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EFFECT OF *Dactyladenia barteri* MULCH AND NPK FERTILIZER ON WEED DENSITY, GINGER PRODUCTION AND SOIL RECAPITALIZATION IN UMUDIKE, SOUTHEAST NIGERIA

[1]Ekeledo P.I. and *[2]Chukwu G.O.

[1]National Root Crops Research Institute, Umudike, Abia State, Nigeria
[2]Department of Soil Science & Land Resources Management,
Michael Okpara University of Agriculture, Umudike, Abia State, Nigeria

*Corresponding author's email: chukwu.godwin@mouau.edu.ng

ABSTRACT

A field study conducted on a Gleyic Luvisol in Umudike, southeastern Nigeria, in 2017 and 2018 evaluated the effect of Dactyladenia barteri mulch and NPK fertilizer 15:15:15 on weed density, ginger production and soil health. Treatment consisted of three levels of mulch (0, 2 and 4 t ha^{-1}) and two levels of NPK fertilizer (0.00 and 400 kg ha^{-1}) laid in a randomized complete block design with 3 replicates on 2 × 2 m plots, using 0.20 × 0.20 m spacing. Planting was done in May each year and harvested eight months after planting. Results showed that control plot had 187.80 higher significant weed density than 2 and 4 t ha^{-1} mulch (88.20 and 81.80), respectively. Fertilizer had no significant effect on weed density. Ginger survival at 2.00 and 4.00 t ha^{-1} mulch (94.40 and 96%) differed significantly from the control plot (42.20%). Number of tillers in mulched plots (t ha^{-1}) followed the order: 4 > 2 > 0 in both years. Fertilizer rate at 400 kg ha^{-1} gave higher significant rhizome yield more than 0 kg ha^{-1} in both years. Mulch at 4 t ha^{-1} increased soil pH by 12% relative to 7.94% increase by NPK fertilizer. Total N, available P and exchangeable K were increased by 12.30, 64.30 and 14.30% respectively, by mulch at 4 t ha^{-1}, while NPK fertilizer increased total N, available P and exchangeable K by 5.60, 31.40 and 9.38%, respectively. It was concluded that application of Dactyladenia barteri mulch and NPK fertilizer reduced weed density, improved ginger production and recapitalized soil in Umudike, southeastern, Nigeria.

Key words: *Dactyladenia barteri* mulch, ginger, leaf litter, soil recapitalization, weed density

INTRODUCTION

Zingiber officinale Roscoe (edible ginger) belongs to the genus *Zingiberaceae*. It is the oldest monocotyledonous tuberous spice usually cultivated as an annual crop (Okwuowulu, 1998; Thankamani *et al.,* 2016). Ginger is grown in tropical and subtropical regions of the world for its spice and medicinal values. It is an important spice crop grown globally for its industrial (flavoring local drinks, food and meat) and medicinal properties, in ethno-medicine and. in clinical medicine.

Mulch is any material placed over the surface of the soil to prevent loss of water by evaporation, suppress weeds, reduce temperature fluctuations, prevent soil erosion and promote productivity of the soil (Okeke and Omaliko, 2000; Obalum *et al*., 2011). Materials such as dry grass, wilted grass, dry leaves, rice husk, saw dust and banana leaves are typical mulches. Mulching is an important agronomic practice in ginger production. Aliyu and Lagoke (2001) recommended 1.50 t ha^{-1} of dry grass mulch to suppresses weed in ginger production. In the humid tropics where there is a high risk of soil erosion, particularly after clearing the land for cultivation, mulching offers a number of benefits that are difficult to achieve in un-mulched and unprotected bare soil surface, which is more prone to severe accelerated soil erosion (Thankamani *et al*., 2016; Dipendra *et al*., 2019; Choudhary, 2020).

