Colloquia SSSN 44 (2020) 277-288

Colloquia Series

Available online at www.publishingrealtime.com

Publishing Real Time

Colloquia SSSN 44 (2020)

Proceedings of the 44th Conference of Soil Science Society of Nigeria on Climate-smart soil management, soil health/quality and land management: synergies for sustainable ecosystem services

Impact of organic mulches on weed suppression and soil quality conservation potentials in Calabar, Nigeria

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Abstract

Dual (early and late) season field experiments were conducted between March and November 2015 at the University of Calabar Teaching and Research Farm, Calabar, Nigeria, to evaluate the effects of organic mulches on weed suppression in maize and on soil physicochemical properties. A randomized complete block design with three replications was used. Ten treatments: sole plots of "egusi" melon, cucumber (live mulches), sawdust, dried grass (dead mulches), "egusi' melon + sawdust, "egusi" melon + dried grass, cucumber + sawdust, cucumber + dried grass, sawdust + dried grass, and the un-mulched control were used. Data taken include weed bioassay, as well as soil physicochemical properties, and analyzed using the analysis of variance method. Means were compared using Duncan's multiple range test. Results indicated that the sole application of sawdust mulch gave best weed suppression, mulching generally suppressed weeds compared to no-mulch in the late season. "Egusi" melon attained above 60 % and 70 % ground cover at 4 and 6 WAS, respectively in the early season and suppressed weeds better than cucumber within the same period, in their sole treatments. Mulching with sawdust alone or in combination with dry grass significantly ($p<0.05$) reduced broadleaf and grass weed populations compared to the un-mulched check, while dry grass mulch significantly ($p<0.05$) increased sedge weed populations compared to the un-mulched control in the early season. The results indicated that neither the chemical properties nor the physical properties of the soil were substantially changed as a result of the treatments. The soil pH was 4.8 at the initial stage but reduced to 4.7 after the experiment. Base saturation increased from 59 % at the initial stage to 90 % after treating with sawdust. Collectively, the results indicated that sawdust was most effective in suppressing weeds and improving soil quality.

Keywords: Organic mulches, mulching, weed suppression, soil quality conservation, Acid soils of Calabar

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https://doi.org/10.36265/colsssn.2020.4440

Peer-review under responsibility of 44th SSSN Conference LoC2020.

1.0 Introduction

Weeds constitute a nuisance in crop production, especially in organic farming systems where chemical weed control is restricted. In sub-Saharan Africa, weed control is achieved mainly by manual means, which is often expensive, tedious and leads to drudgery. In organic farming systems, weed control without the use of chemicals has been successfully practised (Chaya, 2010). To reduce the drudgery of weeding, weeds should be controlled at a very tender stage and are not to be allowed to sprout and colonize the ecological niche. The bigger the weeds get, the more difficult they are to control (Anonymous, 2013). Using the right tools and techniques will help to make weeding manageable or even enjoyable. Weed management in organic cropping systems must involve the use of many techniques and strategies aimed at achieving economically acceptable weed control and crop yields. The more a grower can prevent weed pressure, the more likely it will be economical to produce crops (O'Gara, 2010).

Weeds need water, nutrients, and light to grow. Weed control is the botanical component of pest control, which attempts to stop weeds from competing with cultivated plants. Weeds compete with productive crops or pasture, ultimately converting productive lands into unusable scrubs (Bleasdale and Salter, 1991). Weeds can be poisonous, disastrous (fire hazards); produce burrs, thorns, or otherwise interfere with the use and management of crop plants by contaminating harvest (Stockstad, 2013). Weeds compete with crops for space, nutrients, carbon (IV) oxide, water, and light (Nwagwu *et al.*, 2000). When managing weeds in organic production systems, producers use many techniques. The techniques are mainly cultural and mechanical prevention methods (Curran, 2004). However, biological weed management, which involves the use of living organisms to suppress the vigour and spread of weeds, is becoming increasingly important, especially in organic crop production systems. Such agents can be insects, bacteria, fungi, grazing animals or other plants (Karlen *et al.*, 2000). Smother or low growing plants have been used to control weeds effectively (Nwagwu *et al.,* 2000; Okon and Amalu, 2003).

Smother crops or plants are specified cover crops grown for their ability to suppress weeds (Buhler *et al.* 1999). Besides combating weeds, smother plants could reduce soil erosion and improve soil quality, and the smother plants densities must be such that they do not inhibit the primary crop from achieving its yield potentials. Living vegetation has been used to smother weeds effectively, but this depends on the ability of the smother crops to establish well to gain competitive effects over weeds (Williams 1997).

Soil quality has been defined by Doran and Parkin (1994) as "the capacity of a soil to function, within the ecosystem and land use boundaries, to sustain productivity, maintain environmental quality, and promote plant and animal health". Soil quality degradation sets in when problems of erosion, compaction, acidification, organic matter losses, and chemical contamination are manifested, which reduce its capacity for production of food, fibre, and energy (Schindelbeck *et al.,* 2008; Bunch, 2012). Soil quality degradation can also contribute to reduced ecosystem functioning. On the other hand, if the soil could be used for organic production with some live mulches or smother crops, it can play the multiple functions of weed suppression, soil water and quality conservation (Panitnok *et al.* 2013; Bunch, 2012).

This study seeks means of effectively managing weeds in the organic farming system with the use of live and dead plant mulches without the use of chemicals. Successful identification and utilization of organic mulches that can inhibit the growth of weeds can reduce the drudgery and cost of production, and equally protect the soil quality against degradation.

1.1 Objectives of the Study were to evaluate the impact of different organic (living and dead) mulches on weed suppression, and the impacts of smother-crops as mulches on soil quality conservation in an acid sandy soil environment.

2.0 Materials and Methods

2.1. The study area: The experiment was conducted at the University of Calabar Teaching and Research Farm, Calabar, Nigeria, [Latitude 04^{o} 45´ to 58´ North and Longitude 08^{o} 18´ to 37´ East, the altitude of 30 to 36 m above sea level] (GPS, 2015). Figure 1 shows the study area, characterized by two distinct tropical moist climates – the rainy and dry seasons. The rainy season usually starts from April and ends in November with a double peak usually in July and September. The annual rainfall ranges between 2500 mm and 4000 mm, the annual minimum and maximum air temperatures of Calabar were 23.0 ^{o}C and 30.0 ^{o}C, respectively, while the relative humidity of the area-averaged 86 % (Table 1; NIMET, 2015).

Geologically, the area has parent material consisting of Sandstones and Coastal Plain Sands (Bulk-trade, 1989). The area is well-drained, very porous with soil depth extending beyond two meters deep and gentle sloping with a predominance of sheet and rill erosion. The soils of the area had been classified as Typic Paleudults in the Ultisols order using USDA soil taxonomy (Esu, 2005; Chude *et al.,* 2011). The flora features consist of shrubs, creepers, evergreen trees and herbs while the fauna features of the area include bees, ants and termites. The area is used predominantly for horticultural and arable crop cultivation where crops like maize, watermelon, fluted pumpkin, cassava and yam are grown.

