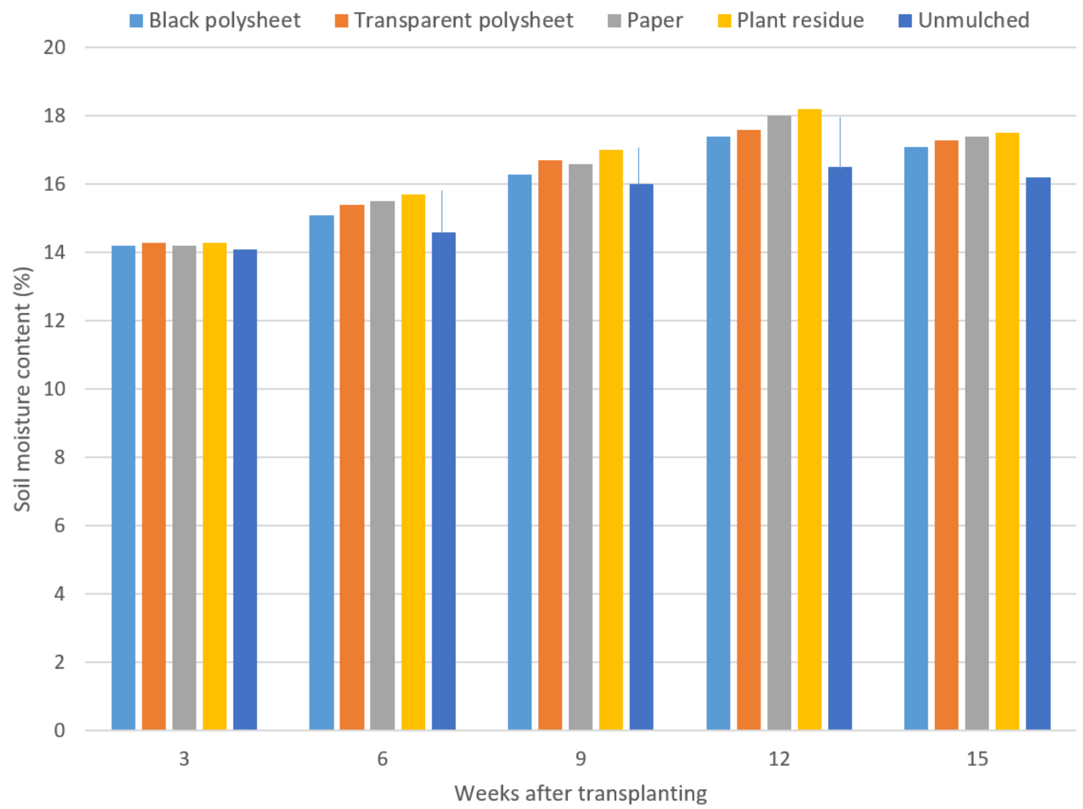

Figure 4a. Soil moisture contents as affected by mulching materials.