Weed constitutes a major limiting factor in ginger production. Judicious weed management is necessary to improve ginger yield and maximize investment in equipment and manpower employed in ginger production. (Tadesse and Melaku, 2015; Hussain *et al*., 2022). Effective and economic weed management often requires the use of highly selective herbicide which is often scarce and costly for the resource-poor farmers. Chemical weed control using herbicide impacts negatively on the environment and human health (Thankamani *et al*., 2016). From the foregoing, it becomes a logical choice to search for a low-external-input, affordable and sustainable weed management that is environment-friendly in ginger production. Mulching is an environment-friendly weed management approach (Obalum *et al*., 2011). It is capable of substituting herbicides to a significant extent (Thankamani *et al.,* 2016; Choudhary, 2020) and reducing the quantity of NPK fertilizers applied in ginger production in southeastern Nigeria (Chukwu and Emehute, 2001).

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Ginger requires moderate to high level of soil fertility. Organic matter management mulching has been identified as critical in conserving soil moisture, moderation of soil temperature, and improving the fertility status of the soil for ginger production (Ohiri and Njoku, 1987; Chukwu, 2002). According to Ohiri and Njoku (1987) mulching at 5-23 t ha^{-1} plus application of NPK 15:15:15 at 400-800 kg ha^{-1} is recommended for ginger production in Nigeria, based on mulch type and soil fertility status. Soil recapitalization is the replenishment of soil fertility as nutrients such as N, P, K, Ca and Mg are added to the soil (Weight and Kelly, 1998). Integrated low-external-input soil nutrient management by combining organic and inorganic fertilizers in soil amendment, recapitalizes soil (Weight and Kelly, 1998) and improved cocoyam yields on Haplic Acrisols of southeastern Nigeria (Chukwu *et al.*, 2014; Chukwu and Madu, 2020). Fertilizer requirement for ginger production in Nigeria by Ohiri (1990), based on soil test values for total N, are 100, 50 and 30 kg N ha^{-1} for soils low in fertility (< 0.15%), medium (0.15-0.20%), and high (> 0.20%) in total N. Chukwu and Emehute (2001) recommended the application of 250 kg ha^{-1} of NPK 20:10:10 on Acrisols of low fertility to maximize the yield of ginger in south-eastern Nigeria. Planted sett sizes ≥ 20 *g* remain un-decayed at crop maturity, have low seed harvest multiplication ratio (SHMR) and may be fully recovered at crop harvest, although the quality may be reduced (Okwuowulu, 1992). Chukwu and Madu (2020) reported that complementary application of organic and mineral fertilizers to cocoyam increased cocoyam yields and recapitalized degraded Haplic Acrisols in southeastern Nigeria. High susceptibility of tropical soils to erosion and other degradation factors necessitates integrating mulch and other cultural management techniques, to recapitalize soils to sustain their productivity in the tropical farming systems (Akinwumi *et al.,* 2013; Hussain *et al.*, 2022). This study was designed to evaluate the effectiveness of *Dactyladenia barteri* much and NPK fertilizer 15:15:15, on weed density, ginger production, seed harvest multiplication ratio (SHMR) and soil recapitalization.

MATERIALS AND METHODS

Site Description

The study was carried out in 2017 and 2018 cropping seasons at the experimental field of College of Natural Resources & Environmental Management, Michael Okpara University of Agriculture, Umudike (latitude 5° 25′ N and longitude 7° 35″ E). The soil of the study area is typical of Gleyic Luvisols of Alagba series, with an isohyperthermic temperature and udic moisture regime, based on soil survey report of Ikwuano Local Government Area, Abia State (Chukwu, 2013). The climate is typical of the humid tropics with distinct rainy and dry seasons, high rainfall, high and high relative humidity (Chukwu, 2013). The rainfall pattern is bimodal with peaks in July and September. The mean annual minimum and maximum rainfall is 1,200 and 2,000 mm, respectively spread between April and early November. The mean minimum and maximum temperatures are 22 and 30°C, respectively. Relative humidity varies from 90.20 to 52.50%. The vegetation is a typology of degraded humid rainforest in the southeast agro-ecological zone of Nigeria.

