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EFFECT OF *DACTYLADENIA BARTERI* (HOOK. F. EX OLIV.), *LEUCAENA LEUCOCEPHALA* (LAM.) DE WIT, *GLIRICIDIA SEPIUM* (JACQ.), AND *SENNA SIAMEA* (LAM.) MULCHES ON EARTHWORM ACTIVITY AND NUTRIENT TURNOVER IN CASTS

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ABSTRACT

A two year field study was conducted to investigate the effects of prunings of *Dactyladenia barteri* (Hook. f. ex Oliv.), *Leucaena leucocephala* (Lam.) de Wit, *Gliricidia sepium* (Jacq.), and *Senna siamea* (Lam.) on the activity of earthworms and soil and worm cast properties. Earthworm activity was measured by quantifying worm casts deposited at the soil surface. Results of the study showed that the effect of the different mulches on earthworm activity was similar. The cumulative trend in surface cast production was also similar under the different mulches. Irrespective of the type of mulch and the year of sampling, the concentration of nutrient elements were significantly ($P = 0.05$) higher in worm casts relative to uningested soil. Worm casts contain 2 – 3 times more Ca, 2 – 3 times more Mg, 3 – 4 times more K, 5 – 6 times more N and 2 – 5 times more organic C than the top 5 cm of the soil.

INTRODUCTION

Mulching is an old practice in agriculture. The practice of mulching is known to influence soil physical, chemical and biological properties that regulate crop growth and productivity. The benefits of mulching include, reduction in soil temperature, weed competition, and soil erosion as well as enhanced biological activity, water infiltration, soil moisture regime, nutrients and soil structure (Lal 1975, 1983; Kamara 1986; Budelman 1989; Mbagwu 1990; Makus *et al*, 1994). Plant materials are commonly used as mulch but plastic materials are sometimes used. Hedgerow trees used in alley cropping are pruned regularly to produce organic materials that can be used as mulch. Earthworms facilitate the decomposition processes of mulch and other organic materials. They play an important role in soil fertility through nutrient cycling and the formation of organic matter (Bargali *et al*, 1993). Since the rate of litter decomposition is a function of litter quality, quantity and initial nutrient concentration (Mulongoy and Gasser, 1993; Bargali *et al*, 1993), it is considered necessary to study the effect of mulch of contrasting quality on activities of earthworms, an organism that regulates litter decomposition. This experiment was therefore designed to (1) investigate the effect of *Leucaena leucocephala, Dactyladenia barteri, Gliricidia sepium* and *Senna siamea* leaves on the biological activity of tropical earthworms. (2)