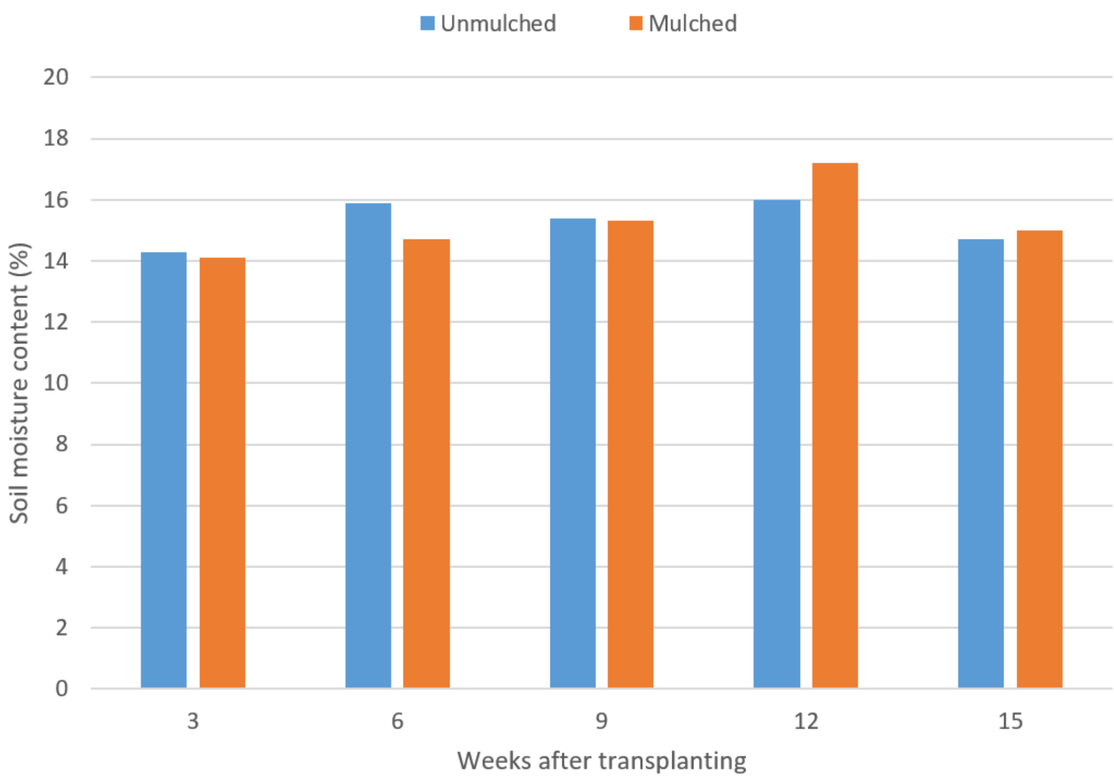

Figure 4b. Soil moisture contents under mulched and unmulched treatments.

3.4. Effect of Mulching Materials on Tomato Growth Variables

The results showed that the effect of mulching materials was significant on height of tomato varieties tested (Table 2). Black Polythene (BP) recorded the highest value, followed by Transparent polythene mulch (TP), Plant residue (PR) and Paper mulch (PA) in that order and control had the least value. UC-82B performed best under BP material while Lindo-F1performed well under Transparent polythene mulch, Plant residue and Paper mulch. Also the least performance was obtained from Control. Akure Local variety did not show response to the mulching materials. The overall performance of Lindo-F1 under the various mulching materials was significantly different from UC-82B, which was also significantly different from AKL. The interaction effect of mulching materials and tomato varieties were significant on plant height in particular black polytene and UC-82B, and TP and Lindo-F1.

Table 2. Effects of variety and mulcing on growth parameters of tomato @50% flowering.

Treatments	Plant height	Number of leaves	Leaf area (m^2)	Fresh biomass	Fresh root weight (g)	Fersh shoot weight (g)	Dry root weight (g)	Dry shoot weight (g)
Varieties								
Lindo F1	30.56	25.60	28.90	6.95	1.90	5.20	1.60	3.32
UC-82B	28.46	19.35	20.65	6.68	2.16	5.32	1.62	3.41
Akure local	26.55	20.17	22.43	6.14	1.78	5.36	1.42	3.03
LSD (0.05)	2.43	3.12	4.11	0.64	0.44	0.33	0.33	0.41
Mulches								
Black polythene	40.76	22.69	33.34	10.09	3.07	7.87	2.34	3.14
Transparent polythene	36.15	23.66	31.16	8.56	2.40	6.40	1.92	4.33
Paper	26.00	20.09	23.43	5.66	1.60	4.30	1.46	2.51
Plant residue	29.83	35.57	20.88	6.10	1.80	4.80	1.52	3.09
Control	19.51	16.60	16.15	3.54	0.95	3.13	0.97	1.96
LSD (0.05)	4.24	5.44	4.35	3.38	0.67	2.06	0.53	1.15
Interactions								
Variety (Var)	x	x	x	ns	x	ns	ns	ns
Mulch (Mul)	x	x	x	x	x	x	x	x
Var * Mul.	x	ns	x	x	ns	ns	ns	x

Note: Ns (non sigificant at $P < 0.05$); x (siginificant at $P < 0.05$).