Field Experiment

Dry leaves of *Dactyladenia barteri* were collected at the *Dactyladenia barteri* alley plantation site at the National Root Crops Research Institute (NRCRI) Umudike, while yellow ginger rhizomes (Umu Gin I) were collected from Ginger Research Programme of the NRCRI, Umudike. Treatments comprising three levels of *Dactyladenia barter* mulch (0, 2 and 4 t ha^{-1}) and two levels of inorganic fertilizer NPK 15:15:15 (0 and 400 kg ha^{-1}) were laid in a randomized complete block design with three replications. Planting was done in May each year using 10 g setts of the rhizome, on beds after ploughing and harrowing. Plants were spaced 0.20 × 0.20 m on 2 × 2 m plots, to get a plant density of 250,000 plants ha^{-1}. Mulch was applied 48 h after planting and NPK fertilizer was applied 12 weeks after planting (WAP) by controlled broadcasting. Weed density was measured using the unrestricted list count method (Maszura *et al*., 2018). A 0.50-m^2 quadrat was placed randomly on each plot and number of weeds (broad leaved, grasses and sedges) within the quadrat were counted at 12 WAP. Percentage sprout count was taken at 6 WAP while the number of tillers and plant height were taken at 12 WAP. Harvesting was done at 8 months after planting, using a digging fork. Rhizome yields were weighed after harvest and seed harvest multiplication ratio (SHMR) was calculated as in Chukwu and Madu (2020) thus: SHMR = quantity of rhizome harvested/quantity of rhizome planted. Composite soil samples were collected at 0-30 cm at pre-cropping at after harvest, to assess the effect of the treatments on soil recapitalization.

Laboratory and Statistical Analysis

Soil samples were air-dried at room temperature and crushed gently with a wooden roller and sieved with a 2-mm sieve. Particle size distribution was analyzed by the modified hydrometer method (Gee and Or, 2002), using sodium hexametaphosphate (calgon) as a dispersant. Total *N* was determined by the micro Kjedahl wet oxidation method (Brenmer, 1996) while available P was determined by Bray-II-method (Bray and Kurtz, 1945). Organic carbon was determined by the method of Nelson and Sommers (1982). Data obtained were converted to organic matter by multiplying by 1.724. Soil pH was determined in soil: distilled water ratio of 1.0:2.5 using Beckman's zeromatic pH meter (Thomas, 1996). Exchangeable bases were extracted with neutral 1N ammonium acetate (NH_4OAc) solution. The Ca and Mg were determined by EDTA titration while K and Na were determined using flame photometry. Exchangeable acidity was determined by KCl extraction following the procedure of Mclean (1982). Effective cation exchange capacity (ECEC) was obtained by summation of total exchangeable bases (Ca, Mg, K, and Na) and exchangeable acidity. Base saturation was calculated as quotient of total exchangeable bases and ECEC multiplied by 100. Data collected were statistically analyzed using analysis of variance. Significant differences between means were detected using least significant difference LSD at $p \leq 5\%$.

RESULTS AND DISCUSSION

Weed Density

Results showed that application of 2 and 4 (t ha^{-1}) *D. barteri* mulch gave similar weed densities (81.80 and 88.20) in 2017 and (90.70 and 95.20) in 2018 that were significantly ($p \leq 0.05$) lower than 187.80 and 243.70 obtained in the control (0 t ha^{-1}) in 2017 and 2018, respectively (Table 1). Application of NPK fertilizer did not influence weed density significantly. The results suggest that the mulch had the capacity to control weed in ginger farm, thereby supporting similar observations by Sengupta *et al.* (2009), Thankamani *et al.* (2016), and Choudhary (2020), that mulching is a cultural method of weed control.