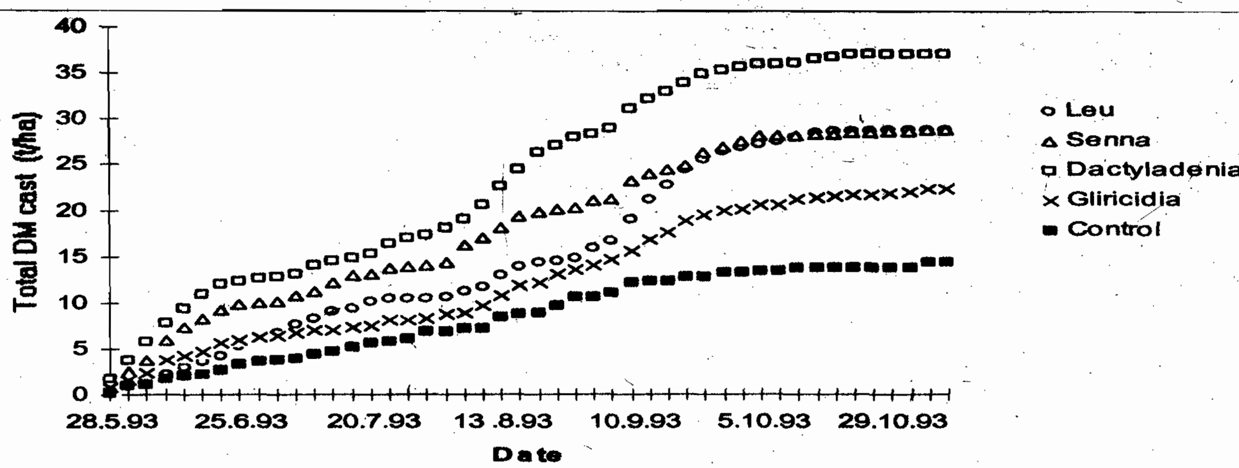

Fig 1. Cummulative amount of earthworm casts under mulches of different tree species; Ibadan, Nigeria, 1993.

assess the possible influence of different mulches on the quality of worm casts and soil. (3) assess the effect of the different prunings on soil organic matter and nutrient turn-over through earthworm casts.

MATERIALS AND METHODS

The experiment was conducted at the International Institute of tropical Agriculture (IITA), Ibadan (7^O 31'N and 3^O 54E), Nigeria, on an Alfisol that was manually cleared of six-year-old fallow. Slashed materials were allowed to dry on the plots for some days, then gathered and removed. The plots which measured 5m x 5m in size were laid out as randomized complete block design (RCBD) with five replicates. Plots were uniformly planted to maize at inter-row spacing of 50cm and intra-row spacing of 30cm without tillage. Three seeds were planted per hole and thinned down to 2 plants two weeks after seed germination. The treatments were leaves of *Leucaena leucocephala, Dactyladenia barteri, Gliricidia sepium* and *Senna siamea* applied a week after seed germination. The leaves were applied at the rate of 5t/ha in the first year and 10t/ha in the second year. The control plot had no pruning applied. Weeding was done on the control plots at two and six weeks after planting. Four square frames of 25cm x 25cm were installed in each plot giving a total of one hundred frames. Old worm casts within the frames were removed after the frames were installed.

Earthworm casts were continuously sampled from May 28, 1993 to November 9, 1993 and from June 7, 1994 to November 29, 1994. Casts produced inside the frames were collected two times per week. Earthworm casts collected were oven dried at 100^OC for 72 hours and weighed to determine the dry matter. The casts were then stored in plastic containers till the end of the season when the cumulative sample from each frame was processed for chemical analysis.

Soil samples were collected from each plot after bush clearing, before planting and after maize harvest. Six soil samples were collected per plot at depths of 0-5cm, 5-10cm and 10-15cm. A composite of the six samples at the same depth was made to obtain three

RESULTS

Earthworm activity

Casting activity of earthworms was assessed over a period of 167 days from May to November in 1993, and 176 days from June to November in 1994. The cumulative amount of casts in the first year (Fig. 1) shows a similar trend in all the treatments. Similar trend was also shown in the second year. Seasonal variation in worm casting activity was significant ($P > F = 0.0001$), indicating changes in cast production from one month to another. This variation follows a similar pattern irrespective of the mulch type (Fig. 2).

