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The Effect of Planting Dates and Mulch Materials on Soil Moisture Content and Temperature on Late Season Banana Productivity in Owerri Southeastern Nigeria

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Abstract- The effect of planting dates, mulch materials, soil moisture content and soil temperature on late season banana productivity was conducted in Owerri Southeastern Nigeria, in the Teaching and Research farm of the School of Agriculture and Agricultural Technology, Federal University of Technology Owerri. The study was laid out in a split plot design where the whole or main plots (Factor A) comprised of three planting dates: September, October and November and the sub-plot treatments (Factor B) comprised of six mulch types namely: blackpolyethene, woodshavings, sawdust, palmbunch refuse, trash and the unmulched plots which served as control plots. The three main plot treatments were randomized within each block whereas the sub-plot treatments were randomized within each whole or main plot. The results revealed that mulching significantly improved soil moisture conservation, soil temperature moderation, days to 50 % flowering and in yield parameters at harvest of plant crop and in first ratoon crop in late season banana production. Also planting date significantly influenced soil temperature moderation, days to 50 % flowering at harvest of plant crop and in yield parameters at harvest of plant crop and in first ratoon crop. Bananas mulched with blackpolyethene recorded the highest soil moisture conservation and moderated soil temperature most. Bananas in plots planted in September and mulched with palm bunch refuse recorded the earliest days to 50 % flowering in the plant crop (268.90 days), while the bananas planted in September and mulched with sawdust matured earliest (263.50 days) in the first ratoon production. Plant crops had higher yield than the first ratoon banana production. In plant crop production, the bananas planted in September and mulched with palm bunch refuse produced the heaviest bunch (9.97tha-1), number of hands per bunch (8.67), number of fingers per bunch (95.67), the heaviest individual finger (94.67g/ finger), while the bananas planted in September and mulched with sawdust produced the longest and largest individual fingers (12.07 cm) and (11.27 cm) at the harvest of plant crop, while the bananas planted in September and treated with sawdust produced the heaviest bunches (7.23tha-1), highest number of hands per bunch (6.67), total number of fingers per bunch (74.00), heaviest finger (40.43 g/ finger), longest finger (7.90 cm) and largest finger (5.90 cm) at harvest of the first ratoon crop. Banana plots planted in September and mulched with woodshavings recorded the highest yield (15.37tha-1) in the total yield obtained at the harvest of plant crop and in the first ratoon crop.

I. INTRODUCTION

Moisture and temperature remain the most critical abiotic factors for crop production in the tropics (Eruola, Bello, Ufoegbune, Mankinde, 2012). Banana is one of the most important staple food crops for both rural and urban populations in Nigeria, and it is predominantly grown by smallholder farmers (Olumba & Onunka, 2020). It is grown for both home consumption and the national market. It has the potential of contributing to food and nutritional security, as well as a source of income for smallholder farmers. Soil temperature is a physical parameter that plays a major role in ensuring crop productivity and sustainability (Jegadeeswari, Dheebakaran, Meena, Panchulakshmi, & Kokilavani, 2025) especially during photosynthesis as it has indirect relationship by regulating root metabolism, water uptake and nutrient availability. It controls the rate of decomposition of soil organic matter which is the critical factor in maintaining global carbon and nitrogen balance (Dutta & Dutta, 2016). The main source of soil temperature is solar radiation. Inadequate soil temperature leads to retarded maturity and undergoes spatiotemporal changes during growing season (Onwuka & Mang, 2018). when soil temperature increases, it results to decrease in organic matter, which leads to a decrease in the cation exchange capacity of the soil (Onwuka & Mang, 2018) causing structural degradation and significant lower crop yield while increase in soil temperature ranges from 25oC to 39oC leads to increased soil pH level (Menzies & Gillman, 2003) which restricts nutrient absorption leading to nutrient lockup, stunted growth and specific deficiencies such as iron chlorosis. At increase soil temperature of 5 oC- 25 oC, phosphorous level of the soil also increase, while soils with low temperature have low availability of phosphate. Increase in soil temperature leads to decrease in soil moisture content and increase in soil aeration (Onwuka & Mang, 2018). One of the strongest indicators of dry season in agriculture is reduced soil water availability (Martínez-Fernández, González-Zamora, Sánchez & Gumuzzio, 2015). Soil moisture management is one of the most important issues, accounting for a major part of the investment in banana enterprises. The global temperature has been increasing over the years due to recurrent climate change and variability, which directly or indirectly affects the agriculture sector. This has made it necessary for the farmers to get the best out of the little rainfall. Banana (Musa sp.) is an important tropical crop that can tolerate short period of water deficit (Surendar, Devi, Ravi, Jeyakumar &Velayudham, 2013), making, its productivity to be greatly affected. Mulches can reduce the irrigation requirement of crop plants, and sometimes, completely compensate the need of irrigation (Kader et al., 2019; Iqbal et al., 2019; Ahmad et al., 2020). Organic mulch provides numerous benefits to the soil ranging from soil temperature amelioration, increased soil life, infilterability, nutrient and water retention in the soil (Salau et al., 2003; Clatterbuck, 2010; Alagba et al., 2017; Shiyam et al., 2010). Including good carbon availability significantly influence soil temperature management in addition to moisture conservation (Kader et al., 2019). Plastic mulches are particularly effective at preventing evaporation and reducing irrigation needs. The black plastic mulch raises soil temperatures more effectively than bare soil (Rajablariani et al., 2012), and it transmits absorbed heat to the soil (Steinmetz et al., 2016) and it raises soil temperatures by 3-6°C compared to bare soil (Rajablariani et al., 2012). Mulch materials limit weed growth and regulate seedling emergence by covering the soil surface (Khan et al., 2022; Kaur et al., 2024). Sharma et al., (2010) observed that mulching is very beneficial for enhancing moisture and nutrient conservation, resulting in increased productivity and improved soil conditions for a sustainable cropping system.

