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SHORT COMMUNICATION

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Litter decomposition of *Acacia auriculiformis* Cunn. Ex Benth. and *Acacia mangium* Willd. under coconut trees on quaternary sandy soils in Ivory Coast

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Abstract Litter decomposition of *Acacia auriculiformis* and *Acacia mangium* on sandy soil under coconut trees was studied in a field trial using the litterbag technique. The study was conducted during 2001 and 2002 in Ivory Coast. Litterbags containing 450 g of dried leaves and 450 g of dried small stems were set up in two coconut plantations of different ages, 3 and 20 years old. Dry matter weight and concentrations of total nitrogen (N), phosphorus (P), potassium (K), magnesium (Mg), and C/N ratio were determined at 90, 180, 270, and 360 days. The decomposition rate constant (k) and the half-life time decomposition of dry matter ($T^1/_2$) were calculated. The study showed that *A. auriculiformis* and *A. mangium* have the same rate of decomposition on each coconut plantation. The k value varied from −1.592 day^{-1} to −1.492 day^{-1}. The half-life time decomposition value of dry matter ($T^1/_2$) ranged from 283 to 301 days. Nitrogen was released between 0 and 180 days with an N concentration for *A. auriculiformis* and *A. mangium* varying from 2.03 to 1.80% and 1.97 to 1.79%, respectively. After 180 days, the litters immobilized N. Phosphorus and Mg were released faster from *A. mangium* than from *A. auriculiformis*. A positive correlation was found between the N concentration of each *Acacia* species and the litter dry weight at 90 and 180 days. Likewise, C/N ratio was positively correlated with litter dry weight at 90 days.

Keywords *A. auriculiformis* · *A. mangium* · Coconut · Decomposition constant · Quaternary sandy soils · Nitrogen · C/N ratio

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Introduction

The majority of smallholder farmers in sub-Saharan Africa have limited financial resources. They cannot afford application of chemical fertilizers, mostly imported and in limited supply, to improve the inherent low soil fertility status and thereby increase the productivity and profitability of their farms. Consequently, crop yields are low and production is made at subsistent level with a high risk to food security and increasing land degradation due to nutrient mining. There is a need to develop an integrated soil fertility system based on the use of available organic matter sources produced on farm. With the development of cover crops (Ibewiro et al. 2000) and alley farming (Kang et al. 1999) systems in tropical Africa, crop residues are increasingly used to compensate for the lack of long fallow periods and the low utilization of chemical fertilizers. Several studies showed that residues from herbaceous cover crops improve the mineral nutrition of the associated food crops (Mulongoy 1986; Tian et al. 1993; Becker and Johnson 1999; Akanvou et al. 2000). In alley farming systems like agroforestry systems, the trees grown in the alley contribute to the reduction of soil erosion and run off. Their prunings also improve soil quality by increasing soil water holding capacity, water infiltration, soil biodiversity and the activity of microorganisms, soil C and N contents, and weed control (Kang 1997; Isaac et al. 2003). The tree species mainly used in agroforestry systems belong to the Leguminosae family because they have the capacity to fix atmospheric N_2 and to scavenge from the subsoil other nutrients such as P, K, and Mg, which are also of interest to the sustainability of the production systems.

Acacia auriculiformis Cunn. Ex Benth. and *Acacia mangium* Willd. are two important leguminous species introduced in Ivory Coast. They are widely used in many cropping systems, particularly in association with plantation crops due to their unique adaptability to local conditions (N'goran et al. 2002). In the quaternary sandy soils of the coastal zone of Ivory Coast, *A. auriculiformis* and *A. mangium* are intercropped with coconut trees. This system provides important quantities of biomass (for firewood) and organic matter (and nutrients contained), which improve the soil chemical fertility and productivity of the coconut trees (Zakra et al. 1996).

To optimize management of organic residues produced from the *Acacia* trees, the decomposition parameters and dynamics in the release of nutrients from litter need to be investigated. Several factors such as N content (Constantinides and Fownes 1994), C content, C/N ratio, P content, C/P ratio (Vitousek et al. 1994; Xuluc-Tosola et al. 2003), lignin content, lignin/N ratio (Tian et al. 1992), soluble polyphenol content and their ratio to N (Palm and Sanchez 1991; Oglesby and Fowes 1992), and the ratio (lignin + polyphenol)/N (Handayanto et al. 1994) can be important in the residue decomposition process. Different methods are used to monitor decomposition of residues and the release of nutrients. Among these, the litterbag technique is one of the most popular because of its simplicity and reliability (Vanlauwe et al. 1997; Cobo et al. 2002).

The purpose of this study was to determine the decomposition rate of *A. auriculiformis* and *A. mangium* residues in litterbags and to monitor the rate and pattern of release of nutrients from the litter under young and mature coconut plantations, grown on sandy soils of the coastal zone of Ivory Coast.

Materials and methods

The study was conducted at the experimental station of Assinie Canal (3°10'N and 4°58'E), located 50 km from Abidjan, Ivory Coast. The main characteristics of the sandy soil are: 96% coarse sand, pH_{H2O} 5.8, 0.38% organic C, 0.02% total N, 13 mg available P kg^{-1} (Olsen) and 0.9 cmol (+) kg^{-1} cation exchange capacity.