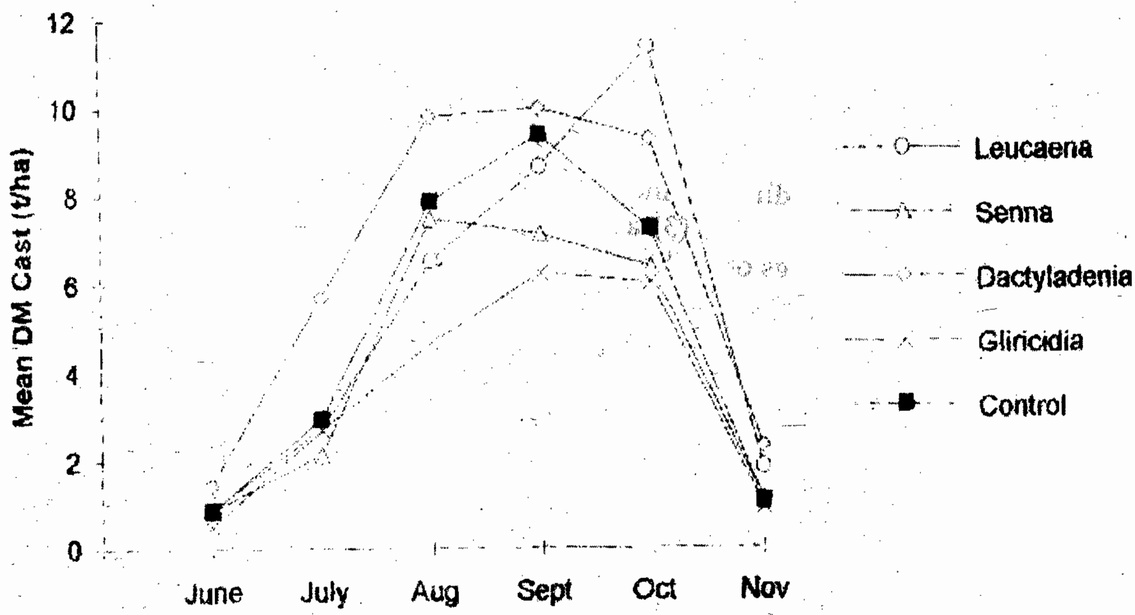

Fig. 2 Seasonal variation in casting activity of earthworms under mulches of different tree species, Ibadan, Nigeria, 1994

In mulched plots, casting in the first year dropped sharply after reaching a peak unlike a more gradual decline in the no-mulch control. In the second year, there was a very sharp decline in casting activity between October and November irrespective of the treatments. The low casting activity of earthworms at this period is a response to dry conditions as indicated by high soil moisture tension (Fig. 3).

Casting activity reaches the peak period earlier under mulches of non-nitrogen fixing plant in the first year. In the second year, casting activity reached a peak in August under mulches of non-fixing tree species, in September in the control and in October under N-fixing tree mulches (Fig. 4). Mean dry matter cast production in both years showed that mulching at the rates applied did not affect the amount of worm casts deposited at the soil surface. There was also no statistical difference between the quantity of worm casts deposited under mulches of N-fixing trees and non N-fixing trees.

Properties of Soil and Earthworm Casts

The concentrations of exchangeable Ca, and Mg, were significantly higher in worm casts than soil in both the mulch and no mulch treatments (Table 1). Worm casts contain 2-3 times more Ca and Mg than the top5cm of soil. The concentrations of exchangeable Ca and Mg were statistically similar between the mulch treatment and the no mulch control. Similarly, concentrations of exchangeable Ca and Mg in both soil and worm casts were unaffected by the use of mulches of N-fixing plants (Leucaena and Gliricidia) relative to the non N-fixing plant mulches (Dactyladenia and Senna). Mulching did not affect soil pH in both years (Table 2). Mulches of N-fixing trees significantly reduced soil pH in both years of the study. Mulch application decreased the pH of worm casts in the second year relative to the control.