II. MATERIALS AND METHODS

The experiment was conducted in the Crop Science and Technology Teaching and Research farm of the School of Agriculture and Agricultural Technology, Federal University of Technology Owerri, located 5o20 N -5o27 N and longitude 7o02E- 7o07E at an elevation of 55m above sea level in the rainforest zone of southern Nigeria (Onweremadu & Peter, 2016). The area has a bimodal rainfall pattern with peaks in July and September, a minimum and maximum annual temperature of 20oC and 32oC respectively, mean annual rainfall of 2316mm and relative humidity of 85 -89 % (Adegun & Balogun, 2015).The soils are deep, porous and derived from sand deposits of the coastal plains which are highly weathered, low in mineral reserve and natural fertility (Onweremadu et al., 2007; Ononiwu, 1990). Soil samples were collected from the field of the experiment at 0-30 cm depth randomly using soil auger after clearing the experimental site for soil physico- chemical characterization. The collected soil samples were air dried in the laboratory, ground and sieve using sieved pan of 2mm and were analyzed for physico-chemical properties as described in (Ojo et al., 2015).

Experimental Design

Allocation of various treatments were done using Gomez and Gomez (1984), Table of random numbers. A split plot design was used in this study where the whole plot or main plot comprised of the three planting dates, September 1, October 1 and November 1, while the sub-plot treatment comprised of six mulch types namely: blackpolyethene, woodshavings, sawdust, palmbunch refuse, trash and the unmulched plots (control plots). The three whole treatments were randomized within each block whereas the sub-plot treatments were randomized within each whole plot. The experimental plot contains four (4) stands per plot that is seventy-two (72) stands of banana suckers per replication and a total of 216 stands of banana suckers.

Land preparation and planting

The experimental site which was a one-year fallow farm was mapped out using measuring tapes, ranging poles, pegs, ropes and was later cleared manually, stumped and packed with the aid of machetes, hoes, spades and axes. The size of experimental plot used was 60 x 30 meters (1800m2) with 1m alley at the boundaries of the experimented plot. Holes with depth of 60 x 60x 60cm were dug, separating the topsoil from subsoil according to Borah, Hazarika, Langthasa, & Duarah (2018). Uniform sword suckers of one meter (1m) high were planted at the planting spaces of 3.0 x 2.0 meters on the first day (1st) of each of the months of September, October and December (2021). The suckers were sourced from a healthy banana plantation from FUTO Plantain Research farm. The suckers were allowed to dry under shade overnight before planting. Each sword sucker was put in each hole and was covered with top soil first and firmed and, then covered with the subsoil.

Poultry manure application:
The cured poultry manure was procured from the Livestock Farm of the Federal University of Technology Owerri. It was weighed using a weighing balance (50Kg Salter Scale) and was applied at the rate of 10 tha-1 in one doze. Each banana plant received a total of 6kg of poultry manure which was incorporated in each depth and was spread in a circumference around the base of the pseudostem after covering the pseudo stem with topsoil that was dug out from the planting holes. The manure was spread in such a way that it covered the base of the planting hole.

Mulching:
After planting the sucker, 4 tha-1(2kg) of each mulch material apart from the black polythene was weighed out on the weighing balance of 50Kg salter scale and was spread around each depth of banana holes planted. The mulch was spread around the base of the banana pseudo stem above the poultry manure layer. The back polyethene was carefully perforated and was spread at the base of the banana sucker above the poultry manure layer. The control plot received the same quantity of manure but was not mulched.

Data collection
Soil moisture content
The moisture content in each core sample was determined by gravimetric method. This was done by taken the fresh weight of 10g of representative soil samples from each core sample which was collected 20cm away from the plants and up to a depth of 30 cm. This depth is expected to be the primary zone for root growth and, therefore, the most appropriate place to measure soil water content (Araya & Blanco, 2001). The collected soils were put in a sealed-off plastic bag to minimize evaporation. The soil samples were dried in the oven 48hours and the dry weight was determined by using the electronic scale. The percentage moisture content was determined using the formula as follows:

$$\% \text{ moisture content} = \frac{\text{fresh weight-dry weight}}{\text{Fresh weight}} \times \frac{100}{1}$$

Soil temperature determination
Soil thermometer was used to determine the soil temperature at each planting hole. The soil thermometers were inserted at the depth in each planting hole for 5minutes at 13:00 hours of the afternoon when the sun was very high and soil temperatures were monitored and recorded.

Days to 50% flowering
The number of days to 50 % flowering in each plot was determined by counting the number of days taken for 50 % of sample plants to flower (shoot) in each plot and dividing it by the number of the 50 % of sample plants in the plots

Harvest of banana
The banana bunches were harvested when they were fully matured in each plot and were weighed with 50 kg salter scale. The bunch weight was converted to tons per hectare, while the number of hands and fingers were determined by taking physical count of the hands in each bunch and fingers in each hand. The values were averaged per plot for plant and first ratoon crops.