3.5. Effect on Number of Leaves of Varieties of Tomato at 50% Flowering

The results showed that unmulched ground recorded the least values of number of leaves which ranged between 7.60 – 5.43, while the highest numbers of leaf were recorded in Paper mulch (37.50 – 33.07) (Table 2) Treatment differences were not significantly different among mulching materials. Interaction between variety and treatment are not significant at $P < 0.05$. There was no significant different among the three varieties of tomato. Also, interaction between tomato varieties and mulching materials were not significant at $P \leq 0.05$.

3.6. Effect on Leaf Area of Tomato Varieties at 50% Flowering

The effect of mulching materials on leaf area of tomato varieties showed that the Black polythene mulching materials had significantly higher leave areas values ranging between ($40.44cm^2$ - $28.18cm^2$) (Tabale 2). This was followed by the transparent polythene (TP) mulching material. There was no significant difference in values obtained from BP and TP. Paper mulching materials (PA) recorded 28.18 - $20.68cm^2$ which was higher than Plant residue mulching material with $22.88cm^2$ and control with 13.26-$8.88cm^2$. The response of tomato variety to mulching materials showed that Lindo-F1 variety recorded the highest value of about $40.44cm^2$ – $13.26cm^2$, followed by UC-82B with the value of $31.40cm^2$ – $11.31cm^2$ and the least in AKL with values of 31.40 – $11.31cm^2$.

3.7. Effect on Biomass Accummulation

Result showed that different mulching material significantly influences the total fresh weight of tomato varieties at 50% flowering stage. (Table 3) BP mulching material recorded the highest value (11.37g) while the control had the least value (2.02g). Variety Lindo-F1 had the highest total fresh weight followed by the UC-82B and the least was recorded under the AKL. Result also showed that total fresh weight per plant of tomato varieties varied significant with different mulching materials. The highest fresh weight was obtained in BP treatment (11.37g), followed by Transparent polythene (9.55g) while the least value was obtained from control treatment (2.02g). There was significant difference among treatment values at P<0.05. The varieties responded to different mulching at significant levels. The highest fresh weight was obtained from LF1 variety (6.95g) followed UC-82B (6.68g) and the least from AKL (6.14g) at significant levels. BP and Lindo-F1 variety which had highest values for fresh weight. Results shwoed that mulching materials affected total dry weight of tomato varieties showed that BP recorded the highest value of dry weight (7.42g), while the least value was obtained from CO (1.82g) (Table 1) There was significant difference among values obtained from various mulching treatment at P<0.05. UC-82B variety recoded the highest mean value of total dry weight of tomato (8.32g) and the least was AKL (4.49g). Black polythene and UC-82B variety produced the highest total dry weight which was significantly different from the other treatment combinations. The results showed that the CO had the least value of dry shoot weight from the experiment with a range of 0.97g (CO) and 5.68gg (BP). (Table 3) The values were significantly different from one another at P<0.05, Also, the varieties of tomato exhibited significant variation in their dry shoot values. UC-82B recorded the highest value (3.4g) followed by LF-1 (3.32g) while the least was AKL (3.03g). Black polythene and UC-82B recorded the highest dry shoot weight of tomato. Table 1 shows that BP recorded the highest mean value in dry shoot weight of tomato (2.34g) while the least values obtained from other (mulching materials), were significantly different other at (P<0.05). Among the varieties, UC variety recorded the highest mean value in dry shoot weight (1.62g) and AKL had the least value (1.42g). The value obtained under BP for both LF-1 and AKL were not significantly different at P<0.05, the UC variety was best combination amongst other treatments combinations. The results showed that fresh shoot weight of tomato varieties of was significantly influenced by mulching materials. The highest fresh shoot weight was obtained under BP mulch (7.05g) and TP recorded the next value (5.86g) while the least value was obtained from control treatment (1.97g) Also, the values of fresh shoot weight of varieties were significantly different from each other at P<0.05. UC-82B variety recorded the highest value (4.94g) and AKL variety had the least (4.41g). Black polythene mulching materials recorded the highest value of fresh root weight compared with (3.05g), TP (2.37g), PR (1.74g), PA materials (1.55g) while the least was obtained for unmulched (0.57g). Among the three varieties of tomato, UC had the highest value of 3.86g under the BP materials and the least was recorded from CO (2.44g).