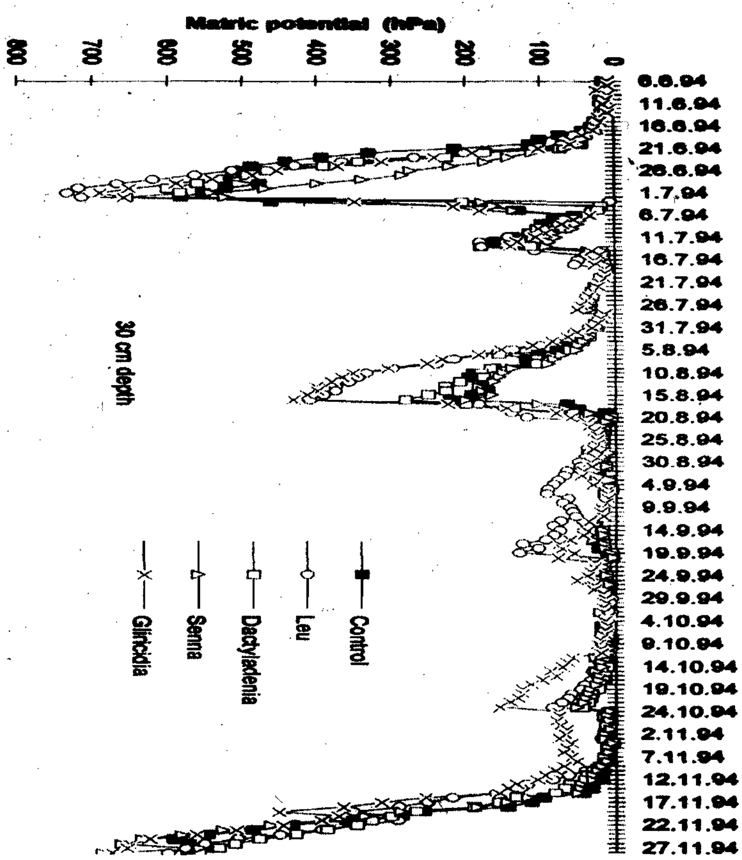

Fig.3 Seasonal variations in matric potential at 30cm soil depth under mulches of different tree species

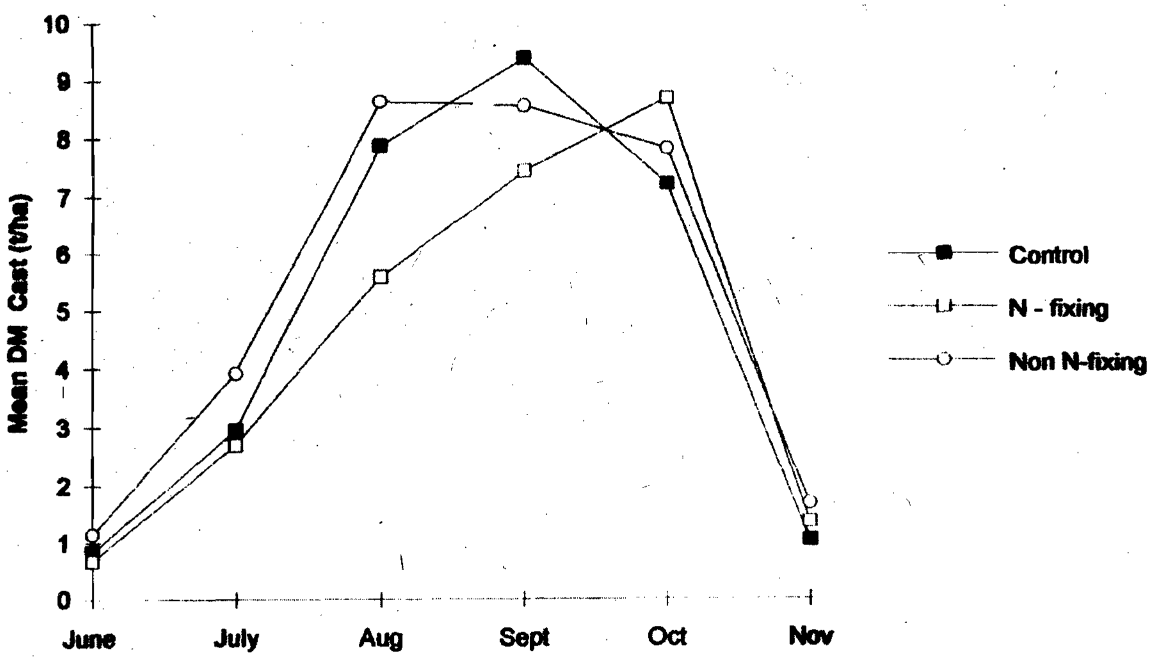

Fig. 4 Seasonal variation in casting activity of rarthworms under mulches of N-fixing and nonN-fixing tree species, Ibadan, Nigeria, 1994

The pH of worm casts was increased under mulches of N-fixing trees relative to the non N-fixing trees in the second but not in the first year. There was significantly higher concentration of exchangeable K in worm casts than in soil being 2-7 times more. Mulching did not affect the concentration of exchangeable K in both soil and worm casts in both years. However, exchangeable K was increased in soil under mulches of N-fixing trees compared to the non N-fixing trees, in the first but not in the second year of this study.