III. RESULTS

The effect of planting dates, mulch materials and their interaction on the soil moisture content (%) at 0 - 30cm soil depth under late season banana planting at 1-5 MAP is shown in Table 2a and 2b. Soil moisture content (%) was significantly (P<0.05) influenced by mulch materials, while planting dates and the interaction of planting dates and mulch materials had no significant effect on soil moisture content (%) at 1-3 MAP. At 1MAP, the least percentage soil moisture content was recorded in the bananas planted in November control plots (9.63 %), while the highest percentage soil moisture content was obtained from the banana plots planted in October and mulched with blackpolyethene (12.15%), closely followed by those in plots planted in September and that received the same mulch

(12.13%). At 2MAP, results indicated that banana plots established in September and mulched with blackpolyethene significantly (P<0.05) conserved the highest soil moisture (11.85 %), while the least percentage soil moisture was conserved in the control plots established in November (8.30 %). At 3 MAP, the highest percentage soil moisture was obtained in the banana plots established in September and mulched with blackpolyethene (10.84 %), this was closely followed by those in plots planted in October a with the same mulch (9.89 %), while the least percentage soil moisture content (%) was recorded in unmulched plots, established in November (7.58%).

Table 1a Effects of planting dates and mulch materials on (%) soil moisture content under late season banana at 1, 2 and 3 MAP

	Planting				dates							
Mulch materials / Planting dates	Sept 1	Oct 1	Nov1	Mean	Sept 1	Oct 1	Nov1	Mean	Sept1	Oct1	Nov 1	Mean
		1MAP			2MAP						3MAP	
Mulch materials												
Blackpolyethene	12.13	12.15	12.02	12.10	11.85	11.19	10.55	11.17	10.84	9.89	9.88	10.13
Woodshavings	11.48	11.29	11.09	11.29	10.18	10.00	9.82	10.03	8.58	8.49	8.37	8.47
Palm bunch refuse	11.47	10.92	10.65	11.01	10.53	9.49	9.23	9.61	9.05	8.74	8.51	8.77
Sawdust	11.58	11.29	10.88	11.11	10.28	10.19	9.52	9.99	9.45	8.61	8.55	8.87
Trash	10.90	10.55	10.38	10.60	9.58	9.38	9.12	9.36	8.40	8.06	7.86	8.11
No mulch	10.55	9.70	9.63	9.91	8.65	8.54	8.30	8.48	8.18	8.05	7.58	7.98
Mean	11.32	10.98	10.74	11.01	10.13	9.78	9.42	9.78	9.07	8.65	8.42	8.71
LSD (0.05), planting dates				0.44(ns)				0.62(ns)				0.69(ns)
LSD (0.05) Mulch materials				0.59				0.59				0.56
LSD (0.05) Mulch x Planting dates				0.99(ns)				1.09(ns)				1.02 (ns)

MAP – Months after planting
% - percentage

The table 1b highlighted the effects of planting dates, mulch materials and their interactions on percentage soil moisture content under late season banana at 4 and 5 MAP. Planting dates had no significant effect on percentage (%) soil moisture content. However, mulch materials and their interactions with planting dates and mulch materials had a highly significant (P<0.05) effect on percentage soil moisture content. At 4MAP, we had the least soil moisture content conserved from the unmulched plots of the bananas established in October (6.70 %), while the highest % soil moisture content was conserved in the bananas in plots planted in November and mulched with black polyethene (10.14 %). At 5 MAP, banana plots established in November and mulched with black polyethene conserved the highest % soil moisture content (11.32 %), followed by the banana plots planted in October and mulched with the same blackpolyethene (10.17 %). The least soil moisture content was obtained in the control plots of banana planted in September (6.92 %) at 5 MAP.

Table 1b Effect of planting dates and mulch materials on soil moisture content (%) under late season banana at 4 and 5 MAP

	planting				dates			
Mulch materials	Sept 1	Oct 1	Nov 1	Mean	Sept 1	Oct 1	Nov 1	Mean
	4MAP						5 MAP	
Mulch materials								
Blackpolyethene	9.18	9.18	10.14	9.49	9.31	10.17	11.32	10.30
Woodshavings	7.77	7.48	8.14	7.79	7.34	9.60	10.00	8.98
Palm bunch refuse	8.07	7.21	8.12	7.80	7.45	8.15	8.30	7.97
Sawdust	7.92	7.79	8.04	7.92	8.14	8.10	9.35	8.53
Trash	8.04	6.74	7.86	7.55	7.30	7.30	9.20	7.93
No mulch	7.64	6.70	7.00	7.11	6.92	7.07	8.12	7.37
Mean	8.10	7.51	8.22	7.94	7.74	8.40	9.38	8.51
LSD (0.05) Planting dates			0.67(ns)					0.58(ns)
LSD (0.05) Mulch materials			0.43					0.36
LSD (0.05) Mulch x planting dates			0.85					0.71

Soil temperature (oC)

The effect of planting dates, mulch materials and their interactions on soil temperature under late season banana at 1-3 months after planting (MAP) (October – December 2021) is presented in Table 2a. Planting dates and mulch materials significantly (P<0.05) influenced the soil temperature at one month after planting, while the interaction of planting dates and mulch materials had no significant effect on the soil temperature (oC) under late season banana. Bananas in the control plots established in November recorded the highest soil temperature (32.47oC), closely followed by bananas in plots established in the same month and treated with trash (32.03oC). The lowest soil temperature was recorded in the banana plots planted in September and mulched with black polyethene (25.53 oC).