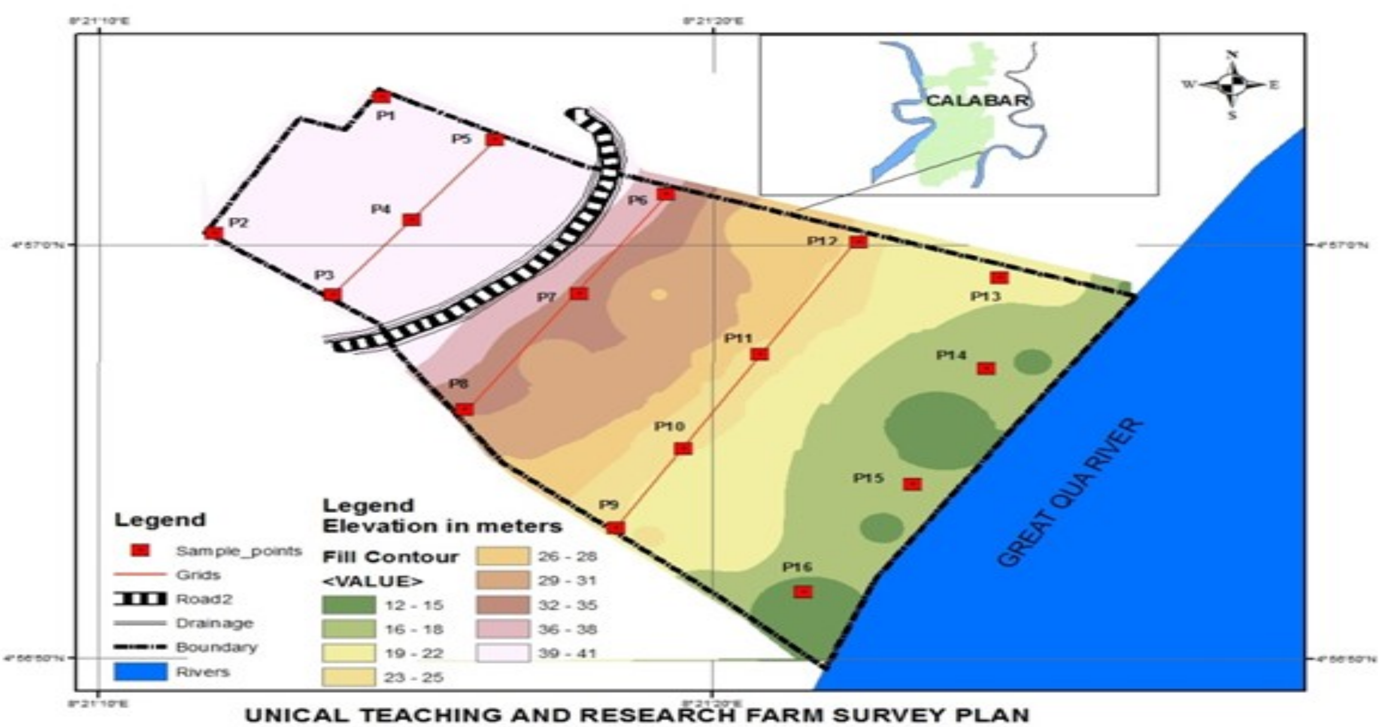

Fig 1: Map of the University of Calabar Teaching & Research Farm. The experimental plots were explicitly located between points P1, P5 and P4 on the map.
(Source: Department of Soil Science, University of Calabar, 201

Table 1: Weather variables from 2012 to 2014 in the study area

	Relative humidity (%)			Min. Temperature (˚C)			Max. Temperature (˚C)			Rainfall (mm)		
Month/Year	2012	2013	2014	2012	2013	2014	2012	2013	2014	2012	2013	2014
January	86	80	82	22.5	23.8	22.1	32.0	33.0	31.3	32.6	1.41	81.1
February	82	83	84	23.6	22.9	23.2	31.5	33.0	33.1	376.7	83.7	61.1
March	82	87	87	25.1	23.9	22.6	33.7	31.9	31.9	38.0	23.14	366.2
April	87	84	84	23.4	23.7	22.9	32.1	32.0	32.1	99.9	286.9	245.0
May	87	84	84	23.4	23.7	22.9	31.7	31.6	31.6	439.4	466.9	332.2
June	92	89	87	23.4	23.8	22.7	30.3	29.8	30.2	398.8	459.8	220.0
July	90	91	92	23.1	23.0	22.2	28.0	27.9	27.8	637.1	477.0	249.9
August	90	91	90	22.9	29.9	21.9	28.4	27.4	28.3	861.3	411.1	410.3
September	90	91	90	22.9	23.3	22.1	29.1	28.8	29.0	619.4	340.4	501.5
October	87	88	89	22.5	22.5	21.1	30.3	29.9	30.1	410.4	306.2	136.8
November	84	87	88	23.7	23.3	22.2	31.0	30.6	31.3	126.5	220.9	136.8
December	83	82	80	23.4	22.1	22.3	32.1	30.8	32.0	30.6	81.1	18.3
Mean	86.33	86.42	86.45	23.45	23.11	22.40	30.85	30.60	30.68	4070.7	3158.5	2759.2

Source: NIMET, 2015

2.2.Experimental design and layout

The experiment was laid out in randomized completed block design (RCBD) with three replications. There were ten organic mulches treatments: egusi melon alone (Ml), cucumber alone (Cu), sawdust alone (SD), dry grass mulch (DG), melon + sawdust (Ml+SD), cucumber + sawdust (Cu+SD), melon + dry grass mulch (Ml+DG), cucumber + dry grass mulch (Cu+DG), sawdust + dry grass mulch (SD+DG), and the un-mulched (control). Details of the treatments are given in Table 2.

Each plot measured 2 m x 3 m, giving 6 m^2 per plot. A total of 30 plots were obtained after replications. A pathway of one meter was allowed in-between plots (beds) and one-meter pathway between blocks. The total experimental area measured 11 m x 29 m (319 m^2).

Table 2: Treatment materials and their descriptions

SN	Treatments	Abbreviations	Smother crop spacing / thickness of mulching	Density of plants/ha (smother crops)
1	Melon alone	Ml	1 m apart	10,000
2	Cucumber alone	Cu	1 m apart	10,000
3	Saw dust alone	SD	5.0 cm thick	
4	Dried grass mulch alone	DG	5.0 cm thick	
5	Melon + sawdust	Ml+SD	1 m + 2.5 cm thick	10,000
6	Cucumber + sawdust	Cu+SD	1 m + 2.5 cm thick	10,000
7	Melon + dried grass mulch	Ml+DG	1 m + 2.5 cm thick	10,000
8	Cucumber +dried grass mulch	Cu+DG	1 m + 2.5 cm thick	10,000
9	Sawdust +dried grass mulch	SD+DG	2.5 cm + 2.5 cm thick	
10	Unmulched control	Control		

Keys: Cu = cucumber; Ml = melon; SD = sawdust; DG = dried grass mulch; m = meter; cm = centimetre.

