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Weed suppressive effects of different organic mulches and their combinations in maize (*Zea mays* L.) field

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ABSTRACT
Field experiments were conducted during the 2016 and 2017 cropping seasons to determine the effects of living, dead organic mulches and their combinations on weed suppression and maize (*Zea mays* L.) performance in Calabar, southeastern Nigeria. Ten treatments: sole mulches of *Egusi* melon (ME), cucumber (CU), sawdust (SD), dry grass (DG), their combinations, and a no-mulch/weedy control (WC), were laid out in a Randomized Complete Block Design (RCBD) with three replications. Data on weeds, maize height and yield were subjected to analysis of variance. Means were compared using Duncan's New Multiple Range Test

(DNMRT) at 5% probability level. Mulching reduced weed density by 43.80% and 45.80%, and weed dry matter by 66.78% and 61.32% in 2016 and 2017, respectively compared with WC. Weed control efficiency was highest in SD+DG (82.14%) and lowest in CU (26.39%) on the two-year average. The SD produced the highest mean maize grain yield (3.21 t ha^{-1}), statistically similar to other mulch treatments except ME+DG, CU+DG and CU, while WC produced significantly the lowest yield (1.30 t ha^{-1}) over the two years.

Keywords: Organic mulch, weed density, weed dry matter, weed control efficiency, maize grain yield.

1. INTRODUCTION

Maize (*Zea mays* L) occupies a central place in the cropping systems of both northern and southern Nigeria as a food security crop (Sahel, 2017). Currently, Nigeria is the 11th world largest producer of maize and second in Africa, following South Africa (Agricdemy, 2020). However, average maize grain yields remain as low as 1.8 MT/Ha in the country (FOSTAT, 2014) due to prevailing constraints, although it has been demonstrated that grain yields up to 6 tons/ha are obtainable with improved production technology (IITA, 2020).

Weed infestation has been identified as one of the major biotic constraints to maize production in Nigeria (Opaluwa *et al.*, 2015; Nwagwu *et al.,* 2015), and elsewhere (Wambugu *et al.*, 2012), accounting for grain yield losses of 20- 60 % (Agricdemy, 2020; Saima *et al.*, 2013). Improvements in crop vegetative and yield characteristics through better cropping practices, soil fertility management and breeding for tolerance/resistance to pests and diseases could be confounded if weeds are not adequately managed in the field.

Mulching is one of the alternative methods to chemical and mechanical weed control for sustainable agriculture (Calkins and Swason, 1995). The ways by which mulches suppress weeds and enhance crop performance have been outlined (Farman *et al.,* 2014; Pupaliene *et al.*, 2015). Weed control and crop yield have been significantly enhanced by dead organic mulches of sawdust (John *et al.*, 2005) and dry grass (Sinkevicine *et al.*, 2009; Uwah and Iwo, 2011). Sawdust is obtainable at cheap or no cost as a waste product from saw mills, however, it is not commonly used for mulching in southern Nigeria. Rather, to avoid over accumulation, it is often burnt in the open air with attendant environmental hazards (Olaposi *et al.*, 2013). Similarly, the burning of dry grasses and other plant debris during bush clearing remains a characteristic feature of slash- and- burn crop production system prevalent among the predominantly small holder farmers of southeastern Nigeria. The farmers rely mainly on repeated manual weeding and the use of different crop mixtures for weed suppression in this region.

In southern Nigeria, maize is usually intercropped with smother crops such as cowpea, groundnut, soybeans (Sahel consulting, 2017) *Egusi* melon (Gbarane, 2018) and cucumber (Mba and Aniekwe, 2013), because in addition to weed suppression, it can contribute to diversification of food and/or income and ensures against crop failure. Weed suppression by cover crops varies depending on many factors such as growth habit and life span (Nwagwu *et al.,* 2000). The complementary use of dead organic mulches at reduced rates with compatible creeping crops could minimize the problems of bulkiness and high transportation cost associated with the dead mulches (Jordan, 2004), while securing early weed control before the canopy of the smother crop fully covers the soil. The experiment was therefore conducted to assess the weed suppressive effects of sawdust, dry grass, *Egusi* melon, cucumber and their combinations in maize field.

