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Effects of Residue Mulch on Weed Growth, Pod Yield and Nutrient Contents in Okra *(Abelmoschus esculentus)* in the Humid Tropical Zone of Southwestern Nigeria

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ABSTRACT: Field experiments were carried out in the early and late seasons of 2000 at the Teaching and Research Farm of The Federal University of Technology, Akure (327 m above sea level; Long. 7^0 16'N, Lat. 5^0 12'E), in the rainforest zone of Southwestern Nigeria, to evaluate the effects of selected weed and tree mulch materials on weed control and okra [*Abelmoschus esculentus* (L.) Moench] yield. Air-dried *Calopogonium mucunoides*, *Chromolaena odorata*, *Panicum maximum*, *Aspilia africana*, *Pennisetum purpureum* clippings and *Tectona grandis* leaves were each applied as mulch materials at 15 t/ha in a randomised complete block design, using three replications per treatment. Unmulched plots were included as control treatment. *A. esculentus* was sown at one plant/hill spaced 60 x 30 cm (i.e. 55, 556 plants/ha). Weed density, dry weight and weed control efficiency (WCE), okra growth, pod yield and nutrient contents were recorded. *Tectona* leaf mulch suppressed weed emergence most distinctly ($p < 0.05$) over time, followed by *Aspilia* and *Panicum* mulch. Okra exhibited better shoot growth in mulched plots than in control plots, and early-season growth was distinctly better in *Aspilia* mulch than in other mulch materials. In the late season, crop shoot growth in *Aspilia*, *Calopo*, *Chromolaena* and *Tectona* mulch were at *a par* and significantly ($p \leq 0.05$) better than in control, *Pennisetum* and *Panicum* mulch. Residue mulching did not significantly affect okra pod size in the early season but *Tectona* mulch gave distinctly better pod length and pod yield, compared well with values from *Calopo*, *Chromolaena* and *Aspilia* mulch in pod diameter and with *Aspilia* mulch in pod yield. Residue mulching did not influence pod K, Ca and Mg contents in the early season and all nutrients in the late season. However, pod N in *Aspilia* and *Chromolaena* mulch, and pod P in *Tectona*, *Calopo* and *Panicum* mulch were distinctly higher than in other treatments in the early season. On the average, okra growth, yield and pod quality were better in *Tectona* and *Aspilia* mulch, and these could be attributed to the distinctly superior tissue organic matter content, total exchange acidity and WCE of these mulch materials.

***Keywords*:** Residue mulching, weeds, pod quality

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INTRODUCTION

Mulching is very effective in mechanical and biochemical (allelopathic) weed suppression (Gill *et al*., 1992; Mloza-Banda and Meterechera, 1999; Schonbeck, 2020). The practice also helps to minimize herbicide and labour requirements for weed control and even obviates herbicide use for vegetable production (Poll, 1997; Schonbeck, 1998). The effectiveness of residue mulching in weed suppression, particularly straw mulching, which is one of the cultural weed control methods in tropical vegetable farms has been extensively reported (Aiyelaagbe and Fawusi, 1986; Okugie and Ossom, 1988; Yakubu and Adewale, 1994; Okhiria *et al*., 1995; Karaye and Yakubu, 2006; Olabode *et al*., 2007).

Generally, mulches reduce the survival of every plant which comes under the mulch surface, crop or weed species populations (Kader *et al*., 2019). Additional benefits of the residue mulch include improved growth and yield of vegetable crops arising from soil protection, improved root growth and proliferation of surface soil, increased fungal populations and organic matter, supply of essential plant nutrients, water- and nutrient-use efficiencies (Budelman, 1991; Tian *et al*., 1994; Sangakkara *et al.,* 2004; Ojeniyi *et al*., 2012; Agbede *et al*., 2014; Iqbal *et al*., 2020; Soni, 2021).

In a rainforest location, grass (*Digitaria horizontalis* Willd.) clippings were more effective in weed suppression in the long term due to greater soil persistence and sustained weed control efficiency (WCE) in *Basella alba* L., than legume (*Calopogonium mucunoides* L.) clippings in the long term, due to rapid decomposition of legume mulch (Smith, 2008, 2017). Crop growth and yield increased markedly with mulch WCE from lower (6,12 t/ha) to medium (12, 15 t/ha) in grass mulch, and from medium (12 t/ha) to higher (18 t/ha) rate in legume mulch. Differential crop growth and edible yield were due to mulch type, soil fertility, crop water and nutrient uptake and nutrient-use efficiency.