2.3 Percentage ground cover of the smother crops: The ground coverage of cucumber and melon vines was determined biweekly from 4 to 10 weeks after sowing (WAS) in both seasons by the use a quadrat measuring 1 m x 1 m, subdivided into 100 equal parts using strings. The quadrat was placed randomly on two locations in each plot, and several units covered by the canopy of the cover crop was counted and the average recorded in percentage.

2.4 Weed management: One hand-hoe weeding was done at 4 WAS, which coincided with the commencement of data collection on weeds.

2.5 Weed studies

The following weed data were collected on a 4-weekly basis, from 4 to 12 WAS.

Weed Density (No/m^2): The weed density was determined by placing a 1 m x 1 m quadrat randomly once on each plot, and the number of weeds enclosed within the quadrat counted and recorded.

2.6 Weed flora distribution (No/m^2): Weeds within the quadrat thrown were harvested, separated into morphological groups, and the number of weeds in each group counted and recorded. Weed species within each morphological group were also identified and noted.

2.7 Weed dry matter (g/m^2): The harvested weed samples were oven-dried at 70 °C, to a constant weight, which was determined using a sensitive Mettler balance and expressed in grams per square meter (g/m^2) to obtain the weed dry matter.

2.8 Soil physicochemical properties

Pre-planting and post-harvesting soil physical and chemical properties were determined. Soils were randomly sampled within each block and bulked together to obtain a composite sample for soil analysis. Soil sample for analysis was taken at a depth of 0 - 20 cm using a soil auger. Soil temperature was also taken using a soil meter probe at 0 - 20 cm depth at the centre of each plot. The soil was sampled from the field on a plot by plot basis, and the inherent properties were determined using routine laboratory methods described by Udo *et al.* 2009, and after that, the obtained values were compared with those of critical standards, and their initial values to ascertain if there had been any improvements due to the mulch treatments given to the soil. The soil properties determined were: physical properties (percentage sand, silt and clay contents, which gave the texture) and chemical properties (soil pH, total nitrogen, organic carbon, organic matter, effective cations exchange capacity (ECEC), exchangeable acidity, available phosphorus, and percentage base saturation).

The particle size analysis (for sand, silt and clay) was determined using the Bouyoucos hydrometer method. The soil pH was determined in a 1: 2.5 soil: water ratio, after stirring the dissolved sampled for about 30 minutes, the pH was then determined potentiometrically with an electrode. Available phosphorus was determined using Bray-1- P method after extraction. Total nitrogen was determined using the wet oxidation method. The effective cations (Ca, Mg, Na) were extracted with 1 N acid and determined through titration. Potassium content was determined using flame photometry. The details of these methods are as recorded by Udo *et al.* (2009).

2.9. Statistical analyses

Data generated were subjected to statistical analysis using the analysis of variance (ANOVA) procedures for Randomized Complete Block Design (RCBD) and significant means compared using the Duncan's Multiple Range Test (DMRT) at 5 % level of probability. The GenStat DE version 10.1 (GenStat, 2016) was the statistical software package used for the ANOVA and computerized mean comparisons.

3.0 Results and Discussion

3.1. Percentage of ground coverage of smother crops

The ground coverage of 'Egusi' melon and cucumber is as shown in Table 3. 'Egusi' melon plots attained significantly ($p < 0.05$) greater ground coverage than those of cucumber at 4 WAS in the early season. Also, in the early season, the CU+SD plots recorded significantly ($p < 0.05$) lower ground cover compared to all other smother crop treatments and Ml+SD at 6 WAS and 8 WAS, respectively. Generally, 'Egusi'- melon attained 60 % and above ground cover at 6 weeks after planting (WAS) in the early season, whereas cucumber attained less than 50 % in the same period. There were no statistical ($p > 0.05$) differences in ground coverage of cucumber and melon vines at all sampling periods in the late season, with values lower than 40 %. There was a general decline in ground coverage of the smother crops beyond 6 WAS in both seasons.

3.2. Weed density

The effect of different organic mulches on weed density in maize is presented in Table 4. The SD and SD+DG treatments recorded significantly ($p < 0.05$) lower weed density than Ml+DG and the unmulched control at 4 and 8 WAS, respectively in the early season. During the late season, all the mulched plots except sole cucumber recorded significantly ($p < 0.05$) lower weed density than the unmulched plots at 4 WAS. At 8 WAS, all mulched plots except the CU and Ml+DG recorded significantly ($p < 0.05$) lower weed density than the control in the late season. Cumulatively, the unmulched plots, and cucumber alone as mulch,

Table 3: Percentage ground coverage of cucumber and 'Egusi' during 2015 early- and late- cropping seasons.

Treatment	Percentage of ground coverage of smother crops							
	Early season				Early season			
	4 ← WAS →	6	8	10	4 ← WAS →	6	8	10
Melon alone	57.72a	77.70a	29.00ab	9.33a	24.67a	24.00a	18.02a	12.00a
Cucumber alone	25.01b	45.32a	25.04ab	2.70a	38.33a	38.33a	25.33a	8.33a
Ml+SD	68.33a	75.02a	46.02a	11.72a	16.33a	24.02a	17.00a	13.33a
Cu+SD	19.00b	38.00b	12.02b	2.72a	19.33a	24.32a	13.33a	5.73a
Ml+DG	41.72a	65.71a	37.71ab	12.33a	18.33a	28.71a	20.71a	7.00a
Cu+DG	26.33b	44.72a	26.73ab	15.00a	7.33a	9.33a	5.70a	7.00a

Means with the same alphabet(s) in the same column are not significantly different from each other at a 5 % level of probability using DMRT

Keys: Ml+SD = Melon+Sawdust;
Cu+SD = Cucumber+Sawdust;
Ml+DG = Melon+ dried grass;
Cu+DG = Cucumber+dried grass;
WAS = Weeks after sowing.

Table 4: Effect of organic mulches on weed density (Number/m2) in maize in 2015 early- and late- cropping seasons

Mulch treatment	Early season 4 WAS	8	12	ES Mean	Late season 4 WAS	8	12	LS Mean
Ml	50.30ab	97.30ab	135.70abc	94.44b	12.00b	17.70c	27.30b	19.00b
Cu	81.30ab	114.30ab	151.30a	115.67a	31.30a	55.70a	76.00a	54.33a
SD	11.70b	19.00b	30.30c	20.33c	5.30b	17.30c	31.30b	18.00b
DG	72.70ab	89.30ab	126.00abc	96.00b	7.90b	20.70c	38.30b	22.29b
Ml+SD	42.00ab	51.00ab	79.30bc	57.44c	5.70b	14.00c	25.00b	14.89b
Cu+SD	59.70ab	91.30ab	113.00abc	88.00b	10.00b	16.70c	30.00b	18.89b
Ml+DG	111.70a	114.70ab	151.30a	125.89a	13.70b	25.30bc	26.70b	21.89b
Cu+DG	34.00ab	57.30ab	81.30abc	57.56c	6.30b	15.30c	24.30b	15.33b
SD+DG	17.00b	18.70b	38.30bc	24.67c	3.70b	9.70c	20.00b	11.11b
Unmulched control	94.30ab	131.00a	178.00a	134.44a	32.70a	48.00ab	70.00a	50.22a