Table 3. Effects of variety, mulch material and interactions on soil, growth and yield variables of tomato at harvest.

Treatments	Root dry weight (g)	Shoot dry weight (dry)	Number of leaves	leaf area (cm²)	No fruits/Plant	Fruit weight/Plant (g)	Soil moisture (%)	Soil temp (°C)	Plant height (cm)
Varieties									
Lindo F1	1.71	4.09	25.59	28.90	13.96	274.12	14.6	33.70	30.56
UC-82B	1.83	4.18	19.35	20.65	4.88	191.72	13.8	34.00	28.46
Akure local	1.58	3.72	20.17	22.43	5.88	140.16	12.9	32.91	26.55
LSD (0.05)	0.36	0.48	3.37	4.22	5.36	17.82	0.88	1.24	2.61
Mulches									
Control	0.78	1.94	13.55	16.15	6.00	215.87	16.7	35.4	19.24
Black polythene	2.70	6.10	22.69	33.34	6.53	126.87	15.8	35.39	40.76

Treatments	Root dry weight (g)	Shoot dry weight (dry)	Number of leaves	leaf area (cm²)	No fruits/Plant	Fruit weight/Plant (g)	Soil moisture (%)	Soil temp (°C)	Plant height (cm)
Trans polythene	2.15	5.26	23.6	31.16	5.33	158.73	14.9	36.13	36.15
Paper	1.51	3.31	20.09	23.43	6.93	248.80	13.8	32.6	26.22
Plant residue	1.63	3.73	25.57	20.88	8.53	326.40	10.4	30.4	29.83
LSD (0.05)	1.11	1.33	3.47	4.26	1.24	21.43	2.51	3.46	5.15
Interactions									
Variety (var)	x	x	x	x	x	x	x	ns	x
Mulch (mh)	x	x	x	x	x	x	x	ns	x
Var * Mul.	x	x	x	x	x	x	x	ns	x

Note: Ns (non sigificant at P < 0.05); x (siginificant at P < 0.05).

3.8. Treatment Effects on Tomato Yields

The mulching materials had varied effects on yields of tomato varieties evaluated.The unmulched ground recorded the least values of number of leaves, while the highest number of leaves was recorded under paper mulch (Table 3). However, treatment differences were not significant. There were no significant differences among the tomato varieties. The number of fruits of tomato varieties was significantly influenced by mulching materials. The highest value was obtained under plant residue mulching material for Lindo F1 followed by paper mulch while the least number of fruits was obtained from variety UC-82B.

3.9. Proximate Composition and Some Biochemical Constituents of Fruits of Tomato Varieties

The effects of variety on the proximate composition and some biochemical constituents of tomato fruits are presented on Table 4a. The results showed that Akure Local had higher contents of crude fibre and crude protein as well as vitamin C. The content of crude fat and water were highest for LindoF1, closely followed by UC-82B. The bioactive phytochemical components of the fruits of tomato varieties differed (Table 4b). Fruits of Akure Local variety of tomato had highest constituents of Phenol, FRAP, flavonoid and lycopene. Lindo F1 variety had highest fruits contents of DPPH while variety ABTS were close for all varieties.

Table 4a. Proximate composition of fruits of tomato varieties.

Varieties	MC (%)	CF (%)	CP (%)	ASH (%)	C.FAT (%)	CHO (%)	Vit C mg/100g
Lindo-F1	77.02	1.14	7.63	0.83	10.06	3.74	6.59
UC-82B	76.12	0.98	6.23	1.91	9.82	5.14	6.19
Ak.LOCAL	74.24	2.63	10.62	1.62	6.53	4.58	8.68
LSD (0.05)	2.37	1.02	1.88	0.66	2.22	1.33	1.56

Note: MC (moisture content), CF (crude fibre), CP (crude protein), C Fat (crude fat) , CHO (carbohydrate), Vit C (Vitamin C).

Table 4b. Bioactive components of fruits of tomato varieties.

