RAINFALL, LIVESTOCK AND NUTRIENT CYCLING IN SEMI-ARID WEST AFRICA: FATE OF NUTRIENTS APPLIED TO SOIL

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Resume

Les systèmes mixtes de production des zones semi-arides. De l'Afrique de l'Ouest sont bases sur le recyclage des éléments nutritifs a support organique en vue du maintient de la productivité des sols. Le passage de la biomasse végétale a travers l' appareil digestif des ruminants joue un rôle primordial dans les cycles d'éléments nutritive dans cette région. La décomposition de matière organique était plus rapide et plus importante dans les tiges du mil que dans le fumier. Les modes de minéralisation de l'azote et du phosphore dans les tiges du mil et le fumier étaient très différents. Compte tenu de la complémentarité entre l'élevage et l'agriculture dans le Sahel, les activités de recherché ne devraient pas seulement viser a accroître la production des cultures au niveau de l'exploitation, mais également a accroître la quantité et la qualité du fourrage.

Introduction

In the semi and region of West Africa, poor soil fertility is one of the major causes of low agricultural productivity (Vlek, 1990; Bationo and Mokwunye 1991). Most of the soil in the region is sandy, highly weathered and inherently deficient in plant nutrients, soil organic matter and moisture retention capacity (Pieri, 1989). Despite poor soil fertility, use of inorganic fertilizer in the region remains low averaging 5.3 kg ha^{-1} (Bationo and Mokwunye,1991). At the same time, high population growth, at about 2.7% per year, has led to a rapid expansion in cultivated land and caused a breakdown in the traditional bush fallow system used for maintaining soil fertility (Cleaver and Schreibar, 1994). Given this scenario, farmers have come to rely on animal manure as an important source of nutrient for soil fertility maintenance and crop production. This reliance on animal manure seems favoured by the large livestock population in the region which, in 1994, included 21 million cattle, 27 million sheep and 30 million goats (FAO 1996).

Cereal Stovers and other crop residues are vital livestock feeds during the dry season, especially in semi-arid West Africa (Powell and Williams, 1993). In these areas, the competition for crop residues between livestock and soil conservation is most acute. High soil temperatures, wind erosion, and sand blasting of young plants pose severe limitations to crop establishment and production. When left in the field, cereal stovers provide a physical barrier to soil movement, allow soil and organic matter to accumulate and enhance soil chemical properties (Geiger *et al.* 1991) and crop yield (Bationo and Mokwunye, 1991). Returning crop residues to fields, however, is not a viable strategy for most mixed farmers in semi-and West Africa given the lack of alternative feeds. Most

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biomass in these mixed farming systems is fed to animals. Only later does it become available as a soil amendment in the form of manure (and urine).

The application of organic amendments to soil such that their decomposition and nutrient release coincide with crop demands can greatly increase the efficiency of nutrient cycling in low-input farming systems (Ikpe *et al*, 2003). The main objective of this paper was to study the decomposition of and nutrient release from millet stover (MS) and sheep faeces (SF) at different locations of Niger Republic with varying rainfall patterns.

MATERIAL AND METHODS

Village Locations

All the study villages are located in Western Niger at Sadore (13^0N 2^0E), approximately 45 km southwest of Niamey, the trial was established in an experimental plot at the ICRISAT (International Crops Research Institute of the Semi-Arid Tropics) Sahelian Centre (ISC) and in farmers' fields in the villages of Sadeize Koara (2^0 15'E 52'N) situated in the dry zone 80 km north of Niamey; Gueladio (2^0 02'E 13^0 05N) in the wetzone 70 km of Niamey; and Sambera (3^0 27'E 11^0 53'N) in a relatively wetter zone southeast of Niamey.

Experimental Treatments

Retrieval dates of litterbags after placement (0,30, 60, 85,and 115 days); (b) location: (i) Sadore, (ii) Gueladio, (iii) Sadeize Koara, and (iv) Sambera; and (c) Organic Amendments: (i) Sheep Faeces and (ii) Millet Stover. Treatments were assigned in a split-split plot arrangement and litterbags were buried in plots in a completely randomized design. Litterbags of 100 micron mesh-size measuring 20 x 20 cm were filled with 25 g of either intact SF or MS (stalks) that were chopped to about 3 cm and buried in soil 10 cm deep. Quadruplicate samples were retrieved 30, 60 85, and 115 days after placement for dry matter DM (ash – free basis), TNC, H, Ce, L, N, P, and K contents determination (Table 1).

Table 1: Rainfall and Surface soil Characteristics of Village Sites in Western Niger.