2. MATERIALS AND METHODS

Field experiments were conducted during the 2016 and 2017 early (April to July) cropping seasons at the University of Calabar Teaching and Research Farm, Calabar, Nigeria, located between latitudes4.5-5.2 ^{0} N, and longitudes8–8.3^{0} E, 39 m above sea level. The mean annual rainfall and temperature range from 2200–3700 mm and 27–35^{0}C, respectively. The experimental site was manually cleared with machete and beds raised with spade. Each plot measured 3 m x 2 m with 1 m pathways between blocks and between plots. The ten treatments: sole mulches of melon (ME), cucumber (CU), sawdust (SD), dry grass (DG), melon + sawdust, (ME+SD), melon + dry grass (ME+DG), cucumber + sawdust (CU+SD), cucumber + dry grass (CU+DG), sawdust + dry grass(SD+DG)and no-mulch/weedy control (WC) were laid out in randomized complete block design with three replications. One week before planting, goat manure was applied at the rate of 50 t ha^{-1} (30 kg plot^{-1}). The SD and DG were evenly applied at a layer thickness of 5 cm (John *et al.*, 2005), in sole treatments and 2.5 cm when combined with other mulches. The ME and CU were sown each at 1m x 1m apart, three seeds per stand, later thinned to two (20,000 plants ha^{-1}) in sole plots, or thinned to one (10,000 plants ha^{-1}) when in combination with SD, DG. Maize (Ife hybrid-6) was sown 25 cm x75 cm apart, two per stand and later thinned to one (53,333 plantha^{-1}). All crops were planted in the second week of April, each year.

Mulched plots were weeded after weed assessment at 2 weeks after sowing (WAS) by hand pulling to avoid crop failure. Weed density was determined by placing a 50 cm x 50 cm quadrats randomly twice on each plot, the enclosed weeds harvested, counted and recorded on basis of m^{2}landarea. The harvested weeds were oven dried at 72^{0}C to a constant weight to obtain the dry matter, which was converted to m^2. Weed control efficiency (WCE) was determined using the formula described by Amare *et al.* (2014):

$$WCE = \frac{WDC - WDT}{WDC} \times 100$$

Where: WCE = Weed control efficiency; WDC= Weed dry mass from control plot (untreated);
WDT = Weeds dry matter from treated plot.

Six maize plants were tagged at the middle row of each plot and used for data collection. Plant height was determined at 8 WAS with a measuring tape and cobs were harvested at maturity 12 WAS, and dried to 12 % moisture content for grain yield determination, which was expressed on hectare basis. Data were subjected to analysis of variance procedures for RCBD and means separated using Duncan's New Multiple Range Test (DNMRT) at 5 % level of probability.

3. RESULTS

Weed density

Weed density in WC was statistically similar (P > 0.05) to most mulched plots at 2 WAS in both years Table 1). The SD and SD+DG treatments produced the lowest weed density, followed by ME+SD and CU+DG across sampling periods in 2016. In 2017, mean weed density was significantly lower (P < 0.05) in DG, followed by SD+DG and ME compared with other mulched plots. Generally, organic mulches reduced weed density by 6.35 – 84.88 % (43.8 % average) in 2016 and by 28.20 – 68.29 % (45.80 % average) in 2017, compared with WC.

Weed dry matter

Weed dry matter was statistically similar (P < 0.05) between WC all mulched plots at 2 WAS in both years, except DG in 2017 (Table 2). Highest weed dry matter was obtained at 10 WAS in both years. Averaged over sampling periods in 2016, SD+DG produced the least weed dry matter, followed without significant difference by SD, while WC and CU had statistically the highest values. Among the mulched plots in 2017, weed dry matter was significantly reduced by SD+DG and CU+DG at 6 WAS and by SD+DG and SD at 10 WAS, relative to CU. On the whole, mulching reduced weed dry matter by 66.78 and 61.32 % compared to WC in 2016 and 2017, respectively.

Weed control efficiency (WCE)

Weed control efficiency in the mulched plots ranged from 12.14% and 40.64% in CU to 93.92% and 70.35% in SD+DG in 2016 and 2017, respectively (Table 3). The SD+DG and SD achieved significantly higher (P < 0.05) weed control efficiency than CU and ME in 2016, while SD+DG attained greater weed control efficiency than CU in 2017.Combining ME, CU with SD or DG enhanced weed control efficiency compared to sole live mulch treatments. Averaged over the years, highest weed control efficiency was obtained from SD+DG, being statistically similar (P < 0.05) to CU+SD and SD, while CU gave the lowest values.