Phytochemicals	Values		Means
FRAP mg/ml Lindo-F1	3.83498	3.896	3.865
UC-82B	3.873	3.725	3.799
Akure local	3.914	3.971	3.945
PHENOL mg/ml			
Lindo-F1	1.787	1.739	1.763
UC-82B	1.755	1.708	1.734
AKURE LOCAL	2.352	2.327	2.337
FLAVONOID mg/ml			
Lindo-F1	0.0062	0.006	0.0061
UC-82B	0.0097	0.008	0.0092
Akure local	0.0169	0.015	0.0153
LYCOPENE mg/100g			

Phytochemicals	Values		Means
Lindo-F1	0.0617	0.0587	0.0603
UC-82B	0.1068	0.109	0.1084
Akure local	0.1188	0.122	0.1204
DPPH %			
Lindo-F1	87.315	88.283	87.799
UC-82B	81.966	84.104	83.037
Akure local	71.779	77.483	74.656
ABTS mMol/g			
Lindo-F1	0.026345	0.026345	0.026192
UC-82B	0.026306	0.026078	0.026192
AKURE LOCAL	0.026002	0.026002	0.026002

Note: FRAP 2,2 diephl-1-prcrylhydrazyl, MC (moisture content), DPPH 2,2-Azino-bis-3-ethylbenzothiazoline-6-sulfonic Acid ABTS, CP (crude protein), CHO (carbohydrate), CF (crude fibre), C FAT (crude fat).

4. DISCUSSION

Mulching is an important management practice for improving productivity of horticultural crops The practice of mulching is widely adopted in horticulture and has proven to significantly improve the growing conditions and yields of crops [21, 23]. The mulching materials affected soil temperature differently during tomato growth. Polythene sheet covering of soil surface produced higher soil temperature compared with organic (paper and plant residue). Black polythene cover produced highest soil temperature followed by transparent, and paper and plant residue mulch. Soil temperatures were most times lower ($P<0.05$) under mulched treatments compared with the unmulched.Soil temperature at 10 cm depth was consitently higher under plastic film mulch cover compared with organic mulches. The thermal characteristics of mulching materials affects absorption of incident solar radiation with consequences on soil temperature under mulch [16].

Mulching produced significant effects on soil moisture content and temperature Among the mulch materials, plant residue mulch was best at soil moisture conservation while the polythene sheet covers (black and transparent) produced lower soil moisture contents. The unmulched plots produced lowest soil moisture contents. The time course of average soil water content (SWC) at depths (0–10 cm, 10–20 cm, 20–40 cm, 40–60 cm) differed under the mulch treatments The average soil water contents were highest at 25 and 40 cm rootzone depth The mulched plots had higher moisture contents compared with unmulched, organic mulches (plant residue and paper) conserved more moisture in the soil during the early (vegetative) growth of tomato. Soil moisture conservation effects of mulching is attributable to mulcing-enhanced water infiltration and storage in the soil in addition to improved soil structure and macro-porosity and reduces evaporation and runoff losses [8, 24, 42]. Mulching increased soil moisture in the root zone and modifies soil temperature, providing a stable environment for seedling growth, establishment and yield of crops compared to non-mulched soil [27, 43]. Research has shown that, although straw mulching maintains the soil water, its impact on soil temperature may be shortlived [16, 21]. The enhanced performance of mulched tomato may be attributed to the favorable environment created by mulching. Mulching is known for ability to improve soil hydrothermal conditions and provides favorable environment for plant growth, reduces insect and weed infestation [14, 44, 45]. Mulching promoted the growth of tomato. This observation can be related to ability of mulching to reduce soil water evaporation, this will resultantly conserve moisture in crop rootzone and promote transpiration and water and nutrient uptake [21]. Mulch application changes changing soil properties (moisture,temperature, nutrients, microbial activities) and such changes affect crop productivity [21].