Means with the same alphabet(s) in the same column are not significantly different from each other at 5 % level of probability using DMRT

Keys: Treatments: Ml= Melon alone; Cu = Cucumber alone; SD = Sawdust alone;
DG = Dry Grass Mulch alone; Ml+SD = Melon+Sawdust; Cu+SD = Cucumber+Sawdust;
Ml+DG = Melon+ dried grass mulch; Cu+DG = Cucumber+ dried grass mulch;
SD+DG = Sawdust+ dried grass mulch; WAS = Weeks after sowing.
ES = Early season (March – July); LS = Late season (August – November)

produced a significantly ($p < 0.05$) higher weed density of 134.4 and 115.7 No/m^2, respectively in the early- and 50.22 and 54.33 No/m^2 in the late - season, respectively compared to other treatments. The least weed densities were observed in plots treated with sawdust alone, and sawdust + dry grass mulch, in both seasons.

3.3 Weed flora distribution

The weed species found in the experimental plots irrespective of mulch treatments and seasons are presented in Table 5. Broadleaf weeds were by far more predominant, constituting 14 (70 %) of the 20 weed species identified, while grasses and sedges had only three species (15 %) each. Among the broadleaves, there were 11 (64.29 %) annual and 9 (35.71 %) perennial species. Two, representing 66.67 % grasses were annuals while all the sedges were perennials. Irrespective of morphology, 11 (55 %) of the weeds were annuals while 9 (45 %) were perennials.

3.4 Broadleaf weeds population

The influence of organic mulches on the occurrence of broadleaf weeds is shown in Table 5. Saw-dust alone significantly ($p < 0.05$) suppressed broadleaves compared to the unmulched control and cucumber+ sawdust at 4, and 12 WAS in the early cropping season. Also in the early season, the application of sawdust alone significantly ($p < 0.05$) reduced the number of broadleaf populations compared to melon alone, melon + dry grass and the unmulched control at 12 WAS. During the late season, all mulched plots significantly ($p < 0.05$) suppressed broadleaf weeds compared to the control at 4, and 8 WAS sampling periods and compared to cucumber alone at 8, and 12 WAS.

Cumulatively, sawdust alone and sawdust + dry grass gave the best broadleaf weed suppression in the early season, while in the late season, all mulched plots except cucumber alone significantly suppressed broadleaves compared to the control.

3.5 Grass weed density

Grass weeds density was significantly ($P < 0.05$) reduced by mulching in melon alone, sawdust alone and sawdust + dry grass plots compared to the unmulched control and

Table 5: Weed floras found in the experimental site during the research period (March – November 2015)

S/N	Weed species	Common names	Morphology	Life cycle
1	*Aspilia africana*	Haemorrhage plant	Broadleaf	Annual
2	*Chromolaena odorata*	Siam weed	Broadleaf	Perennial
3	*Emilia coccinea*	Yellow tassel flower	Broadleaf	Annual
4	*Phyllanthus amarus*	Egg woman	Broadleaf	Annual
5	*Talinum fructiscosum*	Waterleaf	Broadleaf	Perennial
6	*Triumfetta cordifolia*		Broadleaf	Perennial
7	*Commelina benghalensis*	Tropical spiderwort	Broadleaf	Perennial
8	*Asystasia gangetica*	Hunter weed	Broadleaf	Annual
9	*Sida acuta*	Broom weed	Broadleaf	Perennial
10	*Achyranthes aspera*	Devils whip	Broadleaf	Annual
11	*Alternenthera sissilis*	Sessile joy weed	Broadleaf	Annual
12	*Calapogonium mucunoides*	Calopo	Broadleaf	Annual
13	*Caladium bicolour*		Broadleaf	Annual
14	*Centrosema pubescens*	"Centro"	Broadleaf	Annual
15	*Axonopus compressus*	Broadleaf carpet grass	Grass	Annual
16	*Digitaria horizontalis*	Digit grass, crabgrass	Grass	Annual
17	*Panicum maximum*	Guinea grass	Grass	Perennial
18	*Mariscus alternifolius*		Sedge	Perennial
19	*Cyperus rotundus*	Purple nutsedge	Sedge	Perennial
20	*Cyperus esculentus*	Yellow nutsedge	Sedge	Perennial

Table 6: Effect of organic mulches on the density of broadleaf weeds (no/m^2) in maize in 2015 early- and late- cropping seasons

Mulch treatments	Early season 4 WAS	Early season 8 WAS	Early season 12 WAS	ES Mean	Late Season 4 WAS	Late Season 8 WAS	Late Season 12 WAS	LS Mean
	4	8 WAS	12		4	8 WAS	12	LS Mean
Ml	20.30ab	53.30a	66.00a	46.56ab	3.67c	7.00bc	11.67abc	7.44b
Cu	18.70ab	27.30ab	40.00ab	28.67bc	10.33b	23.67a	31.67a	21.89a
SD	6.70b	10.00b	13.30b	10.00d	2.67c	7.67bc	13.33bc	7.89b
DG	10.30ab	19.30ab	34.30ab	21.33bc	8.67bc	9.00bc	17.67bc	11.78b
Ml+SD	21.30ab	24.00ab	37.00ab	27.44bc	4.67c	7.00bc	11.33bc	7.67b
Cu+SD	35.00ab	43.30ab	51.70ab	43.33ab	4.67c	7.00bc	13.33bc	8.33b
Ml+DG	40.70ab	47.70ab	67.00a	51.78a	8.67bc	14.00bc	14.00bc	12.22b
Cu+DG	14.70ab	28.00ab	36.70ab	26.44bc	3.67c	8.67bc	12.00bc	8.11b
SD+DG	11.00b	10.70b	13.70b	11.78d	2.00c	5.33c	11.00c	6.11b
Unmulched control	39.00a	42.00ab	65.00a	48.67ab	13.00a	20.33a	29.00ab	20.78a

Means with the same alphabet(s) in the same column are not significantly different from each other at 5 % level of probability using DMRT

Keys: Treatments: Ml= Melon alone; Cu = Cucumber alone; SD = Sawdust alone;
DG = Dry Grass Mulch alone; Ml+SD = Melon+Sawdust; Cu+SD = Cucumber+Sawdust;
Ml+DG = Melon+ dried grass mulch; Cu+DG = Cucumber+ dried grass mulch;
SD+DG = Sawdust+ dried grass mulch; WAS = Weeks after sowing
Seasons: ES = Early season (March – July); LS = Late season (August – November)

Table 7: Influence of organic mulches on grass weed density (No/m^2) in 2015 early- and late- cropping seasons