Table 1: Effects of organic mulches on weed density (no m^{-2}) in maize field in 2016 and 2017 cropping seasons

Mulch treatments	Weed density (m^{-2}) 2016 Weeks after sowing				2017 Weeks after sowing			
	2	6	10	Mean	2	6	10	Mean
ME	50.30ab	97.30ab	135.70abc	94.43d	185.30bc	116.06bc	108.00cd	136.45g
CU	81.30ab	114.30ab	151.30a	115.63c	306.70ab	156.00b	178.70ab	213.80b
SD	17.0b	18.70b	38.30c	24.67g	237.30abc	105.30bc	102.70cd	148.43ef
DG	72.70ab	89.30ab	126.00bc	96.00d	132.00c	64.00c	93.30cd	94.43h
ME + SD	42.00ab	51.00ab	79.30bc	57.43f	370.70a	117.30bc	82.70cd	190..23cd
ME + DG	111.70a	114.70ab	151.30a	125.90b	225.30abc	113.30bc	133.30bc	157.30e
CU + SD	59.70ab	91.30ab	113.00abc	88.00e	348.00ab	132.00bc	93.30cd	191.1cd
CU + DG	34.00ab	57.30ab	81.30abc	57.53f	340.00ab	126.00bc	76.00cd	186.67d

SD + DG	11.70b	19.00ab	30.30c	20.33g	241.33abc	100.00bc	61.30d	134.21g
WC	94.30b	131.00a	178.00a	134.43a	192.00bc	473.30a	228.00a	297.77a

Means followed by same letters in a column do not differ significantly at 0.05 probability level (DNMRT)

Table 2: Effects of organic mulches on weeds dry matter (gm^{-2}) in maize field in 2016 and 2017 cropping seasons

	Weed dry matter (g m^{-2})							
	2016 Weeks after sowing				2017 Weeks after sowing			
Mulch treatments	2	6	10	Mean	2	6	10	Mean
ME	3.32a	56.20ab	70.36ab	43.29b	64.70abc	20.70bc	81.30bc	55.57de
CU	6.99a	74.20ab	91.53a	57.56a	86.70ab	34.70b	106.70ab	76.03bc
SD	2.30a	6.04d	9.11c	5.82ef	69.70abc	26.70bc	98.70abc	65.03cd
DG	4.87a	14.42cd	25.65bc	14.98d	41.30c	16.00bc	68.00c	41.77f
ME + SD	2.22a	23.49cd	30.50bc	18.74cd	94.70a	22.00bc	129.30ab	82.0b
ME + DG	5.83a	31.74b	38.21bc	25.26c	64.00abc	15.30bc	82.70bc	54.0de
CU + SD	5.04a	12.05cd	20.80bc	12.63de	104.70a	17.30bc	109.30ab	77.1b
CU + DG	3.49a	12.35cd	25.10bc	13.65de	66.70abc	11.30c	77.30bc	51.77ef
SD + DG	1.80a	3.38d	6.76c	3.98f	55.30bc	12.00c	64.00c	43.77ef
WC	7.16a	87.88a	101.55a	65.53a	86.70ab	226.00a	158.70a	157.13a

Means followed by same letters in a column do not differ significantly at 0.05 probability level (DNMRT)

Table 3: Weed control efficiency of different organic mulches in maize field in 2016 and 2017

	Weed control efficiency (%)		
Mulch treatments	2016	2017	Mean
ME	33.94b	62.14ab	48.04e
CU	12.14c	40.64c	26.39f
SD	91.11a	65.99ab	78.55ab
DG	77.14ab	67.82ab	72.48bc
ME+SD	71.40ab	59.16abc	65.28cd
ME+DG	61.45ab	61.42ab	61.44d
CU+SD	80.72ab	66.27ab	73.50abc
CU+DG	79.17ab	53.19abc	66.18cd
SD+DG	93.92a	70.35a	82.14a
WC	-	-	-

Means followed by same letters in a column do not differ significantly at 0.05 probability level (DNMRT)

Table 4: Effect of organic mulches on plant height (cm) and grain yield (tha^{-1}) of maize in 2016 and 2017

	Plant height (cm)		Grain yield (t ha^{-1})		
Mulch treatments	2016	2017	2016	2017	Mean
ME	158.31b	193.90a	3.25ab	2.90ab	3.03ab
CU	167.62b	111.10b	2.65cd	2.15c	2.40cd
SD	232.52a	169.10ab	3.40a	3.01ab	3.21a
DG	201.20ab	191.20a	2.80cd	3.17ab	2.99ab
ME+SD	158.21b	118.30b	3.00abc	2.72bc	2.86abcd
ME+DG	181.81b	147.90ab	2.10e	3.08ab	2.59bcd

CU+SD	191.51ab	125.40b	2.20e	3.04ab	2.62abcd
CU+DG	175.32b	104.00b	2.55de	2.18c	2.37cd
SD+DG	183.52b	155.60ab	2.85bcd	3.39a	3.12ab
WC	183.50b	120.80b	1.50f	1.10d	1.30e

Means followed by same letters in a column do not differ significantly at 0.05 probability level (DNMRT)

Maize growth and yield parameters

Table 4 shows the mean effects of organic mulches on height and grain yield of maize. Tallest plants were observed in SD, which differed significantly ($P<0.05$) from WC and other mulched treatments except DG in 2016. The ME produced statistically taller ($P < 0.05$) plants than all other treatments except SD, ME + DG and SD + DG in 2017.