In okra, *Calopo* mulch (CM) gave better crop growth and yield than NPK fertilizer, and minimum weed density compared to lime, wood ash, NPK fertilizer, poultry manure and unamended soil (Smith and Ajayi, 2004; 2005). Similarly, Smith and Akinseye (2005) revealed that residue mulching with *Tectona grandis* leaves, *Tithonia diversifolia* twigs and Fallow mulch each applied at 5 t/ha during okra establishment enhanced weed growth in the early season, but suppressed weed growth considerably in the late season. *Tectona* was more effective in weed suppression than Fallow and *Tithonia* mulch. The integration of *Tectona* mulch at 5 t/ha, 10 kg/ha NPK and 4 t/ha poultry manure is suggested for optimum weed control and okra pod yield and quality. Recent reports (Smith and Fasanmi, 2016) confirmed the superiority of *Tectona* applied at 5 t/ha to Fallow and *Tithonia* mulch in both dry- and wet- season okra. In a forest-savanna transition location, Bello (2019) reported that *Tectona* applied at 15 t/ha showed distinctly higher WCE, followed by *Aspilia africana* and *Calopo* mulch in both early- and late-season okra. Similarly, okra treated with *Tectona* mulch was superior in almost all pod yield parameters, especially pods/plant and pod fresh yield in both seasons. Elsewhere, weed growth and cover under hay mulches and chipped kenaf straw were substantially reduced in tomato, transplanted onion, pepper and cabbage (Russo *et al.*, 1997; Schonbeck, 1998).

In Nigeria, previous reports on the effects of residue mulching in okra were on growth and yield benefits (Ojeniyi and Adetoro, 1993; Smith *et al*., 2001; Smith and Akinseye, 2005; Smith and Ajayi, 2004, 2005; Smith, 2008, 2017; Smith and Fasanmi, 2018; Bello, 2019). However, successful commercial production of okra depends not only on the quantity of consumable pods but also on sustenance of profitability, which largely depends on the quality of consumable pods and the associated global demand. The objective of this study therefore, was to assess the effects of mulch materials from some important fallow weeds (*C. mucunoides*, *Chromolaena odorata* L.M. King & Robinson, *A. africana* (Pers.) C.D. Adams, *Pennisetum purpureum* Schumach., *Panicum maximum* Jacq.) and non-legume agroforestry species (*T. grandis* L.) on weed control and pod nutrient contents in the rainforest agroecozone of Southwestern Nigeria.

MATERIALS AND METHODS

The experiments were carried out in the early (May-July) and late (Sept.-Nov.) seasons of 2000, at the Teaching and Research Farm of the Federal University of Technology, Akure (327 m above sea level; Long. 7^0 16'N, Lat. 5^0 12'E) in the rainforest zone of Southwestern Nigeria. Soil samples were randomly collected from the experimental area for analysis of physical and chemical properties; particle analysis was by hydrometer method of Bouyoucos (Bouyoucos, 1951); phosphorus by Bray-P1 method (Bray and Kurtz, 1945); exchangeable bases by atomic absorption spectrophotometer (Ca, Mg), and flame photometer (K); organic carbon by the method of Walkley and Black (1934) and converted to organic matter by using a factor 1.724; total nitrogen by the macro-Kjeldahl method (Jackson, 1962). The soil was a sandy clay loam containing 6.4% organic matter, 0.15% N, 0.001% P, 0.14% K, 0.10% Ca and 0.05% Mg. Mulch samples were analyzed for their tissue organic matter and exchangeable acidity (determined by the KCl extraction method; Jackson, 1962) in other to obtain preliminary information on mulch persistence on soil surface (Table 1).

The experimental area (14.5 x 8.0 m) was manually cleared, and the plant debris allowed to decompose over two weeks before sowing okra seeds into manually prepared 2 x 2 m seedbeds, at two seeds per hill and 60 x 30 cm spacing. There were seven treatments, viz. 15 t/ha each of air-dried *C. mucunoides*, *C. odorata*, *P. maximum*, *A. africana* and *P. purpureum* clippings and *T. grandis* leaves, and an unmulched (unweeded) control, arranged in a randomized complete block design (RCBD) and replicated three times. The mulch materials were uniformly applied on the seedbeds. Weed samples were collected from two 20 x 20 cm quadrats randomly-placed in each plot at 3 and 5 WAT (weeks after treatment, equivalent to 5 and 8 weeks after planting okra), counted and oven-dried at 80^0C for 48 hr. WCE was calculated from weed density (WD) using the procedures described by Subramanian *et al.* (1991), viz. WCE%= WDC-WDT x 100/WDC, where WDC= weed density in control plot and WDT= weed density in treated plot. Okra plant height, stem girth, leaves plant, leaf area, pod yield parameters and nutrient (N, P, K, Ca, Mg) contents were recorded. All data collected were subjected to analysis of variance (ANOVA) and the means compared using the Least Significant Difference (LSD) test at P= 0.05.