Concentrations of total N and organic C in both soil and worm casts were not affected by mulching in the first year (Table 3). There were however, higher concentrations of total N and organic C in worm casts deposited on mulched plots relative to the control in the second year.

Total N and organic C in both soil and worm casts did not vary appreciably between plots treated with mulches of N-fixing plants when compared with those of non N-fixing plant mulches. Generally, total N and organic C were significantly higher in worm casts than in soil. There were 5-6 times more N and 2-5 times more organic C in worm casts than in soil.

Nutrient turnover in Worm casts

Nitrogen returned to the soil surface through casts under mulch (Table 4) averaged 81.4 kg/ha in the first year and 118.39 kg/ha in the second year. Average figures for the no mulch control were 42.9kg/ha in the first year and 103.23 in the second year. Organic carbon in casts deposited at the soil surface ranges from 273-419.9 kg/ha under mulch compared to 152.5 kg/ha in the control treatment in the first year. In the second year, organic carbon averaged 1451.03 kg/ha in casts under mulch compared to 1195.19 kg/ha in the control. However, mulching did not affect the quantity of nutrients recycled through worm casts. Also, mulching with leaves of N-fixing plants showed no significant advantage on the quantity of nutrients turned over in earthworm casts.

Table 1: Concentration of ex changeable Ca, and Mg [cmol (+) kg^{-1}] in earthworm casts and surface soil (0-5cm) as influenced by different plant mulches.

Mulch	Exchangeable Ca			Exchangeable Mg		
	Soil	Cast	t	Soil	Cast	t
		1993				
Leucaena	6.76	17.47	**	1.34	3.64	*
Senna	6.95	18.82	**	1.21	3.65	***
Dactyladenia	6.29	16.58	***	1.16	3.30	**
Gliricidia	6.46	19.47	**	1.98	3.13	**
Control	6.23	17.85	***	1.30	3.98	***
AOV single d.f. comparison						
Mulch vs none	NS	NS		NS	NS	
N fixers vs none	NS	NS		**	NS	
		1994				
Leucaena	7.08	14.52	***	1.44	2.69	***
Senna	8.61	17.04	***	1.45	2.67	***
Dactyladenia	6.22	13.68	***	1.14	2.46	***
Gliricidia	8.23	14.51	**	1.70	2.82	***
Control	7.68	14.86	***	1.20	2.46	**
AOV single d.f. comparison						
Mulch vs none	NS	NS		NS	NS	
N fixers vs none	NS	NS		NS	NS	

NS = ntosignificant. * = Significant at p = 0.05. ** = Significant at p = 0.01. *** = Significant at p.=0.001

DISCUSSION

Casting activity of earthworms varied seasonally due probably to the climatic variables that determine the level of soil dryness or wetness. Consequently, the rate of worm casts production will not be uniform throughout the season. Earthworm activity occurs during the rainy season, usually from April to November. The implication of seasonal variation in casting activity is that estimating worm cast production from samples collected at a particular period will lead to either under or over estimation

Table 2: Effects of mulch on pH and concentration of exchangeable K [cmol(+) kg^{-1}] in surface soil (0-5cm) and worm cast. Ibadan, Nigeria