Chrematistics		Sadeize Koara	Sadore	Gueladio	Sambera
Annual Rainfall mm*		350-400	560-600	650-700	700-750
Rainfall (1992) mm		569	586	600	760
Particles Sizes %:	Sand	93.8	94.3	89.4	86.3
	Clay	3.5	4.2	5.6	5.9
	Silt	2.6	1.4	5.0	7.8
Soil Texture		Sandy	Sandy	Sandy	Sandy
Soil pH:	(H_2O)	6.3	5.6	5.3	5.9
	(KCI)	5.3	4.6	4.2	4.9
Total N ppm		107.0	263.5	252.3	386.37
NO_3-N ppm		1.6	4.0	2.6	3.0
NO_4-N ppm		5.1	2.8	5.2	4.6
Organic C%		0.10	0.28	0.21	0.47
C:N Ratio		9.5	0.28	8.4	12.1
Available P ppm		2.2	5.9	2.1	3.6
Exchangeable K Cmol Kg^{-1}		42.0	210.4	46.3	87.1

***Sources:** Direction de la Meteorologie Nationale
Ministere du commerce de I'ndustrie et des Transports. Republic de Niger.

Chemical Analysis of SF and MS

Chemical analyses were performed on SF and MS before the beginning of the experiment (Table 2) and thereafter for each subsequent recovery from the field plot and farmers' field. Samples of SF and MS were ground to pass 1 mm screen prior to DM (oven-drying at 105^0 C for 24 hours) and organic matter OM (ashing in a muffle furnace overnight at 400^0 C) determinations. Hemicellulose, Ce, and L contents in SF and MS were determined by the method of Goering and van Soest, (19670), while TNC was analyzed using the phenol-sulphuric acid method of Guiragossian *et at.* (1977). For N, P, and K analysis, ground SF and MS samples were digested in suphuric acid using aluminum block digester (Bremner and Mulvaney, 1982). The N and P contents of digests were determined using an autoanalyzer while the K content was by the flame emission spectrophotometry.

Table 2: Organic Matter (OM) total non structural carbohydrates (TNC), cellulose (Ce), hemicelulose (H), lignin (L), mand N, P and K Concentrations of in Sheep Faeces and Millet Stover.

Soil Amendment	g kg^{-1}							
	OM	TNC	Ce	H	L	N	P	K
Sheep Faeces	867.8	69.0	241.7	112.2	109.1	13.8	2.6	8.2
Millet Stover	955.6	99.4	501.3	213.8	132.6	7.2	1.3	15.0

Statistical Analysis

The single exponential function ($Yt = P e^{*1t}$), where Yt = fraction of the original material/nutrient remaining after time t; P = relative pool size; k = daily decay/release constant and t = time in days, was used to determine the decay/release rate constants in the non-linear (NLIN) model of the Statistics Analytical System. SAS (1985).

Results and Discussion

The decomposition of SF and MS at all the locations varied significantly. Millet stover decomposed faster than SF (Table 3). This observation was consistent with results obtained from a two year field incubation studies at Sadore (Ikpe *et al* 1994). The fastest decomposition rate for MS was at Gueladio followed by Sadeize Koara, Sambera and Sadore. The decay rate constants (k) for SF ere not significantly different at Sadore, Gueladio and Sambera. The greatest k for SF was observed at Sadeize Koara.

Table 3: Decay Rate Constants k (g day^{-1}) of Sheep Faeces and Millet Stover Village Locations in West Niger, Wet Season.

Location	Soil Amendment	K	R^2
Sadore	Sheep Faeces	Y = 0.0046	0.76
	Millet Stover	Y = 0.0067	0.77
Gueladio	**Erreur ! Liaison incorrecte.**	Y = 0.0046	0.90
	Erreur ! Liaison incorrecte.	Y = 0.0101	0.92
Sadeize Koara	Sheep Faeces	Y = 0.0052	0.89
	Millet Stover	Y = 0.0086	0.95

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Sambera	**Erreur ! Liaison incorrecte.**	Y = 0.0049	0.91
	Millet Stover	Y = 0.0078	0.91
S.E. ±		0.00052	

All models are significant at $p < 0.01$ probability level.

Annual rainfall had a key influence on decomposition and nutrient release patterns at the village locations. The availability of moisture enhances microbial activity which precedes the mineralization of organic compounds to inorganic (available) forms (Parr and Papendick, 1978). Although the initial N content was twice as high in SF than in MS (Table 2), MS decomposed faster (Table 3) and released N faster than from SF in most of the locations. This was attributed to the better leaching properties of MS than SF and the higher OM content of MS than that of SF (Table 2). Furthermore, majority of the N in ruminant manure is in the form of undigested dietary N which is concentrated in feed cell wall components, and non-dietary fractions. The N in the cell wall components, particularly as ligno-proteins, are difficult to catabolise both by rumen and soil micro-organisms (Mason, 1969).

The release of N, P and K in the present study fairly coincided with the rainfall received a the locations in 1992. Also, the physical and chemical properties of SF and MS, had a profound influence on their decomposition and nutrient release. However, differences in the soil chemistry, distribution of decomposers, and interactions between the chemistry of SF and MS and the metabolic character of decomposers may serve to explain why decomposition and nutrient release patterns were not a function of moisture (rainfall) alone.

Conclusion

The C and N mineralization of millet stover and sheep faeces and the release of nutrients related to their biochemical composition. The decomposition of SF and MS was possibly influenced by the soil environment especially moisture, soil C:N ratio, pH and fertility status. However some gaps still remain on the mechanisms and the specific organisms that were involved at each village location in the breakdown of the organic fractions.

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