Table 1: Tissue organic matter and exchangeable acidity of selected mulch materials

Mulch materials	**Organic matter (%)**	**Exchangeable acidity (meq 100 g^{-1})**
Calopogonium mucunoides L.	88.8	4.2
Chromolaena odorata L.M. King & Robinson	82.3	3.9
Tectona grandis L.	91.2	10.0
Aspilia africana (Pers.) C.D. Adams	79.2	9.2
Pennisetum purpureum Schumach.	87.5	7.3
Panicum maximum Jacq.	86.8	3.4

RESULTS AND DISCUSSION

Weed growth and control

In the early season, *Tectona* mulch gave distinctly lower weed growth compared to other treatments, and distinctly higher WCE in established okra followed weakly by *Aspilia* mulch, and negative WCE in other treatments (Table 2). In the late season, *Tectona* mulch also gave a distinctly lower weed growth and a relatively appreciable WCE, followed by *Pennisetum* and *Panicum* mulch, and negative WCE values in other treatments. On the average, weed density and dry weight were distinctly lower in *Tectona* mulch than in other treatments.

Of all the mulch materials used in this study, *Tectona* leaf mulch was the most persistent, and this coupled with the thickness and larger unit leaf surface area, quasi-continuous soil coverage due to dense packing on the soil surface and distinctly high organic matter (91.2%, Table 1), lignin (1.3%; Bello, 2019) and saponin (1.92%; Bello, 2019) contents, enhanced mechanical hindrance to weed emergence through the distinctly high WCE.

These observations agree with the reports of Budelman (1991), Smith and Akinseye (2005), Schonbeck and Tillage (2011) and Saunders (2018). The possible contribution of high tissue exchangeable acidity in *Tectona* mulch to soil pH and allelopathic effects is also indicated in this high weed control efficiency. In the absence of *Tectona* leaves, *Aspilia* (0.5% lignin, 3.80% saponin; Bello, 2019) mulch could be used in the early season, and *Pennisetum* (0.3% lignin, 1.26% saponin; Bello, 2019) and *Panicum* (0.4% lignin, 1.32% saponin; Bello, 2019) mulch in the late season, at a higher rate to ensure a thicker, extensive ground cover, and/or supplemented with one timely early hand-weeding at the current rate of 15 t/ha, for effective weed control.

Contrarily, the ineffectiveness of *Calopo* and *Chromolaena* mulch in weed control can be primarily attributed to their considerably low lignin (0.6%, 0.2% respectively; Bello, 2019) and saponin (0.91%, 0.4% respectively; Bello, 2019) contents and ease of biodegradation (Smith and Alli, 2007; Smith, 2008, 2017), in spite of their moderate tissue organic matter contents (Table 1). This, in addition to the potentially high nutrient additions and improved soil conditions (Schonbeck and Tillage, 2011; Liang *et al*., 2002; Smith *et al*., 2006; Ojeniyi *et al*., 2012; Smith, 2017) under the latter two mulch materials encouraged rapid weed emergence and more aggressive weed infestation during okra growth. Traditionally, *Chromolaena* residue mulch is largely used for soil fertility maintenance for sustainable crop production (Ojeniyi *et al*., 2012), especially vegetable production (Lal *et al*., 1980; Ilori *et al*., 2011) under dry-season irrigation (Ojeniyi and Adetoro, 1993).