Mulch	pH			Exchangeable K		
	Soil	Cast	t	Soil	Cast	t
		1993				
Leucaena	6.48	6.89	Ns	0.37	1 00	**
Senna	6.63	7.09	**	0.28	1.39	**
Dactyladenia	6.46	6.89	*	0.24	1.29	**
Gliricidia	6.75	6.99	Ns	0.17	1.22	**
Control	6.77	7.05	*	0.26	1.05	***
AOV single d.f. comparison						
Mulch vs none	NS	NS		NS	NS	
N fixers vs none	**	NS		*	NS	
		1994				
Leucaena	6.52	6.59	Ns	0.53	0.82	**
Senna	6.82	6.88	Ns	0.34	0.73	**
Dactyladenia	6.60	6.61	Ns	0.28	0.61	**
Gliricidia	6.76	6.84	Ns	0.44	0.87	*
Control	6.75	7.00	ns	0.26	0.62	***
AOV single d.f. comparison						
Mulch vs none	NS	*		NS	NS	
N fixers vs none	**	**		NS	NS	

NS = ntosignificant. * = Significant at p = 0.05. ** = Significant at p = 0.01. *** = Significant at p.=0.001

Table 3: Effects of mulch on concentration of N and Organic C (%) in surface soil (0-5cm) and earthworm casts. Ibadan, Nigeria.

Mulch	Total N			Organic C		
	Soil	Cast	t	Soil	Cast	t
		1993				
Leucaena	0.28	1.57	***	3.05	6.25	***
Senna	0.30	1.72	*	3.03	6.41	**
Dactyladenia	0.24	1.24	***	2.45	5.65	***
Gliricidia	0.30	1.69	*	3.14	5.49	**
Control	0.28	1.78	*	2.87	5.59	**
AOV single d.f. comparison						
Mulch vs none	NS	NS		NS	NS	
N fixers vs none	NS	NS		NS	NS	
		1994				
Leucaena	0.22	0.43	***	2.22	5.09	***
Senna	0.25	0.44	***	2.54	5.74	***
Dactyladenia	0.19	0.37	***	1.82	4.36	***
Gliricidia	0.25	0.41	**	2.51	5.10	***
Control	0.20	0.37	**	1.96	4.29	**
AOV single d.f. comparison						
Mulch vs none	NS	*		NS	**.	
N fixers vs none	NS	NS		NS	NS	

NS = ntosignificant. * = Significant at p = 0.05. ** = Significant at p = 0.01. *** = Significant at p.=0.001

Mulching with different plant materials did not significantly affect the quantity of cast produced compared to the control. This observation was consistent for the two years of the study but contrary to the report by Lal (1978) of 5-7 times more earthworm casts under mulch than in no mulch control. This study was conducted on a

land that was high in nutrient status (Table 5), hence the availability in soil, of enough resources that can sustain the worms may be more important than nutritional and other benefits of the mulch.

Table 4: Cumulative amounts of worm cast and nutrient turnover in earthworm casts deposited at the soil surface as influenced by different plant mulches

Mulch	DM cast (t/ha)	Nutrient contents of earthworm casts (Kg/ha) Ca	Mg	K	Total N	Org. C
		1993				
Leucaena	5.76	19.05	2.23	2.11	77.18	345.20
Senna	7.41	21.75	2.63	3.19	92.75	362.50
Dactyladenia	5.74	24.36	10.43	3.75	92.16	419.90
Gliricidia	4.44	16.85	8.55	2.07	63.35	273.90
Control	2.85	9.69	1.36	1.08	42.93	152.50
AOV single d.f. comparison						
Mulch vs none	NS	NS	NS	NS	NS	NS
N fixers vs none	NS	NS	NS	NS	NS	NS
		1994				
Leucaena	31.91	91.83	10.38	10.37	135.44	1609.57
Senna	38.46	86.91	8.26	7.16	112.76	1470.74
Dactyladenia	25.00	104.75	11.46	9.06	139.80	1661.05
Gliricidia	20.94	61.76	7.32	6.53	85.56	1062.76
Control	29.26	78.45	8.57	7.00	103.23	1195.19
AOV single d.f. comparison						
Mulch vs none	NS	NS	NS	NS	NS	NS
N fixers vs none	NS	NS	NS	NS	NS	NS