At 2 MAP, planting dates and the interaction of planting dates and mulch materials had no significant effect on the soil temperature (oC). However, mulch materials significantly (P<0.05) influenced the soil temperature under late season bananas. Bananas established in the control plots in November recorded the highest soil temperature (33.27oC), closely followed by those in plots planted in October unmulched plots (33.13oC), the lowest soil

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temperature was recorded in the banana plots established in September and mulched with black polyethene (31.20 oC).

Planting dates and the interaction of planting dates and mulch materials significantly (P<0.05) improved the soil temperature at 3 MAP. The lowest soil temperature was recorded in the banana plots established in September and mulched with woodshavings (32.53 oC) while the highest soil temperature was recorded in the banana plots planted in control plot of November (34.70 oC), followed by those bananas planted in same month and mulched with trash (34.40 oC). Soil temperature was not significantly influenced by mulch materials at 3 MAP.

Table 4.22a Effects of planting dates and mulch materials on soil temperature (oC) under late season banana at 1, 2 and 3 MAP

	Planting				Dates							
Mulch materials	Sept1	Oct1	Nov1	Mean	Sept1	Oct1	Nov1	Mean	Sept1	Oct1	Nov1	Mean
Months after planting	[illegible]MAP					[illegible]MAP				at Harvest		
Blackpolyethene	25.53	28.67	31.83	28.71	31.30	31.80	31.83	21.54	31.88	30.10	31.93	31.31
Woodshavings	26.17	28.50	30.50	28.39	31.40	31.47	32.40	31.76	31.53	30.63	34.28	31.44
Palm bunch refuse	26.40	29.47	30.07	28.65	31.90	31.20	32.50	32.12	31.18	32.50	34.18	31.57
Sawdust	27.00	28.87	30.87	28.84	32.03	31.03	31.40	32.15	31.08	33.03	34.08	31.54
Trash	27.67	31.31	32.03	30.01	32.17	32.81	32.97	32.66	31.50	33.03	34.40	31.77
No mulch	27.07	31.43	32.47	30.28	32.60	33.33	33.27	33.03	31.40	34.13	34.70	34.00
Mean	26.77	29.36	31.31	29.14	31.88	32.21	32.04	32.22	31.32	33.01	34.21	31.62
LSD (0.05) Planting dates				1.19				0.54(ns)				0.41
LSD (0.05) Mulch materials				0.7				0.83				0.57(ns)
LSD (0.05) Mulch x planting dates				1.47(ns)				1.37(ns)				0.96

At 4 MAP (Table 2b), there was no significant difference with respect to planting dates, mulch materials and in their interaction on soil temperature under late season banana. However, at 5 MAP, soil temperature under late season banana was significantly (P < 0.05) influenced by planting dates only. The highest soil temperature was recorded in bananas planted in the control plots of September (36.37 oC), followed by those in plots planted in the same month but mulched with black polyethene (35.90 oC). The lowest soil temperature was recorded in the banana plots planted in November and mulched with palm bunch refuse (31.83 oC).

Table 2b Effects of planting dates and mulch materials on soil temperature (oC) on late season banana at 4 and 5 MAP

	Planting	dates						
Mulch materials	Sept1	Oct1	Nov1	Mean	Sept1	Oct1	Nov1	Mean
		4MAP					5MAP	
Months after planting								
Blackpolyethene	35.43	33.30	34.94	34.56	35.90	33.97	32.09	33.99
Woodshavings	34.30	33.15	34.67	34.11	34.57	34.30	32.56	33.74
Palm bunch refuse	35.07	32.58	35.07	34.10	33.17	34.11	31.83	33.70
Sawdust	34.57	23.13	34.60	30.77	34.63	33.74	32.35	33.37
Trash	34.87	33.47	34.93	34.42	35.00	34.20	32.51	33.90
No mulch	33.70	35.50	34.98	34.73	36.37	34.23	32.83	34.47
Mean	35.02	31.48	34.88	33.79	35.27	34.08	32.36	33.90
LSD (0.05) Planting dates			3.44(ns)					0.82
LSD (0.05) Mulch materials			3.00(ns)					0.74(ns)
LSD (0.05) Mulch x planting dates			6.58(ns)					1.29(ns)

Days to 50 % flowering at the harvest of plant crop and in the first ratoon crop of late season banana.

The number of days to 50% flowering in the harvest of plant crop in the late season banana in (Table 3) indicated highly significant (P < 0.05) influence of planting dates, mulch materials (P < 0.05) and in their interactions (P< 0.05). The highest days to 50% flowering was recorded in the bananas planted in the unmulched plots of November (314.20 days), followed by those planted in the control plots of October (304.27 days), while the least record of the of days to 50 % flowering was obtained from the bananas in plots planted in September and mulched with palm bunch refuse (268.90 days), while in the days to 50 % flowering of the harvest of the first ratoon of late season banana (Table 3), only the application of mulches significantly (P < 0.05) influenced days to 50 % flowering. The bananas planted in the control plots established in October flowered latest (309.30 days), while the closest days to 50 % flowering was obtained from the bananas in plots planted in September and mulched with sawdust flowered earliest (263.50 days), followed by those in plots planted in September and mulched with trash (272.20 days).

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Table 3: Days to 50 % flowering at the harvest of plant crop and in the first ratoon crop of late season banana.