Table 2: Effect of residue mulching on weed growth in the early season at 3 and 5 weeks after treatment (WAT) in the early and late seasons

Mulch treatments	WAT 3	WAT 5	WAT 3	WAT 5	Mean WCE (%)
	Weed density ---(no. m^{-2})---		Weed dry weight ----(g m^{-2})----		
Early season					
Control	22.3	49.3	2.6	18.7	-
C. mucunoides	35.3	70.0	0.8	16.5	-24.3
C. odorata	25.3	95.3	1.4	13.4	-39.4
T. grandis	14.0	32.7	0.4	6.3	42.9
A. africana	25.3	84.7	3.0	20.9	12.2
P. purpureum	30.0	98.7	1.6	15.1	-37.4
P. maximum	32.7	87.7	1.8	20.0	-74.2
LSD (0.05)	5.9	38.7	NS	6.4	-
Late season					
Control	40.7	26.0	4.5	64.0	-
C. mucunoides	44.0	26.0	0.8	83.0	-0.3
C. odorata	37.0	33.0	1.4	103.0	-5.3
T. grandis	10.0	15.0	0.4	26.0	19.9
A. africana	36.0	34.0	2.7	77.0	-5.3
P. purpureum	23.0	30.0	2.3	93.0	11.7
P. maximum	30.0	32.0	2.0	71.0	6.7
LSD (0.05)	9.1	7.1	1.4	15.9	-

Okra growth, yield and pod nutrient contents

Okra growth was considerably better in mulched plots than in unmulched (control) plots in both seasons (Tables 3-6). Organic plant mulch, including those used in the current study, enhances both soil and crop productivity through its effects on soil physical, chemical and biological conditions (Lal *et al*., 1980; Awodun and Ojeniyi, 1998; Tian *et al*., 1994; Smith and Alli, 2005; Soni, 2021). The embedded effect of initial nutrient release from decayed plant debris before sowing okra is also indicated.

In the early season, *Aspilia* mulch gave distinctly ($p<0.05$) taller established okra plants and larger crop leaf area than all other treatments in which okra plants were uniformly shorter with considerably smaller leaf areas (Tables 3-4). Residue mulch did not significantly influence pod length, pod diameter, and pod K, Ca and Mg contents of okra (Table 5). Contrarily, pod fresh weight was significantly higher in *Aspilia*, *Tectona* mulch and control plots than in other treatments, in which pods produced relatively comparable fresh weights. *Aspilia* and *Tectona* mulch gave distinctly higher pod N and P contents, respectively than other treatments. In the late season, established okra in *Aspilia*, *Tectona*, *Calopo* and *Chromolaena* mulch were significantly taller, had considerably larger leaf areas and apparently thicker stems than those in *Pennisetum*, *Panicum* mulch and control treatments (Tables 3-4). However, leaves plant was distinctly higher in *Tectona* mulch than in other treatments. Okra pod nutrient contents did not significantly differ with residue mulch treatments (Table 6). Contrarily, pod length and fresh weight were distinctly higher in *Tectona* mulch than in other treatments. Also, pod diameter in *Tectona* mulch was comparable to those in *Calopo* and *Aspilia* mulch, but these were all significantly higher than in other treatments. Apparently, control plots gave the lowest pod yield, and pod N, P and K contents, in spite of the comparable pod fresh weight, pod length and diameter with okra in *Panicum* mulch. Olabode *et al*. (2007) reported similar findings on okra response to mulching in a savanna location.

Evidently, the effects of residue mulching on okra growth, pod yield and nutrient contents vary with the mulch type and resistance to decomposition. Of particular importance are the contrasting tissue organic matter and exchangeable acidity of the mulch materials (Table 1) which may explain the distinct efficiency of the persistent *Tectona* mulch both in weed control and soil protection (Kang *et al*., 1990; Opara-Nadi, 1993; Tian *et al*., 1994). Smith (2008) attributed differences in *B. alba* performance in mulched plots to differential soil fertility under grass (*Digitaria*) and legume (*Calopo*) clippings arising from residue quality and decomposition. However, the parity of pod fresh weights in control and *Aspilia* and *Tectona* mulch in the early-season crop in the current study (Table 5) may be due to rapid soil mineralization in the control plots. The partial contribution of season to differential crop response in residue mulch materials is indicated by the superior benefit of *Aspilia* mulch in the early season, and *Tectona* mulch in the late season (Tables 3-6), on okra growth and yield (Smith and Akinseye, 2005; Smith, 2006; 2008). The possible contribution of differential water and nutrient uptake, and nutrient-use efficiency of okra to pod yield and quality response in contrasting mulch materials may be attributed to the generally poor soil fertility benefits of the residue mulch materials used in the current study on pod nutrient composition.