Mulch treatments	Early season 4 WAS	Early season 8 WAS	Early season 12 WAS	ES Mean	Late Season 4 WAS	Late Season 8 WAS	Late Season 12 WAS	Late season
Ml	3.30b	15.72b	30.72ab	16.56c	4.33ab	5.67b	8.00ab	6.00b
Cu	33.30ab	53.02ab	69.72ab	52.00ab	12.33a	19.67a	25.67a	19.22a
SD	3.30b	06.72b	12.01b	7.33d	1.67b	6.33b	12.00ab	6.67b
DG	25.70ab	27.64ab	39.30ab	30.89bc	4.33ab	7.00b	10.33ab	7.22b
Ml+SD	20.00ab	25.33ab	38.00ab	27.78bc	1.00b	4.33b	7.67ab	4.33b
Cu+SD	20.03ab	35.34ab	41.30ab	32.22bc	3.33ab	5.00b	7.67ab	5.33b
Ml+DG	48.33a	50.72ab	65.30ab	54.78ab	2.33b	4.67b	7.00ab	4.67b
Cu+DG	18.73ab	12.01b	22.73ab	17.78cd	2.67b	4.33b	7.33ab	4.78b
SD+DG	4.71b	6.33b	19.00b	10.00c	1.33b	2.67b	4.67b	2.89b
Unmulched control	44.70a	73.00a	92.04a	69.89a	11.67a	14.33ab	22.67a	16.22a

Means with the same alphabet(s) in the same column are not significantly different from each other at 5 % level of probability using DMRT

Keys: Treatments: Ml= Melon alone; Cu = Cucumber alone; SD = Sawdust alone;
DG = Dry Grass Mulch alone; Ml+SD = Melon+ Sawdust; Cu+SD = Cucumber+ Sawdust;
Ml+DG = Melon+ dried grass mulch; Cu+DG = Cucumber+ dried grass mulch;

melon + dry grass at 4 WAS, and the unmulched control at 8 WAS in the early season (Table 6). Cumulatively in the early season, sawdust alone recorded the least grass weed density, followed by sawdust + dry grass, melon alone, and cucumber + dry grass, while the unmulched plots had the highest densities, indicating better grass weed suppression in that order.

In the late season, sawdust alone, melon + sawdust, and combinations of dry grass with cucumber, melon or sawdust significantly ($p < 0.05$) reduced grass weeds compared to cucumber alone and the control at 4 WAS. On the other hand, cucumber alone recorded significantly ($p < 0.05$) higher densities of grasses compared to all other treatments except the control at 8 WAS and sawdust + dry grass at 12 WAS. Generally, in the late season, all mulched plots, except cucumber alone, significantly ($p < 0.05$) reduced grass weed densities in comparison with the unmulched control.

3.6. Sedge weeds density

Table 7 shows the density dynamics of sedge weeds as affected by living and dead organic mulches. In the early season, sawdust alone, sawdust + melon and sawdust + dry grass recorded significantly ($p < 0.05$) lower density of sedges compared to dry grass alone and cucumber alone throughout the sampling periods, and melon alone at 4 and 12 WAS. Conversely, plots mulched with dry grass alone recorded significantly ($p < 0.05$) lower sedge densities than the unmulched control in the early season.

Sedge weed densities were generally low with no significant ($p > 0.05$) differences among treatments at 4 WAS in the late season. After that, all mulch treatments significantly ($p < 0.05$) reduced sedge weed populations except cucumber alone at 8 WAS, and cucumber and dry grass alone at 12 WAS

3.7. Weed dry matter (g/m^2)

Table 8: Effects of organic mulches on sedge weed density (No/m2) in the 2015 early and late cropping seasons

Mulch treatments	Early season 4 WAS	Early season 8 WAS	Early season 12 WAS	ES Mean	Late Season 4 WAS	Late Season 8 WAS	Late Season 12 WAS	Late season
Ml	26.70ab	28.30bc	39.00ab	31.33ab	4.00a	5.00b	7.67b	5.56b
Cu	29.30ab	34.00ab	41.70ab	35.00ab	8.67a	12.33a	18.67a	13.22a
SD	1.70c	2.30c	5.00c	3.00c	1.00a	3.33b	6.00b	3.44b
DG	36.70a	42.30a	52.30a	43.78a	3.33a	4.67b	10.33ab	6.11b
Ml+SD	0.70c	1.70c	4.30c	2.22c	0.00a	2.67b	6.00b	2.89b
Cu+SD	4.70c	12.70bc	20.00bc	12.44bc	2.00a	4.67b	9.00b	5.22b
Ml+DG	22.70bc	16.30bc	19.00bc	19.33abc	2.33a	6.67b	9.00b	6.00b
Cu+DG	0.70c	17.30bc	22.00bc	13.33bc	0.00a	2.00b	5.00b	2.33b
SD+DG	1.30c	1.70c	4.70c	2.56c	0.33a	1.67b	4.33b	2.11b
Unmulched control	10.70bc	16.00bc	21.00bc	15.89bc	8.00a	13.33a	18.33a	13.22a

Means with the same alphabet(s) in the same column are not significantly different from each other at 5 % level of probability using DMRT

Keys: Treatments: Ml= Melon alone; Cu = Cucumber alone; SD = Sawdust alone;
DG = Dry Grass Mulch alone; Ml+SD = Melon+ Sawdust; Cu+SD = Cucumber+ Sawdust;
Ml+DG = Melon+ dried grass mulch; Cu+DG = Cucumber+ dried grass mulch;
SD+DG = Sawdust+ dried grass mulch; WAS = Weeks after sowing
Seasons: ES = Early season (March – July); LS = Late season (August – November)

The influence of organic mulches on weed dry matter in the early- and late- maize cropping seasons is in Table 8. Weed dry matter was lowest and statistically (P > 0.05) similar across all the treatments at 4 WAS in both seasons. Saw-dust and sawdust + dry grass significantly (p < 0.05) reduced weed dry matter compared to melon alone, melon + cucumber, and the unmulched control at 8 WAS, and cucumber alone, melon alone and the sawdust alone.

3.8. Effects on soil physicochemical properties

Results of the soil physical and chemical properties on which the experiment was superimposed during both the early- and late- cropping seasons in 2015 are presented in Table 9. The soil remained strongly acidic before and after the experiment. The soil pH was 4.8 before but recorded a lower mean of 4.7 after the experiment. Similar results were obtained for some other chemical properties such as total nitrogen. Physical properties such as sand, silt and clay contents remained slightly unchanged as the texture of the soil did not change from its sandy loam status. However, some chemical properties were affected by some of the treatments that had sawdust components. Base saturation was improved from 59 % to 90 % in plots with sawdust alone and melon + dry grass, and up to 92 % in sawdust + dry grass. Similarly, the effective cations exchange capacity (ECEC) of the soil was increased from 4.30 cmol/kg by the application of treatments melon +SD, sawdust alone and dry grass alone, to 6.02, 6.38 and 6.36 cmol/kg, respectively. These were more than 40 % increments in the effective cations exchange capacity of the soil. Generally, the variations in the results of soil physicochemical properties were not significantly (p > 0.05) different from the initial soil values. The temperature range was between 29 and 31°C before the experiment commenced and after the experiment, the temperature range in the plots, which were treated with dry grass mulch and saw dust was between 26 and 27 °C, indicating that these treatments reduced soil temperature, though the seasonal influence could be a factor.