Harvest period	Plant Crop				First ratoon crop			
Planting dates	Sept1	Oct1	Nov1	Mean	Sept1	Oct1	Nov1	Mean
Mulch materials								
Blackpolyethene	283.07	284.27	290.80	286.05	277.30	280.90	285.30	281.2
Woodshavings	279.90	282.70	283.70	283.90	272.20	284.20	286.20	280.9
Palm bunch refuse	268.90	271.60	280.87	273.79	274.70	275.70	277.90	281.2
Sawdust	270.60	277.73	279.23	277.85	263.50	273.60	275.70	270.9
Trash	282.47	284.57	292.07	286.37	295.60	298.60	304.00	299.4
No mulch	283.10	304.27	314.20	300.52	299.20	309.30	305.30	304.6
Mean	279.01	284.19	290.05	284.41	280.42	287.05	289.06	285.5
LSD (0.05) planting dates				2.52				7.16(ns)
LSD (0.05) Mulch materials				4.97				8.19
LSD (0.05) Mulch x planting dates				8.05				14.20(ns)

Results in table 4, highlighted the effect of planting dates, mulch materials and their interaction on bunch weight, number of hands per bunch and number of fingers per bunch in late season banana at harvest of plant crop of late season banana. From the results, there was a significant (P<0.05) effect of planting dates, mulch materials and their interactions on bunch weight while, planting dates and mulch materials significantly (P<0.05) improved the number of hands per bunch and number of fingers per hand in late season banana at harvest of plant crop. The interaction of planting dates and mulch materials showed no significant effect on the number of hands per bunch and number of fingers per hand. The heaviest bunch weight (t ha-1) was recorded in the banana plots planted in September and mulched with palm bunch refuse (9.97 t ha-1), this was followed by those planted in October and mulched with same palm bunch refuse mulch (9.53 tha-1). The least bunch weight (t ha-1) was obtained in the bananas in the control plots planted November (4.27t ha-1). Bananas planted in September and mulched with palm bunch refuse recorded the highest number of hands per bunch (8.67) at harvest of the late season banana in (Table 4), this was followed by those planted in September and mulched with sawdust (8.33). The least number of hands per bunch was recorded in the bananas in the control plots established in November (5.55).

The highest number of fingers per bunch was obtained from the bananas in plots planted in September and mulched with palm bunch refuse (95.67), this was followed by bananas in plots planted in same month and mulched with sawdust (88.00). The least total number of fingers per bunch was recorded in the bananas in the control plots planted in November (41.00).

Table 4: Effect of planting dates and mulch materials on bunch weight (t ha^{-1}), number of hands per bunch and number of fingers per bunch of the late season banana at harvest of the plant crop

Yield data	bunch weight (tha^{-1})				number of hands per bunch				total number of fingers per bunch			
Planting dates	Sept1	Oct1	Nov1	Mean	Sept1	Oct1	Nov1	Mean	Sept1	Oct1	Nov1	Mean
Mulch materials												
Blackpolyethene	8.07	5.93	5.37	6.46	7.33	7.00	6.67	7.00	84.33	84.33	78.67	82.44
Woodshavings	8.57	6.70	6.00	7.09	8.00	7.50	7.00	7.50	85.00	86.67	80.67	84.11
Palm bunch refuse	9.97	9.53	7.57	9.02	8.67	8.00	8.00	8.22	95.67	89.00	88.78	91.15
Sawdust	9.00	7.50	6.43	7.64	8.33	8.25	8.00	8.19	88.00	84.00	85.67	85.89
Trash	8.20	6.90	6.43	7.18	7.00	6.90	6.33	6.74	78.67	75.67	70.00	74.78
No mulch	6.53	5.20	4.27	5.33	6.33	5.67	5.55	5.85	51.33	41.67	41.00	44.67
Mean	8.39	6.96	6.01	7.12	7.61	7.22	6.83	7.25	80.50	78.89	74.13	77.17
LSD (0.05) Planting dates				0.33				0.78				3.20
LSD (0.05) Mulch materials				0.55				0.46				4.52
LSD (0.05) Mulch x planting dates				0.38				1.00(ns)				7.31(ns)

Yield data of the harvest of the first ratoon crop bunch weight (t ha-1), number of hands per bunch and total number of fingers per bunch at harvest of the first ratoon crops of late season banana.

The results in Table 5, indicate that the application of different mulch types significantly (P<0.05) improved all the parameters measured, while planting dates, significantly (P<0.05) favoured the bunch weight (t ha-1) and total number of fingers per bunch in first ratoon crops of late season banana. However the interaction of planting dates and mulch materials showed no significant difference in all the parameters measured in Table 5.

The heaviest yields of first ratoon late season banana bunches were obtained from the bananas in plots planted in September and mulched with sawdust (7.23 t ha-1), this was followed by those planted in the same month and treated with (6.80 t ha-1) woodshavings mulch, on the other hand, the least yields of first ratoon late season banana bunch was recorded from the control plot of November (2.10 t ha-1). The largest hands per bunch was obtained from the bananas in plots established in September and treated with sawdust (6.67),this was followed by those planted in September and October and treated with woodshavings and in those banana plots planted in October and mulched with sawdust (6.33), while the least number of hands per bunch was recorded from the bananas in plots planted in November and mulched with black polyethene and in the banana plots planted in the unmulched plots of November which respectively had (3.67).

Banana plots planted in September and mulched with sawdust recorded the highest total number of fingers per bunch (74.00), followed by those planted in October that received same mulch sawdust (69.33), while the least total number of fingers per bunch was obtained from the bananas planted in November and mulched with trash (42.00).

Table 5: Effects of planting dates and mulch materials on bunch weight (t ha-1), number of hands per bunch and total number of fingers per bunch in the first ratoon crops of the late season banana.