Among the tomato varieties, vegetative growth of Lindo F-1 variety surpasses other varieties under mulch compare with unmulched.However, UC-82B under black polythene mulch produced more vigorous plants while the least performed variety was Akure local based on growth and yield variables measured. It appears that varietal response to mulch is genotype specific, the genetic constitution of tomato variety was responsible for adaptation and behaviour under different mulching materials [14, 18]. Also, it has been reported that mulches moderate crop root zone temperature and moisture and improved root development, biomass accumulation and yield of crops [6, 27]. Tomato varieties responded differently to mulching. Lindo F1 and UC grown under black polythene mulch produced best vegetative growth. Based on the phenological characteristics, Lindo F1 and UC (improved varieites) had better performance and similar responses to mulching. This can explain higher vigour of growth and yield compared with Akure Local variety. Tomato variety UC-82B had best improved leaf development while Lindo F1 was best for growth and fruit yield production closely followed by UC-82B. However, Akure local had highest values of proximate and biochemical attributes measured compared with the improved varieties (UC-82B and Lindo F1).

Based on weight of fruit harvested, the best varieties were lindo F1 and UC-82B with indeterminate growth habit. These varieties did not attain senescence early unlike the Akure local variety that had determinate growth habit. The better vigour of growth of Lindo F1 and UC-82B might have stemmed from the fact that they are are hybrids. Mulching improved the growth variable of tomato across the varieties evaluated.. Tomato variety UC-82B had best improved leaf development while Lindo F1 was best for growth and fruit yield production closely followed by UC-82B. However, Akure local had highest values of proximate and biochemical attributes measured compared with the improved varieties (UC-82B and Lindo F1). Generally, literature reports affirmed that polythene sheet mulches have the potential to retain soil moisture, reduce weed interference for enhanced crop growth [46, 47]. However, transparent polythene mulch had higher temperatures which could be responsible for lower performance of tomato compared with black film mulch. The mulch materials produced favorable conditions in tomato rootzone for enhanced growth and yield of tomato . The positive effects of mulching using organic and inorganic materials for soil covering on vegetable crops such as tomato, pepper, eggplant, cucmber and okra have been documented [6, 14, 17, 18, 22, 23]. Mulching establishes a linkage between soil and atmosphere thus modifying crop-growing environment [21, 32]. Such relationships determine soil water and heat transfer mechanism under mulching is important to water availability and efficiency of its usage [27, 28]. Mulching materials differed in colour, such differences may stem from the magnitude of energy recieved and light regimes around plants. Such impacts may be positive on on crop photosynthesis, dry matter accretion for yield production [15].

Mulching prolonge soil water availability which would have enhanced nutrient absorption by tomato with positive consequences on its growth on mulched soil compared with the unmulched (bare) soil. Similar observation has been reported on crops such as watermelon, tomato and okra. Parmar, et al. [48]; De Silva and Godawatte [49]; Tegen, et al. [50]; Singh, et al. [51], Ajibola and Amujoyegbe [18] and Choudhary, et al. [14] reported that soil moisture and vegetative growth of cucumber was significantly influenced by application of mulching. Similarly, the use of mulching materials such as polythene and biodegradable substances for conservation of soil moisture and increase tomato yields [23, 47].

The efficiency of organic mulches (plant residue and paper) for soil moisture conservation and temperature regulation was short lived compared with plastic film mulches. During the early growth phases of tomato (transplanting to flowering), plant residue and paper mulches conserved higher moisture in the soil compared with plastic film mulch materials. Plant residue and paper mulches would have increased nutrient contents in the soil following its decomposition. Increased nutirents in the soil would have increased The improved performance of tomato aside from the hydrothermal benefits of mulching could have stemmed from organic mulches-enhanced soil fertility status Mulching enhanced soil nutrient status and such effect vary depending on the type of mulch, soil chemistry, and the specific nutrients of interest [19]. Studies have reported the effects of plant residue (straw return) mulch on performance of staple crops such as corn, soybean, rice, and wheat [4].

Effect of mulching materials on yield and yield components of tomato.Result of this study showed that yield and yield components of tomato were enchanced by mulching. This osbervation can be attributed to mulch enhanced rootzone environment [14, 47]. Although black polythene can conserve more heat energy (high soil temperatures), it appeared to have retained enough moisture contents in the soil for tomato use. Ajibola and Amujoyegbe [18] reported that soil moisture and vegetative growth of cucumber was significantly influenced by application of mulching. Similarly, the use of mulching materials such as polythene and biodegradable substances for conservation of soil moisture and increase tomato yields [9, 47].