3.9. Effects on soil quality and conservation

As it was shown in the results, the quality of the soil was significantly (P<0.05) enhanced with the introduction of the mulch treatments. The base saturation of the soil was raised from 59 to 89 % while the treatment considerably conserved the other parameters such as soil pH, total nitrogen content, organic matter and the non-dynamic physical parameters. There were no significant changes in these soil parameters after the 8 months of experimentation (Table 9). By utilizing visual observation, one of the methods of assessing soil quality, it was observed that the soil was not eroded during the period of the experiment. The mulch material held the soil intact form detachment and transportation by the heavy rainfall of the study area (Table 1). These lent some credence to the treatment materials as they served a dual purpose of conserving the soil as well as suppressing weeds.

Table 9: Pre- and post- cropping physical and chemical properties of the soil used for the experiment

Mulch treatment		pH	Org. C (%)	TN (%)	Avail. P (mg/kg)	Ca^{+}	Mg^{++}	K^{+}	Na^{+}	Al^{3+}	H^{+}	ECEC	BS	Clay	Silt	Sand	Texture
						cmol/kg							%				
POST-CR	Ml	4.8	1.99	0.17	32.40	4.80	0.80	0.09	0.07	0.40	1.20	7.38	78.00	8.00	16.00	76.00	SL
	Cu	4.7	1.38	0.11	28.60	4.40	0.60	0.08	0.07	0.28	0.44	5.87	88.00	6.00	10.00	84.00	LS
	SD	4.9	1.46	0.12	40.00	4.80	0.80	0.10	0.08	0.20	0.38	6.38	90.00	10.00	11.00	79.00	LS
	DG	4.9	1.28	0.11	29.00	4.40	0.60	0.09	0.07	0.40	0.80	6.36	81.00	7.00	12.00	81.00	SL
	Ml+SD	4.8	1.34	0.11	26.00	4.00	0.60	0.08	0.06	0.60	0.68	6.02	79.00	8.00	11.00	81.00	LS
	Cu+SD	4.8	1.20	0.10	34.00	4.20	0.60	0.09	0.07	0.24	0.72	5.92	84.00	9.00	10.00	81.00	LS
	Ml+DG	4.6	1.14	0.09	22.70	4.20	0.60	0.09	0.07	0.20	0.36	5.52	90.00	11.00	11.00	78.00	SL
	Cu+DG	4.6	1.28	0.11	26.87	3.60	0.60	0.07	0.06	0.48	1.08	5.89	73.00	8.00	13.00	79.00	SL
	SD+DG	4.6	1.63	0.14	28.87	4.60	0.80	0.10	0.08	0.00	0.48	6.06	92.00	9.00	12.00	79.00	SL
Unmulched control		4.7	1.28	0.10	30.60	4.00	0.60	0.08	0.06	0.28	0.76	5.78	82.00	9.00	12.00	79.00	LS
Mean		4.7	1.40	0.12	29.90	4.30	0.66	0.09	0.07	0.31	0.69	6.12	83.70	8.50	11.80	79.70	SL
PRE-CR	Composite	4.8	1.46	0.12	42.00	2.00	0.40	0.08	0.06	0.00	1.76	4.30	59.00	5.70	16.00	78.30	SL

Treatments: Ml= Melon alone; Cu = Cucumber alone; SD = Sawdust alone; DG = Dry Grass Mulch alone; T06 = Melon+ Sawdust; Cu+SD = Cucumber+ Sawdust; Ml+DG = Melon+ dried grass mulch; Cu+DG = Cucumber+ dried grass mulch; SD+DG = Sawdust+ dried grass mulch.
Control = bare soil with sole maize.
Seasons: ES = Early season (March – July); LS = Late season (August – November); WAS = Weeks after sowing.
Soil parameters: Org. C = Organic carbon; TN = Total Nitrogen; Avail P = Available phosphorus; Ca = Calcium; Mg = Magnesium; K = Potassium; Na = sodium; Al = Aluminum; H = hydrogen ion; ECEC = Effective cation exchange capacity; BS = Base saturation;
SL = Sandy Loam; LS = Loamy sand; PRE-CR = Pre- cropping; POST-CR = Post- cropping.

3.10 Relationships among selected weed, crop and soil parameters

The relationships among some weed parameters, crop growth and grain yield components and selected soil physicochemical properties were studied using Pearson Correlation Coefficients (r). Table 10 shows that maize grain yield correlated negatively with weed density in both cropping seasons. The correlation coefficients (r) between maize yield and weed density ranged from -0.12 to -0.38. Weed density also correlated negatively with soil parameters; with 'r' values of -0.21 and -0.27 recorded between weed density and ECEC and clay content of the soil, respectively. Weed density also affected maize heights negatively, with 'r' values of -0.16 to -0.17 in early and late seasons, respectively. The soil parameters correlated positively with plant growth and yield. Soil pH and available phosphorus showed 'r' values of 0.37 and 0.57, respectively with maize height.

Similarly, grain yield returned 'r' values of 0.35 and 0.34 with available phosphorus and base saturation, respectively. However, weed dry matter correlated positively with

Table 10: Correlation matrix (r) of selected weed, crop and soil parameters in the 2015 early and late maize cropping seasons.

	WD ES	WD-LS	Grain Yield – ES	Grain Yield – LS	Soil pH	Avail. P.	Soil ECEC	Soil Clay content	Soil Base Sat.	WDM
WD-ES	1									
WD-LS	0.69	1								
Grain Yield –ES	-0.36	-0.32	1							
Grain Yield –LS	-0.38	-0.12	0.67	1						
Soil pH	-0.14	-0.08	0.64	0.25	1					
Avail. P.	-0.39	-0.04	0.35	0.33	0.64	1				
Soil ECEC	-0.21	-0.27	0.71	0.25	0.53	0.47	1			
Soil clay	-0.13	-0.37	-0.31	0.13	-0.20	0.09	-0.24	1		
Base Sat.	-0.12	0.11	-0.25	0.34	-0.10	0.16	-0.28	0.41	1	
WDM	0.77	0.87	-0.19	-0.14	-0.13	-0.14	0.03	-0.36	-0.16	1