Growth and Yield of Ginger

The *D. barteri* mulch influenced percentage sprout count at 6 WAP. The rates 4 and 2 t ha^{-1} gave higher ($p \leq 0.05$) percentage sprout count of 86.80 and 93.40 in 2017 and 92.20 and 96.00 in 2018 than the control (0 t ha^{-1}) that gave 53.50 in 2017 and 42.20% in 2018 (Table 2). Mulch increased ginger sprouting via soil temperature moderation and soil water conservation (Wilgen, 1997; Obalum *et al*., 2011). Similar to the present results, Ohiri and Njoku (1987) and Obalum *et al*. (2017) reported higher percentage sprout in mulched than no-mulch plots for ginger at Umudike and fluted pumpkin at Nsukka, respectively. Application of NPK fertilizer 15:15:15 had no significant effect of percentage sprout count.

Table 3 shows the effect of the treatments on tiller number per plant. The number of tillers increased as the mulch rates increased. The magnitude of increase in number of tillers with respect to mulch application (t ha^{-1}) followed the order: 4 > 2 > 0 in both years. This could be explained by the observation of Ohiri (1990) at Umudike, who reported that mulching increased percentage sprouting in ginger and conserved soil moisture that boosted its growth and yield higher than in plots without mulch. Probably, because the experimental site is of medium fertility (Table 6), application of fertilizer had no significant effect on the tiller number relative to the control. Application of NPK fertilizer at 400 kg ha^{-1}, gave higher significant rhizome yield of 12.60 and 13.50 t ha^{-1}, respectively in 2017 and 2018, respectively, than 8.97 and 7.56 t ha^{-1} obtained from 0 kg ha^{-1} in 2017 and 2018, respectively (Table 4). Similar trend was obtained with the application of mulch because rhizome yield varied directly with the rate of mulch (0, 2 and 4 t ha^{-1}), respectively, in both years. The table also shows that mulching at the highest rate (4 t ha^{-1}) slightly increased rhizome yield higher than the application of NPK at 400 kg ha^{-1}. Application of NPK fertilizer might boost early growth of ginger but over time, some of the unabsorbed nutrients could be lost by leaching and runoff. As mulch decays, it mineralizes to release nutrients, to further boost ginger growth till anthesis, to increase rhizome yield. This probably explained the slight higher rhizome yield with mulching at 4 t ha^{-1} compared with the application of NPK fertilizer at 400 kg ha^{-1}. Mulch $\times$ fertilizer interaction at 4 t ha^{-1} $\times$ 400 kg ha^{-1} gave higher significant rhizome yield than mulch $\times$ fertilizer at 2 t ha^{-1} $\times$ 400 kg ha^{-1} in 2007 but not in 2008 (Table 4). The results are similar to those reported by Chukwu and Emehute (2001) at Umudike. The treatments influenced SHMR significantly (Table 5). The results showed that planting material used was multiplied four times when mulch and NPK fertilizer were applied against three times obtained in the control plot. Okwuowulu (1992) reported similar increase in SHMR in ginger production due to mulching and sett size used.

Table 1: Effect of *Dactyladenia barteri* leaf mulch and inorganic fertilizer (NPK 15:15:15) on weed density

NPK (kg ha^{-1})	*D. barteri* mulch (t ha^{-1}) 2017				*D. barteri* mulch (t ha^{-1}) 2018			
	0	2	4	Mean	0	2	4	Mean
0	203.00	105.00	91.70	133.20	250.00	102.30	94.70	149.00
400	172.70	71.30	72.00	105.30	237.30	89.00	80.70	137.70
Mean	187.80	88.20	81.80		243.70	95.70	90.70	
LSD ($p \leq 0.05$)				NS				NS
NPK mulch rate				52.70				57.20

NS - not significant at $p \leq 0.05$

Table 2: Effect of *Dactyladenia barteri* mulch and NPK 15:15:15 on sprouting (%) at 6 WAP

NPK (kg ha^{-1})	*D. barteri* mulch (t ha^{-1}) 2017				*D. barteri* mulch (t ha^{-1}) 2018			
	0	2	4	Mean	0	2	4	Mean
0	48.00	90.70	89.10	75.90	54.00	88.50	92.30	78.20
400	58.60	92.80	97.60	83.00	54.80	90.00	99.70	83.30
Mean	53.50	86.80	93.40		42.20	92.20	96.00	
LSD ($p \leq 0.05$)				NS				NS
NPK mulch rate				4.10				6.79