Yield Parameters	Bunch weight (t ha^{-1})				number of hands per bunch				total number of fingers per bunch			
Planting dates	Sept1	Oct1	Nov1	Means	Sept1	Oct1	Nov1	Means	Sept1	Oct1	Nov1	Means
Mulch materials												
Blackpolythene	4.57	4.23	3.80	4.20	5.00	4.67	3.67	4.44	45.00	48.33	48.67	49.22
Woodshavings	8.88	8.20	8.03	8.34	6.33	6.25	5.35	6.08	71.33	68.67	67.00	69.00
Palm bunch refuse	5.18	4.70	3.93	4.58	5.00	4.67	5.00	4.89	61.00	61.33	57.33	60.56
Sawdust	7.23	8.30	5.67	6.40	6.67	6.33	6.00	6.33	74.00	69.33	65.00	69.44
Trash	4.93	4.23	3.93	4.37	5.00	4.33	5.00	4.78	47.00	44.67	42.00	44.56
No mulch	3.33	3.03	2.10	2.82	4.33	4.00	3.67	4.00	45.00	45.67	43.33	44.67
Mean	5.33	4.78	4.24	4.79	5.39	5.06	4.78	5.07	58.58	56.67	53.56	56.24
LSD $_{(0.05)}$ Planting dates				0.40				0.48(ns)				2.68
LSD $_{(0.05)}$ Mulch materials				0.39				0.59				4.38
LSD $_{(0.05)}$ Mulch x planting dates				0.69(ns)				1.08(ns)				7.20(ns)

The total yield (t ha-1) at harvest of plant crops and first ratoon crop of the late season banana.

The total yield (t ha-1) of late season plant crop and first ratoon crop of banana (Table 6) indicated highly significant ($P<0.05$) effect of planting dates and mulch materials but the interaction of planting dates and mulch materials was not significant. The highest total yield of plant crop and first ratoon crop of banana was obtained in plots planted in September and mulched with woodshavings (15.37 t ha-1), followed by the bananas in plots planted in same month and treated with palm bunch refuse (15.07 t ha-1), while the lowest total crop yield was obtained in the control plot of November (6.37 t ha-1)

Table 6: Effects of planting dates and mulch materials on the total yield (t ha-1) at harvest of plant crops and first ratoon crop of the late season banana.

Yield parameters				
Planting dates	Sept1	Oct1	Nov1	Mean
Mulch materials				
Blackpolyethene	12.64	10.15	9.17	10.65
Woodshavings	15.37	12.83	12.03	13.41
Palm bunch refuse	15.07	14.23	11.47	13.59
Sawdust	12.89	13.77	12.10	12.92
Trash	13.13	11.33	8.27	10.84
No mulch	9.86	8.23	6.37	8.15
Mean	13.16	11.72	9.90	11.59
LSD $_{(0.05)}$ Planting dates				1.27
LSD $_{(0.05)}$ Mulch materials				1.31
LSD $_{(0.05)}$ Mulch materials x planting date				2.28(ns)

IV. DISCUSSION

Soil temperature (oC) and soil moisture content (%)
The significant effect of mulch materials across all the planting dates on the percentage moisture content of the soil may be attributed to the fact that mulch materials had high influence on soil moisture retention and in temperature conservation and moderation as reported by El-Beltagi et al. (2022). The unmulched plots recorded the least soil moisture content and the highest soil temperature across all the planting dates. This may be as a result of the fact that a bare soil quickly absorbs heat, becomes hot during the hot season and becomes cold during the cold season according to Onwuka (2016). Mulching acts as a thermal insulator and significantly affects the soil temperature according to Nwankwo and Ogugurue. (2012), however Jiménez et al. (2007) and Onwuka and Mang (2018) agreed that mulch materials do not allow soils to become either too hot during dry season or too cold during the rainy season. Pramanik et al. (2015) noted that less heat will flow into a mulched soil compared to a bare soil. The percentage soil moisture content was reduced as dry season progressed, (October, 2021 to February, 2022) while the soil temperature was increased with time and into drier season, until the onset of rainy season from March, 2022, and the conditions of the soil stabilized a little. It may be because the amount of radiation from the sun that a soil received and absorbed affected the variability of soil temperature according to Geiger et al. (2003) also reported that an increase in surface temperature will lead to a decrease in the soil moisture which invariably increase the soil temperature and vice versa.

Bananas in plots planted in November recorded the least percentage soil moisture content and the highest soil temperature in all the planting dates irrespective of the mulches used until the rain started in March 2022. This could be as a result of dryness associated with the time of planting as confirmed by Atubiga et al. (2025) that one of the strongest indicators of dry season in agriculture is reduced soil water availability. The bananas in plots mulched with blackpolyethene recorded the highest percentage soil moisture content while the bananas mulched with blackpolyethene and woodshavings moderated soil temperatures in all the planting dates during the day. This is in line with the report of Amare and Desta (2021) that black polyethene had significant impact in increasing soil heat by absorbing high amount of radiation, while Alagba et al. (2017), Kader et al. (2017), Zhang et al. (2017) and Demo and Bogale (2024) agreed that plastic mulch is completely impermeable to water and therefore prevents soil evaporation and limits water losses and erosion. Black polythene mulch contributed to water conservation at different growth stages, showing varying percentages, it demonstrated more outstanding residual moisture content than transparent polythene mulch (Otuaro et al., 2024).