The mulches exerted different effects with respect to fruit yield and yield components of tomato. Tomato grown on black polythene mulched plot had better vigour of growth and higher yields followed by transparent film mulch. Although black polythene can conserve more heat energy (high soil temperatures), it appeared to have retained enough moisture contents in the soil for tomato use. The efficiency of organic mulches (plant residue and paper) for soil moisture conservation and temperature regulation was short lived compared with plastic film mulches [52]. During the early growth phases of tomato (transplanting to flowering), plant residue and paper mulches conserved higher moisture in the soil compared with plastic film mulch materials. Plant residue and paper mulches would have increased nutrient contents in the soil following its decomposition. Increased nutirents in the soil would have increased tomato performance.

Tomato is widely cultivated in the agroecologies and seaosns in Nigeria, and despite its widespread cultivation, the average yield is low due to inadequate adoption of improved agrotechnologies and production methods. Improved tomato performance on mulched plots can be attributed to mulch effects on soil conservation (moisture, evaporation, temperature regulation) and improved soil phyical and fertility status Under the high-temperature conditions of the late season in the study area, plastic mulch-enhanced soil temperatures (energy conserving) may become injurious to growth of crops such as tomato [52] . The organic mulches produced averagely, lower soil temperatures and acted as insulators for cooling temperatures within crop rootzone but increased water and possibly nutrient status of soil Following decomposition, organic mulches decompose, humus is supplied to the soil, increasing its water-holding ability [14, 17]. The optimum temperature for tomato is about 29.3 °C while the maximum is around 34 °C [52]. Mulch ameliorated the hydrothermal regime of the soil, improved vegetative growth and yield variables of tomato comapred with bare ground. Thermal stress limit root development, water and nutrient uptake and transpiration [10, 51]. Such limitations may expalin the low performance of tomato from the unmulched plot. Thermal stress in crop rootzone may affect ater and nutreint uptake and root growth due to involve decreases in shoot carbon provided to roots or changes in root water relations driven by increased shoot water demand, which then affect root growth and nutrient uptake [33, 52]. In this study, mulching confer multiple benefits especially on soil conservation growth and yield of tomato. These benefits may be attributed to modification of hydrothermal conditions, rainfall infiltration, within crop rootzone, improved soil physical and fertility status, and reduce evaporation [5, 26]. These benefits have been reported in the literature: The efficacy of mulch and potentials for improving soil condiiton and crop performance are affected by characteristics of mulch material, duration of soil cover, agroecologies and seasons of sowing [3, 12, 13, 26-30, 32]. Previous studies have showed the ability of organic (plant residue, paper) and inorganic (transparent plastic film) to conserve soil moisture, improve soil temperature, accelerate crop growth, and enhance yield and water use efficiency [5, 11, 53-55].

5. CONCLUSIONS

Mulching of soil surface with various materials (plant residue/straw, paper, transparent and black polyethylene sheets), conserved moisture contents with diffrent effects on soil temperatures. Mulching promoted growth and yield varaiables of tomato. Plant residue and paper mulch were best for soil moisture conservation and soil temperature reduction. Tomato varieties differed in responses to mulching and growth, yield and quality: the variety UC-82B had best improved leaf development while Lindo F1 enhanced growth as well as yield, these varieties (Lindo F1 and UC-82B) outyielded Akure Local variety. However, Akure local had highest values of proximate and biochemical attributes measured compared with improved varieties (Lindo F1 and UC-82B). Although, plants residue mulch best promoted growth and yield of tomato and moisture conservation., plastic film mulch improved soil moisture contents compared with polythene film mulches Tomato variety Lindo F1 produced heaviest fruits while plant residue mulch are recommended for late season production in the study area. Although black polythene can store more of heat energy (high soil temperatures), it appeared to have retained moisture longer in the soil for tomato use. This study established the relevance of mulching and benefits for soil moisture conservation, amelioration of heat stress (high soil temperatures) , growth and yield enhancement of tomato.

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