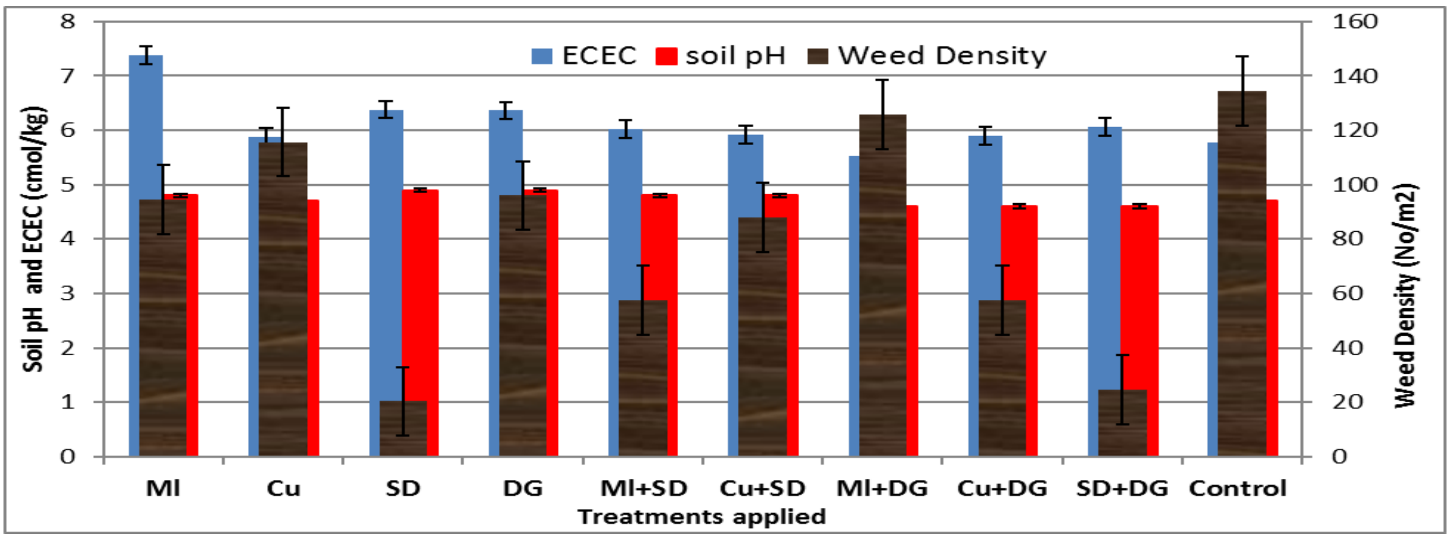

Fig. 2. Relationships between weed density and some soil fertility indicators in the early rainy season

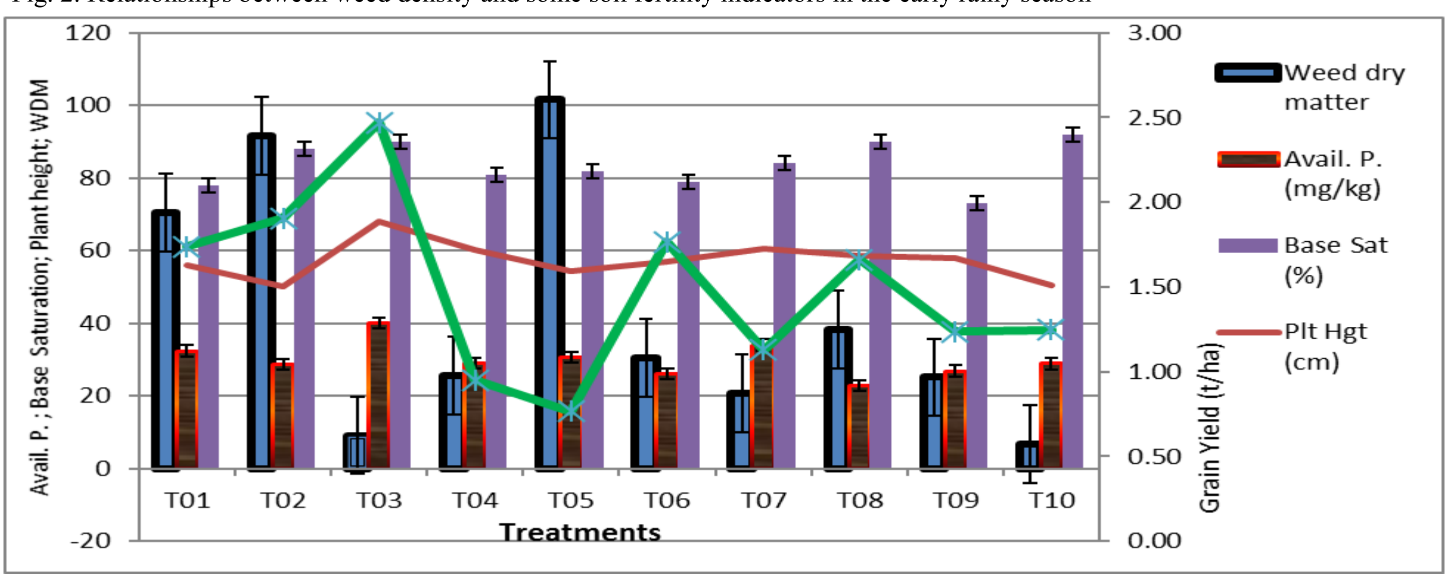

Fig. 3. Relationships between weed dry matter, crop yield and soil parameters in the late rainy season

weed density, with 'r' values of 0.77 in the early- and 0.87 in the late planting seasons. The fact is that weed dry matter was directly obtained from the weeds flora.

Figure 4 shows the relationships between some edaphic factors and the crop grain yield under the various treatments in the early-season planting. The figure revealed that weed density was a primary set- back to crop yield. The higher the weed density bar, the lower the yield of the crops. The lowest yield was obtained where the weed density was highest at the un-mulched control, while the highest yield (3.40 t/ha) was obtained where the soil effective cations exchange capacity was highest with melon alone. Soil reactions (pH) seem not to have any effect as it remained nearly constant in all treatment. In the late-season planting (Fig. 5), the grain yield of maize crop followed the same pattern as in the early season. Where weed dry matter was least, the yield of maize was most significant as observed with sawdust alone as mulching material.

4.0. Discussion

'Egusi' melon vines attained quicker and greater ground coverage than cucumber at 4 and 6 WAS in the early season, which resulted in relatively lower weed density in the former than the latter. This could be attributed to faster early growth and spread of melon, which enabled it to cover a broader area of the soil and smother weeds better than a cucumber in the sole plots. Fast early growth, quickly spread, and profuse branching is among the crop features that enhance their competitiveness against weeds (Akobundu *et al.*, 1999; Nwagwu, 2004). Akobundu et *al.* (1999) and Ekeleme *et al.* (2003) had earlier reported that legumes and cover crops are useful in smothering weeds and improve soil fertility. However, weed suppressive ability of smother crops can differ according to species and cultivar. Nwagwu *et al.* (2000) reported broader ground coverage, longer life span and hence, better weed suppression by pumpkin (*Cucurbita pepo*) than 'Egusi' melon in cocoyam field at Ibadan, south-western Nigeria. In this study, melon spread faster and smothered weeds better than a cucumber in the early season as seen in its ability to reduce grass weeds significantly at 4 WAS compared to cucumber alone. However, the inability of either cover crops used in this study to attain full (100 %) created niches for weeds to thrive, thereby necessitating additional measures for effective weed control. As a result, sole plots of the live mulches recorded statistically higher weed density and weed dry matter values than those combined with dead plant mulches or the dead mulches alone at most sampling periods.

The general decline in the coverage of melon and cucumber from 8 WAS could be attributed to senescence of the smother crops and this further created niches for weed resurgence in those plots. This finding indicated that, while an in-situ live mulch can provide early weed suppression, it may not offer all-season weed control, especially if it has a short life span.