Table 3: Vegetative growth response of okra NHAE 47-4 to residue mulching at specified weeks after treatment (WAT) in the early season

Mulch treatments	WAT		WAT	
	5	8	2	5
	Plant height (cm)		Leaf area (cm^2)	
Control	14.1	33.3	15.9	153.7
C. mucunoides	14.6	34.0	14.6	176.8
C. odorata	14.2	35.2	22.4	165.3
T. grandis	13.1	33.3	19.9	154.7
A. africana	19.9	51.7	30.4	278.9
P. purpureum	13.0	31.3	15.4	178.8
P. maximum	13.0	30.9	14.0	150.5
LSD (0.05)	3.43	7.79	6.47	74.91

Table 4: Vegetative growth response of okra NHAE 47-4 to residue mulching at specified weeks after treatment (WAT) in the late season.

Mulch treatments	WAT		WAT		WAT		WAT
	2	8	5	8	5	8	8
	Plant height (cm)		Stem diameter (cm)		Leaves $plant^{-1}$ (no.)		Leaf area (cm^2)
Control	8.1	22.9	3.5	3.5	5.3	8.1	237.9
C. mucunoides	9.7	33.2	4.1	4.2	6.8	7.4	508.3
C. odorata	8.6	31.2	3.8	3.8	6.2	7.8	493.6
T. grandis	8.5	33.5	4.1	4.2	9.1	11.3	505.9
A. africana	9.3	34.2	4.4	4.0	6.6	8.0	480.3
P. purpureum	9.0	29.5	3.4	3.4	5.9	7.6	363.0
P. maximum	8.3	25.2	3.2	2.9	5.3	7.0	380.5
LSD (0.05)	0.89	5.05	0.67	0.56	1.23	0.96	66.11

Table 5: Pod yield response and nutrient contents of okra NHAE 47-4 to residue mulching in the early season

Mulching treatments	Pod length (cm)	Pod diameter (cm)	Pod fresh weight (g $plant^{-1}$)	N	P	K	Ca	Mg
				Pod nutrient contents (%)				
Control	8.8	10.2	34.4	2.67	0.48	0.03	2.91	0.52
C. mucunoides	8.3	9.6	30.7	3.20	0.71	0.04	2.75	0.40
C. odorata	8.1	9.4	26.8	3.75	0.62	0.05	2.89	0.45
T. grandis	8.4	9.8	33.0	3.20	0.79	0.04	2.15	0.51
A. africana	9.7	10.0	38.4	3.98	0.61	0.05	2.16	0.38
P. purpureum	8.1	9.0	31.0	3.09	0.65	0.05	2.30	0.48
P. maximum	7.6	8.6	22.1	3.46	0.68	0.05	2.69	0.45
LSD (0.05)	NS[a]	NS	7.9	0.67	0.16	NS	NS	NS

[a]NS= Not significant at p= 0.05.

Table 6: Pod yield response and nutrient contents of okra NHAE 47-4 to residue mulching in the late season

Mulching treatments	Pod length (cm)	Pod diameter (cm)	Pod fresh weight (g plant^{-1})	Pod nutrient contents N	P	K (%)	Ca	Mg
Control	4.7	7.7	35.8	2.68	0.48	0.03	2.91	0.52
C. mucunoide	*s*5.9	8.9	90.6	3.20	0.71	0.04	2.75	0.40
C. odorata	5.9	8.5	78.8	3.75	0.62	0.05	2.89	0.45
T. grandis	6.7	8.7	215.0	3.20	0.79	0.04	2.15	0.51
A. africana	5.9	8.8	137.5	3.98	0.61	0.05	2.16	0.38
P. purpureum	4.9	7.9	40.8	3.09	0.65	0.05	2.30	0.48
P. maximum	4.9	7.7	32.0	3.46	0.68	0.05	2.69	0.45
LSD (0.05)	0.6	0.8	83.3	NS	NS	NS	NS	NS

[a]NS= Not significant at p= 0.05.

CONCLUSION

Okra was most productive under *Tectona* and *Aspilia* mulch mainly due to the highly favourable soil conditions for okra growth, primarily attributed to their distinctly superior tissue organic matter, total exchangeable acidity and WCE, compared to other residue mulch materials. Further research is necessary however, to characterize the quality of the mulch materials used in this study with respect to C/N ratio, polyphenol and lignin contents, and the dynamics of mulch degradation, in other to better understand their potential benefits in conservation agriculture for sustainable production of okra and other important warm-season vegetables.

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