Table 5. Initial properties of the soil at the start of the trial

Soil depth (cm)	Ca	Mg	K	Total N	Org. matter
	-------- cmol (+) kg $^{-1}$ --------			--------- % -------	
0 – 5	8.33	1.55	0.39	0.23	3.93
5 – 10	5.01	0.96	0.22	0.14	2.13
10 – 15	4.29	0.86	0.22	0.12	1.61

Compared to the amount of mulch applied in the first year, the additional mulch applied in the second year caused an 18% increase of worm casting activity under Dactyladenia but a **reduction under the other residue mulches by 0.9%, 27% and 38% in** Leucaena, Senna and **Gliricidia respectively. This result indicates that a high rate of certain mulch types** (> 5 t/ha) may **suppress the activity of earthworm** fauna in the **soil.**

The greater concentration of nutrients in the casts relative to the soil in this study can be explained in part by the fact that earthworms ingest preferentially higher amounts of finer soil particles rich in organic matter, which consequently reflect on the properties of the casts. Other workers (Lal 1983; Cortez et al 1989) have made similar observation. Low utilization efficiency of nutrients by earthworms (Syers *et al* 1979; Heine and Larink 1993) can also partly explain the observed differences in nutrient concentration between worm casts and soil. Christensen (1987) showed that most of the soil C and N was in the clay (50-65% C and 56-68% N), the silt having smaller proportions (29-41% C and 27-38% N), while sand fraction accounts for only 4-7% of the organic matter. Since worm casts have higher proportions of clay and silt fractions but lower contents of sand than parent soil (Asawalam 1997), selective ingestion of finer soil particles can also explain the difference between nutrient concentration in soil and earthworm casts. Finner soil particles are richer in plant nutrients than the coarse particles. The non-significant effect of mulch on chemical properties of soil and worm casts in the first year of the study was probably due to the fact that the worms derived from soil sufficient C and N to meet their needs. Significant effects of mulching on pH, total N and organic C in worm casts but not in soil were observed in the second year. This result demonstrates that dependence on surface litter by earthworms is a secondary option that is exploited when soil reserve is depleted to a certain level.

Nutrient recycling is an important process related to the nutrition of plant in natural ecosystems. While loss of soil and nutrients through surface runoff can be controlled, nutrient losses through leaching and deep percolation remains a problem. Translocation to the soil surface of potentially leachable nutrients in the soil is thus very beneficial especially where the cost of soil improving amendments are beyond the reach of farmers ~~as is the case~~ in most parts of sub-sahara Africa. Soil fauna, especially earthworms, is important for the recirculation of soil nutrients and the decomposition and mineralization of crop residues (Brussaard *et. al* 1993). Earthworms can cause increase in holocellulose and lignin mineralization (Scheu, 1993), which explains why they can mobilize from organic materials large amounts of nutrients and store them in their casts. Nutrients in worm casts can benefit crops in the season when they are produced as well as in subsequent seasons. Clay is easily dispersed from fresh worm casts (Hindell *et al* 1994), the wetter the soil is and the longer it stays wet, the longer the casts remain in a dispersible and structurally unstable state. As worm casts ages, mineralization of nutrients contained in it is temporarily blocked in compact structure (Lavelle and Martin 1992) because the outside of casts display a dense layer which consists of fine particles that can impede water and air movement (Blanchart *et. al.* 1993) enabling the conservation of nutrients. The protected organic material associated with clay particles show high degree of decomposition (Hassink *et al* 1993), confirms that nutrients held in the aggregate structure of worm casts are subsequently made available to plants following the breakdown of the casts structure. Consequently, promoting worm casting activity is a potential means of conserving and recycling mineral nutrients for sustainable crop production.

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