Mulching with sawdust alone or sawdust in combination with dry grass gave the best reduction in weed density and weed dry matter and reduced numbers of weeds irrespective of the morphological group. Several reasons could be adduced for the more effective weed suppression by sawdust alone or in combination with dry grass compared to the live mulches or dry grass alone. First, the early (3 days before sowing) and even application of sawdust on the soil surface coupled with the thickness of the biomass must have left little or no niches for weeds to thrive, and enhanced its ability to impede weed seedling emergence and deny weed propagules of direct sunlight. Secondly, it is possible that leachates and decaying matter from the sawdust could have contained allelochemicals that affected weeds, though this was not determined in the study.

On the other hand, the significantly higher population of sedges in plots mulched with dry grass compared to the un -mulched plots could be that the grass mulch contained viable sedge weed seeds or propagule like tubers, which were unconsciously introduced into the plots through the grass mulch. Previous research findings indicated that extraneous weeds could be introduced into crop farms through applied organic materials such as grass mulch and animal dung (O'Gara, 2010).

Generally, the different mulch treatments, except sole cucumber, provided superior weed suppression, by recording consistently lower weed density and weed biomass compared to no mulching in the late season. This finding indicates that the mulches were effective in weed control. At this point, it is essential to note that, the concept of 'less is better (LIB)' as was proposed by Lal (1998) for soil quality could be adopted in weed studies as well. This was well observed and illustrated in the study where the weeds were highest in control plots without mulch, which consequently translated to lower grains yields of the test crop, *Zea mays.* The trend was similar in both early and late planting season. It could, therefore, be corroborated that weed infestation could drastically reduce the yield of crops (Jhale *et al.,* 2016; FAR-FOCUS, 2013).

Broadleaf weeds predominated the field during the period of study. This could be attributed to the dominant weed flora in the ecosystem studied. The preponderance of annual broadleaf and grass weeds compared to perennials in the research field agrees with the findings of Baberi and Casino (2001) that, frequent soil disturbance leads to weed species succession in favour of annuals. However, all the sedges present were perennials, namely *Marischus alternefolius, Cyperus seculentus and Cyperus rotundus.* These *Cyperus* spp., which are among the world's worst weeds, reproduce sexually and asexually via tubers and are therefore difficult to control. Their resilience and ability to proliferate rapidly could further account for why these sedges predominated the plots mulched with dried weeds.

Mulching with sawdust alone enhanced most growth parameters of maize compared with the no mulch treatment, while other mulch treatments did not show a consistent pattern in both seasons, but most recorded higher values than the un-mulched control. Saw-dust stood out as the best mulch materials for enhancing the vegetative performance of maize. The scientific deduction from this observation would be that sawdust alone was able to suppress weeds and conserve soil moisture for the crop at the early stage of growth of the maize crop. This was followed by dry grass mulch. Ogbonnaya (2012) noted that sawdust used as mulch around the base of the plant, not more than 15 cm could impede weed growth and improve plant growth. Williams (2015) also reported that organic mulches usually increase growth rate in plants. Eze *et al.* (2009) further reported that mulch treatment consistently produced the tallest plants in sorghum and millet during the vegetative growth period. In this study, the numbers of leaves were significantly different at the early stages of growth, but in later growth stages, there were no differences among the various treatments in the number of leaves per maize plant, as growth became sluggish.

4.1. Summary and Conclusion:

A two-season field experiment was conducted at the University of Calabar Teaching and Research Farm, to evaluate the effect of organic mulches on weed suppression, soil physicochemical properties and the performance of maize. Ten treatments comprising a living and dried grass mulches and an unmulched control were used. The sole- live treatments were melon and cucumber, while the sole-dead organic materials were sawdust and dried grass mulch. The dead mulches and smother crops treatments were also combined in a 1:1 manner.

Melon demonstrated quicker ground coverage, and better weed suppression at 4 WAS than the cucumber. The test crop growth parameters were positively affected as there were some significant differences in maize height, the number of leaves per plant and stem girth amongst the treatments at the earlier stages of growth (4 to 6 WAS). Treatments with SD and SD+DGM proved superior to the smother crops throughout the study, as the treatments were able to reduce weeds proliferation. Sole sawdust and sole melon mulches significantly enhanced maize grain yield compared to no-mulch treatment.

The results of the experiment, as revealed by the soil analysis, showed that neither the chemical properties nor the physical properties were significantly changed as a result of the treatments. The soil was highly acidic and outside the acceptable range for maize production. The pH was 4.8 at the initial stage but reduced to a mean of 4.7 after the experiment. The percentage base saturation increased from 59% at the initial stage to 90% after treating with sawdust. In this research, two smother crops (melon and cucumber) and two dead mulch materials (dried grass clippings and sawdust from machine-sawing of wood) were used to suppress weeds and conserve soil moisture in an organically managed maize field.

5.0. Conclusion

It is concluded that sawdust treatment and its combination with dry grass mulch can suppress weeds effectively more than the smother crops (melon or cucumber). Slow growing smother crops such as cucumber allowed broadleaf weed to proliferate in the field, as it was unable to cover the soil at early stages of crops growth. Combining cover crops with dry-grass mulch did not prove more effective than sole use of the mulch materials. Dry grass mulch alone did not prove significantly different from other treatments as it increased the proliferation of grasses weed density in the field. Dry grass mulch may have shredded weed propagule into the soil, thereby increasing the soil weed seed bank. Sawdust was found to increase nutrient, soil available water and practically did not compete with the test crop for soil nutrients and energy. Therefore, for the sustainability of the treatment on the crop and soil, there is a need for the liming materials to be added to the soil specifically for maize cultivation, as the pH was extremely low.

5.1. Recommendations

From the initial findings and conclusions, it is recommended that:

i. The use of smother crops like melon and cucumber should not be relied upon as the sole means of weed control as it does not last long and weed control is not complete to the end of the crop cycle. The use of smother crops such as melon and cucumber as intercrops with maize should be reconsidered due to possible competition with maize by the smother crops for the soil nutrients, available soil water and space for energy. However, in mixed cropping, the distance between the crops can be increased, and the complementary yield of the smother crops will increase the economy of the farm. Yields were not significantly reduced

ii. The best treatment for both weed suppression and soil fertility improvement was the use of sawdust at the thickness of 5 cm above the soil surface, as practically done in treatment with sawdust alone in this work. The sawdust will suffocate the weeds, control soil water evaporation, thereby conserving the available water for crops uptake and eventually, it decomposes fast and adds some nutrients into the soil since the sawdust is in small bits. Saw-dust is therefore recommended for weed control and soil enhancement in maize if findings of this study are confirmed by further research.

iii. To reduce the cost of weeding, which is the most tedious of farming operations, farmers should adopt some methods needed to increase the yields for the production of maize. Thus, organic mulches and smother crops are recommended for the production of short duration crops to smother weeds to reduce the cost weeding and increase production as well as having some economic benefits from the living plants used in smothering weeds. Care must be taken in when applying the dry grass mulches so as not to introduce weed seeds through plant propagules like the roots and rhizomes, etc.

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