The SD produced the highest maize grain yield, but statistically similar to ME and ME+SD, while CU+SD and ME+DG gave significantly the lowest grain yield among mulched plots in 2016. The CU and CU+SD produced statistically the lowest maize grain yields compared with other mulched treatments except ME+SD in 2017.Mulchingnearly doubled or tripled maize grain yield across treatments relative to WC, with the highest mean yield from SD (3.21 t ha^{-1}), statistically similar to other mulch treatments except ME+DG, CU+DG and CU. The WC produced the lowest grain yield (1.30 t ha^{-1}), equivalent to53.57% yield reduction compared with mulched plots over the two years.

4. DISCUSSION

The similarity in weed density and weed dry matter between WC and most mulched plots at 2 WAS could be attributed to the influence of tillage, which has been reported to affect weed seedbank and weed density (Oliveira *et al.*, 2019). The surge in weed biomass at 10 WAS could have been due to decreasing effects of the mulches on weed suppression as the dead mulches decomposed and ground coverage of the smother crops reduced over time due to senescence, which could have created niches for weeds to resurge and thrive. This is consistent with the findings of Abouziena and Radwan (2015).

A number of reasons could account for the best weed suppression obtained in SD, DG sole and combined treatments. First, the early, even application and the layer thickness of these dead mulches over the soil surface must have enhanced their ability to suppress weeds by impeding weed seedling emergence and denying weed propagules direct sunlight, compared with the living mulches (ME, CU) which vines require 4 weeks or more to cover the soil surface sufficiently to smother weeds. Secondly, these dead mulches could have suppressed weeds for longer duration due to slow decomposition as a result of their high carbon: nitrogen ratio, enabling them last longer on the field (Jhala *et al.,* 2014).

The good weed control achieved by melon in sole and combined mulch treatments agree with previous research reports that melon smothered weeds and reduced the frequency of weeding in maize (Akobundu, 1983) and other crops (Nwagwu and Udo, 2019). Conversely, the relatively higher weed density and lower weed control efficiency of sole cucumber could be due to inadequate canopy cover of the vines, possibly due to wide spacing (1 m x 1 m) and slow vine growth. Mba and Aniekwe (2013) reported effective weed suppression by an elite cucumber variety Poinsett 76, even in un-weeded plots, when closely spaced at 50 cm x 30 cm. These observed differences in weed control by sole CU and sole ME support previous findings that, cover crops differ in their weed suppressive potentials (Nwagwu, *et al*, 2000, Michael, 2015). However, when CU was combined with DG or SD, weed control was enhanced, indicating complementarity. The demonstrated effectiveness of the mulch treatments in weed suppression in this study is consistent with previous research findings (Tesfey *et al.*, 2015, Farman *et al.*, 2014).

Mulching significantly enhanced maize grain yield compared with the no-mulch/weedy control. This finding agrees with previous researchers who reported enhanced maize grain yield form the use organic mulches (Kwabiah 2003;Saima *et al.*, 2013).The highest maize grain yield obtained from SD followed by SD+DG is attributable to superior weed suppression achieved by these treatments and aligns with the results of Sinkeviciene *et al.*, (2009). The significantly greater yield of maize obtained from ME relative to CU reflects the better weed control attained in ME plots. Melon often enhances the yield of intercrops, due possibly to its weed suppressing ability, short life span, quick senescence and addition of organic matter into the soil through biomass decay (Nwagwu, *et al.*, 2000).

5. CONCLUSION

The findings of this research indicated that the dead mulches SD, DG and their combination gave best weed suppression and enhanced maize grain yields compared with the live mulch CU. However, ME live mulch) significantly suppressed weeds and gave maize grain yields similar to SD and DG treatments. Combining CU with SD at 50 % of their sole applications tended to enhance weed suppression and the performance of maize compared to sole CU. Farmers can use sole SD, DG, their combination or ME for effective weed suppression and optimized maize grain yield in the study area.

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Authors' contributions

Dr. Francis Nwagwu conceived the research, supervised the field work, and wrote the manuscript.
Mrs. Afiong Okon conducted the field work, collected and analysed the data in 2016.
Miss Idorenyin Udoidiok conducted the field work, collected and analysed the data in 2017.

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The authors declare that there are no conflicts of interests.

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All data associated with this study are present in the paper.

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