Sawdust and woodshavings equally recorded high percentage soil moisture. This agrees with the studies of Davis and Strik (2022) and Ashiono et al. (2017) who all noted that sawdust absorbs moisture and holds moisture for longer period of time. Trash mulched plots had low ability in conserving soil moisture content and in moderating soil temperature. This could be because trashes are lighter, this corroborated with the report of Alagba et al. (2018) that grass mulches used in late season plantain gave poor protection to plantain further into the dry season because they were easily degraded by termites (Alagba et al., 2018).

Reproductive parameters of the plant crop and first ratoon crop late season bananas

Bananas planted in mulched plots flowered earlier than those in the control plots at all the stages of planting. This could be due to availability of more nutrients as a result of mineralization of organic manure and mulches used as well as moisture conserving benefits of mulches on the soil. Banana planted in September and mulched with palm bunch refuse were the earliest to flower (268.90 days), closely followed by the bananas in plots planted in the same month and mulched with sawdust (270.60 days). This is in contrast with the report of Ravi andVaganan (2016) who reported that the banana inflorescence (flowering stalk) is produced 10 to 15 months after planting. The early flowering in these mulches could be due to the combined beneficial effects of palm bunch refuse and sawdust, type of planting materials used and the favourable environment, although bananas were affected by water stress during the flowering stages. This confirms the study done by Kader et al. (2019) who noted that mulching is the most effective at water conservation when rainfall events are less frequent in banana production, Also El-Beltagi et al. (2022); Ahmad et al. (2020); Kader et al. (2019) and Iqbal et al. (2019) all corroborated this report and noted that mulching improves water supply capacity and can reduce irrigation requirements of crops.

The bananas planted in November delayed flowering in all the treatments, while the bananas in plots planted in September flowered earliest in all the treatments. This is in line with Salau et al. (2016) who noted that planting in September is characterized with consistent rainfall pattern that is good for vegetative growth of banana. However, Kubiriba et al. (2016) contrasted the study that planting of banana is best done towards the end of dry season and the beginning of wet season for adequate initial moisture and to avoid water logging of young plants. Salau et al. (2016) agreed that planting in May / June is associated with excessive rainfall with an extreme high temperature that can reduce banana production. It is good to plan planting dates and harvest in accordance with market demands (Robinson & Sauco, 2010). Joshi et al. (2023) and De Holanda et al. (2022) supported that the optimal temperature for the development of banana ranges from 28oC to 32oC. Temperatures below 15oC can stunt growth and negatively impact fruit development (Joshi et al., 2023; Kubiriba et al., 2016).

Time to 50 % flowering and subsequent harvest was significantly influenced by mulch materials. The variation may be due to the effect of time of planting and different mulches on banana phenology. Earlier sucker proliferation in response to good nutrition may have been as a result of early and fast growth of the first ratoon crop. The first ratoon bananas planted in September and mulched with sawdust recorded the earliest days to 50 % flowering (263.50 days) compared to the plant crop that recorded its earliest days to 50 % flowering in 268.90 days from the bananas in plots that were mulched with palm bunch refuse. Okoli et al. (2020) explained that sawdust mulch plots in late season plantain significantly gave higher yield than those mulched over other organic mulches in plant first ratoon crops. Ashiono et al. (2017) agreed that a higher carbon-to-nitrogen ratio in sawdust can potentially shorten the time it takes for ratoon crops to reach 50 % flowering compared to the initial plant crop. This is likely due to the fact that sawdust and woodshavings, with their high C: N ratios, can initially bind nitrogen, which is essential for plant growth, making it less readily available for plant uptake. But over time these mulches degrade to release carbon and nitrogen which help to improve growth and therefore the ratoon crops received this benefit from the mulch's organic matter turn over for plant crop nutrition.

The longest time to 50 % flowering was obtained from the bananas in the control plot planted in November. This may be due to the fact that the control plots, received no mulch although, blind application of poultry manure was applied to the entire crop. Emma-Okafor et al. (2019) affirmed that days to 50 % flowering was influenced by manure rate and time of planting where mulched plots were earlier in flowering compared to the unmulched plots (control plots). In their earlier research Shiyam et al (2010) opined that mulched and manured plots had better yield in the ratoon than plantains in control plots.

Yield parameters of the plant crop of late season bananas

Planting dates, mulch materials and their interaction had significant effect on bunch weight (t ha-1) and finger weight (g), however mulch materials significantly influenced all the reproductive and yield parameters of late season banana. This may be attributed to the time of planting, quality of suckers used and the positive influence of different mulches used on soil properties, crop growth and yield and favourable influence of planting in the dry season. Emma- Okafor et al. (2017) and Abd-Allah et al. (2011) confirmed this report that dry season planting of banana is done around September to December to make banana fruits and suckers available all year round to reduce the surplus that occurs in July to December which is caused by March and May plantings and to take advantage of higher prices in the dry seasons (January - June). Alagba et al. (2017) and ITFN (2016) maintained that dry season cultivation of plantain / banana is done around September, October, November, and December, since banana requires 10 to 12 months from planting to harvest. Furthermore Alagba et al. (2018) and Obiefuna and Oti (2009) emphasized that optimum 3 - crop total plantain yields were obtained when the suckers were planted in August to December. This was corroborated by Emma- Okafor et al. (2017) who explained that days to 50 % flowering in late season bananas were influenced by the application of organic manure and time of planting.