WAP - weeks after planting, NS - not significant

Table 3: Effects of *Dactyladenia barteri* mulch and NPK fertilizer on tiller number per plant

	Mulch rate (t ha^{-1}) 2017				Mulch rate (t ha^{-1}) 2018			
NPK (kg ha^{-1})	0	2	4	Mean	0	2	4	Mean
0	2.41	8.20	5.87	4.22	2.83	4.25	5.47	4.18
400	4.13	4.20	7.20	5.18	3.27	3.93	5.47	4.22
Mean	3.27	4.70	6.53		3.05	4.08	5.47	
FLSD ($p \leq 0.05$)				NS				NS
NPK mulch rate				1.59				1.11

NS - not significant

Table 4: Effect of *Dactyladenia barteri* mulch and NPK 15:15:15 rate on fresh ginger rhizome yield (t ha^{-1}) in 2017 and 2018

	Mulch rate (t ha^{-1}) 2017				Mulch rate (*t* ha^{-1}) 2018			
NPK (kg ha^{-1})	0	2	4	Mean	0	2	4	Mean
0	5.03	6.88	15.00	8. 97	4.78	5. 99	11.90	7.56
400	9.44	11.70	16.70	12.60	10.00	14.20	16.30	13.50
Mean	7.23	9.29	15.90		7.39	10.10	14.10	
FLSD ($p \leq 0.05$)								
NPK	2.80				2.25			
Mulch rates	2.48				2.54			
NPK × mulch	1.23				NS			

NS - not significant

Table 5: Effect of *Dactyladenia barteri* mulch and NPK 15:15:15 rate on seed harvest multiplication ratio in 2017 and 2018

	Mulch rate (t ha^{-1}) 2017				Mulch rate (t ha^{-1}) 2018			
NPK (kg ha^{-1})	0	2	4	Mean	0	2	4	Mean
0	2	3	3	3	2	4	4	3
400	4	5	4	4	3	4	4	4
Mean	3	4	4		3	4	4	
FLSD ($p \leq 0.05$)								
NPK	0.25				0.25			
Mulch rates	0.13				0.15			

Soil Physical and Chemical Properties

The initial mean soil properties of the experimental site are shown in Table 6. The project site is a medium loamy soil with sandy clay loam textural class and strongly acid (Veldkamp, 1992) with a mean pH of 4.91. Generally, the sites are low in available P and organic matter but medium in total N and exchangeable K, respectively, based of soil fertility rating of soils of southeastern Nigeria (Enwezor *et al.,* 1989). The soils are eutric (Soil Survey Staff, 2014) with a mean base saturation of 78.90%. Post cropping soil data (Table 7) showed that the soil was more degraded in the control plots without mulch (0 t ha^{-1}) relative to the application of NPK alone at 400 kg ha^{-1}. Application of mulch at 2 and 4 t ha^{-1} recapitalized the soil (improved soil fertility) (Table 7). There was 2.24% increase in soil acidity in the control plot. Similarly, organic matter, total N, available P and exchangeable K decreased by 13.10, 26.10, 1.42 and 16.70%, respectively.

Table 6: Mean Soil chemical properties of the experimental site at 0-30 cm depth

Soil parameters	2017	2018	Mean
Sand (g kg^{-1})	480.00	500.00	490.00
Silt (g kg^{-1})	200.00	210.00	205.00
Clay (g kg^{-1})	320.00	290.00	305.00
Textural class	SCL	SCL	SCL
pH (H_2O)	4.82	5.00	4.91
Organic matter (g kg^{-1})	12.00	15.60	13.80
Total N (g kg^{-1})	30.00	27.00	28.50
Available P (mg kg^{-1})	10.30	8.96	9.13
Exchangeable cations (cmol kg^{-1})			
Calcium	1.97	2.14	2.06
Magnesium	1.38	1.25	1.32
Potassium	0.42	0.32	0.37
Sodium	0.08	0.08	0.08
Exchangeable acidity	0.76	0.84	0.80
Effective cation exchange capacity	4.61	3.97	4.17
Base saturation (%)	83.50	74.30	78.90