The bananas in plots planted in September and mulched with palmbunch refuse had the heaviest bunch (9.97 t ha-1), highest number of hands per bunch (8.67), highest number of fingers per bunch (95.67), and the heaviest fingers (94.67g/ finger) while the longest and largest fingers were recorded from the bananas in plot planted in September and mulched with sawdust (12.10 cm) and (11.27cm). This result may be attributed to the fact that palm bunch refuse is rich in potassium as Caliman et al. (2001) suggested that potassium is the primary content of palm bunch refuse and it is released into the soil within 3MAP. Kumar and Kumar (2008) agreed that potassium is another element of high importance for growth of banana. Senthilkumar et al. (2017) agreed that the concentration of potassium in the plant system is much higher than all other nutrients, or even all the mineral nutrients combined. Mustaffan and Kumar (2012) reported that the supply of potassium (K) fertilizers in adequate quantity not only increases growth and yield in banana, but in the physiology of the plant and offers resistance against biotic and abiotic stresses. It is also known for stimulating early shooting, increasing number of hands, finger size according to Radha and Mathew (2007).

Yield parameters of the harvest of the first ratoon crop of late season bananas

The bananas in plots planted in September and mulched with sawdust recorded the heaviest bunch (7.23 t ha-1), highest number of hands per bunch (6.67) and the highest total number of fingers per bunch (74.00), in the first ratoon banana crop. Although the first ratoon crops recorded yield declined as compared to the main plant crops. The findings of Nwauzoma and Shauibu (2008) reported that yield characteristics like bunch weight, number of hands and fingers show a steady decrease with increasing cycle. However, Ndukwe et al.(2009), Baiyeri et al. (2005) and Oluma et al. (2004) contrasted the report that ratoon crop plants yield were higher than the plant crop at harvest. Furthermore, the report of Tosi et al. (2022) and Valentina et al. (2021) all reported that under normal ratoon cultivation practices, crop ratoons often experience reduced stress tolerance, compromised growth conditions, and decreased yield and quality. Wang et al. (2024) noted that the ecological factors of untilled rhizospheric crop ratoon soil undergo long-term evolution that leads to deficiencies in essential nutrients and accumulation of allelopathic substances released through root exudation and organic matter decomposition. There was significant influence of planting dates with respect to bunch weight and total number of fingers per bunch in the late season first ratoon banana. Banana plots utilizing organic mulches and planted in September demonstrated superior performance compared to those planted in October and November. This is likely due to the time of planting relative to the dry season and the benefits of mulching, particularly in managing soil moisture content and temperature. This report followed the same trend in the plant crop. Robinson and Sauco (2010) agreed that it is good to plan the planting date and harvest in accordance with the market demand. Thus bananas planted in September were planted for higher market prizes. Abd-Allah et al. (2011) and Emma-Okafor et al. (2019) corroborated the study with the fact that dry season monthly planting of plantain is done around September to December to make banana fruits and suckers available all year round and to reduce the surplus that occurs in June to September which is caused by March and May plantings and to take advantage of higher prices in the dry seasons (February-April). Unlike other fruits, the vegetative growth, flowering and fruit growth is not seasonal in banana and are largely influenced by time of planting, type and size of planting material and prevailing temperature (Bindhu & Girijadevi, 2016).

The total yield (t ha-1) at harvest of plant crops and first ratoon crop of the late season banana

The results obtained in the total yield (t ha-1) at harvest of plant crop and in the first ratoon crop indicated that the bananas plots planted in September and mulched with woodshavings recorded the highest yield (15.37 t ha-1).This may be due to the fact that the mulches of sawdust, woodshavings and palm bunch refuse contain lignin, cellulose, and hemicelluloses which decompose slowly over time (Singh et al., 2022; Tahir et al., 2021) and this decomposition process contributes to soil health by adding nutrients. These mulches play a crucial role in the soil's organic matter and nutrient cycling. This supported the study of Rossi et al. (2024) who stated that organic mulches (e.g., wood, straw, and other derivatives) have beneficial impacts on soil physics and they increase water retention, carbon stock, and nutrient bioavailability, and reduce bulk density. Furthermore, this slow decomposition is advantageous as it ensures a sustained release of nutrients into the soil. This is in agreement with report of Rossi et al. (2024) who noted that organic mulches decay over a long period of time especially sawdust and woodshavings. Also Rossi et al. (2024) highlighted that organic mulch decays over time and adds nutrients to the soil as it breaks down and increases long-term nutrient availability in the soil for crop growth and development.

V. CONCLUSION

The experiment exrayed the effects of six (6) mulches and three (3) planting dates on late season banana productivity in Owerri Southeastern Nigeria. The results showed that Bananas mulched with blackpolyethene recorded the highest soil moisture conservation and moderated soil temperature. Sawdust and woodshavings equally moderated soil temperature. The bananas in plots planted in September and mulched with palm bunch refuse produced the heaviest bunch (9.97 t ha-1), highest number of hands per bunch (8.67) and highest total number of fingers per bunch (95.67), in plant crop. Bananas in plots planted in September and mulched with palm bunch refuse recorded the earliest day to 50% flowering in the plant crop (268.90 days), while the bananas planted in September and mulched with sawdust matured earliest (263.50 days) in the first ratoon crop. In the first ratoon crop, the bananas in plots planted in September and mulched with sawdust recorded the heaviest bunch (7.23 t ha-1), highest number of hands per bunch (6.67) and the highest total number of fingers per bunch (74.00). Banana plots planted in September and mulched with woodshavings recorded the highest total yield (15.37 t ha-1) at the harvest of plant crop and in the first ratoon crop. Bananas planted in September had the highest performance in all the parameters measured in plant crop and in the first ratoon crop, while those planted in November performed poorest across the three planting dates. Ratoon yield was significantly reduced across all the mulches except in sawdust and woodshavings.

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