SCL - sandy clay loam

Table 7: Soil recapitalization as influenced by *Dactyladenia barteri* mulch and NPK fertilizer 15:15:15

Treatments	Soil (H_2O)	Total N (g kg^{-1})	OM (*g* kg^{-1})	Available P (mg kg^{-1})	K^+ (cmol kg^{-1})
Mulch rate (t ha^{-1})					
0	4.91 (4.80)	28.50 (20.50)	13.80 (12.00)	9.13 (9.00)	0.30 (0.25)
	−2.24*	−28.10*	−13.00*	−1.42*	−16.70*
2	4.91 (5.30)	28.50 (30.80)	13.80 (14.60)	9.13 (10.50)	0.32 (0.38)
	7.94*	8.07*	5.80*	15.00*	18.90*
4	4.91 (5.50)	28.50 (32.00)	13.80 (16.40)	9.13 (15.00)	0.35 (0.40)
	12.00*	12.30*	18.80*	64.30*	14.30*
NPK 15:15:15 (kg ha^{-1})					
0	4.91 (4.80)	28.50 (20.50)	13.80 (12.00)	9.13 (9.00)	0.30 (0.25)
	−2.20*	−28.1 *	−13.0*	−1.42*	−16.7*
400	4.91 (5.30)	28.50 (30.00)	13.80 (12.50)	9.13 (12.00)	0.32 (0.35)
	7.94*	5.26*	−9.42*	31.4*	9. 38*

Values in parenthesis represent post-cropping soil analysis. * - represents percentage improvement or otherwise over pre-cropping soil value, OM - organic matter, N - nitrogen, P - phosphorus, K^+ - potassium ions

Application of NPK fertilizer 15:15:15 at 400 kg ha^{-1} recapitalized the soil similar to application of mulch at 2 t ha^{-1}, except that the NPK fertilizer reduced organic matter by 9.20%. Application of mulch at 4 t ha^{-1}, recapitalized the soil more than the NPK fertilizer at 400 kg ha^{-1}. For instance, mulching at 4 t ha^{-1} increased soil pH by 12% relative to 7.94% increase by NPK fertilizer (Table 7). Similarly, total N, available P and exchangeable K were increased by 12.30, 64.30 and 14.30% respectively by mulch at 4 t ha^{-1}, while NPK fertilizer increased total N, available P and exchangeable K by 5.60, 31.40 and 9.38%, respectively. The moderation of soil temperature by mulch and protecting the soil against direct impact of rainfall (Ohiri and Njoku, 1987; Wilgen, 1997) and its decay to mineralize and add more nutrients in the soil (Chukwu *et al.*, 2014; Chukwu and Madu, 2020), most likely, accounted for its higher improvement in soil fertility relative to NPK fertilizer. Additionally, the application of mulch is a better soil management practice that mimicks upland rainforest ecology, as in Ado-Ekiti, where Kadiri *et al*. (2022) found that relative litter accumulation improved soil organic carbon stock and soil fertility. The results confirmed that application of mulch and NPK fertilizer are strategies to recapitalize soils as reported by Chukwu and Madu (2020).

CONCLUSION

It is concluded that application of *Dactyladenia barter*i leaf mulch is a good cultural method of weed control in a ginger farm. Although, the application of the mulch up to 4.00 *t* ha^{-1} and NPK fertilizer, 15:15:15 at 400.00 kg ha^{-1}, increased ginger rhizome yields, it appears that higher rates of these soil amendments are required to optimize yields. The use of mulch and NPK fertilizer 15:15:15 are proven strategies to improve soil fertility.

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