Leaves (all ages) and fine (less than 5 cm diameter) stems of *A. auriculiformis* and *A. mangium* were collected from 2-year-old trees and cut into pieces 2–5 cm long, dried and placed in 40×40-cm bags with a mesh size of <2 mm. For each *Acacia* species, 32 bags were prepared. Each experimental litterbag weighed 900 g and contained equal portions of leaves and stems (450 g of dried leaves and 450 g of dried stems). The litterbags were set up over the soil surface in two coconut plantations of contrasting age (a 3-year-old plantation and a 20-year-old plantation) on December 8, 2001 and left in place until December 5, 2002. In the young plantation, the canopy of the young coconuts was still open (open vegetation cover), whereas the 20-year-old mature or adult plantation had a closed canopy (closed vegetation cover).

Monthly rainfall and temperature during the trial period are presented in Fig. 1.

Every 90 days until 360 days, four litterbags of each *Acacia* species were sampled for analysis from each of the two coconut plantations. At each sampling date, the mass of litter left in the bag was recorded after drying in an oven at 60°C until constant weight was achieved. A subsample of each treatment was ground into 0.5-mm particles for analysis of total N, C, P, K, and Mg using the procedures of Pauwels et al. (1992). The initial nutrient content of the litters was also determined. The *k* value (decomposition constant) was calculated using the linear equation of Wieder and Lang (1982):

$$X_t = X_0 + kt \qquad (1)$$

Where X_t is the litter dry matter weight (g) on time t (day); X_0 is the initial litter dry matter weight (g) and k is the decomposition constant ($day^{-.1}$).

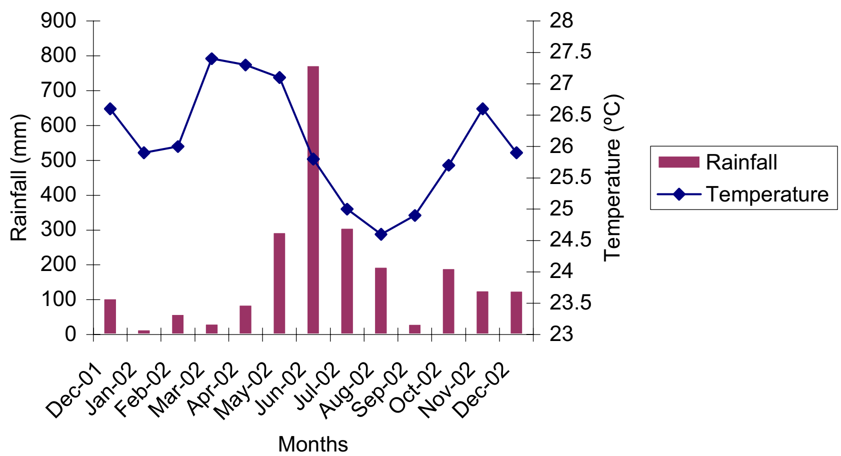

Fig. 1 Monthly rainfall and mean temperature during the trial period (December 2001 until December 2002) at Assinie-Canal

The time necessary for the decomposition of half of the initial litter weight is $T^1/_2$. It was calculated according to the following equation:

$$T1/2 = \frac{X_0}{2k} \quad (2)$$

derived from (1)

The experiment was laid down using a split-plot design with four repetitions. The size of the plot was 284 m^2, containing four trees and four litterbags per tree. The coconut plantation was the main factor and the acacia species, were the subfactors. Data on litter weight and C, N, P, K, and Mg contents were analyzed using the statistical procedure of MSTAT.

Results

With regard to litter weight no interaction was found between the coconut plantation and the *Acacia* species at 90, 270, and 360 days after placement of the litterbags. However, at day 180, the interaction plantation × *Acacia* species was significant ($P = 0.003$). At 90 days after placement of the litterbags, litter weight varied between the two plantations ($P = 0.001$) and between *Acacia* species ($P < 0.001$). The remaining litter in the bags from the young

Table 1 Evolution of weight (g), N content (%), C/N ratio, P content (%), K content (%) and Mg content (%) as a function of type of *Acacia* and age of plantation

Treatment	Days				
	0	90	180	270	360
Weight					
Aa × young plantation	900	797.5	669.6	430	377
Aa × adult plantation	900	763.2	640.7	420	362
Am × young plantation	900	779.2	649.4	428.9	375
Am × adult plantation	900	751.17	600	410	369
LSD		5.49	7.55	6.15	6.35
N content					
Aa × young plantation	2.03	1.96	1.83	2.20	2.25
Aa × adult plantation	2.03	1.94	1.77	2.21	2.22
Am × young plantation	1.97	1.93	1.81	2.18	2.23
Am × adult plantation	1.97	1.90	1.76	2.19	1.98
LSD		0.01	0.02	0.04	0.06
C/N ratio					
Aa × young plantation	27.47	27.2	24.27	22.65	23.52
Aa × adult plantation	27.47	27.05	23.75	22.43	23.71
Am × young plantation	28.03	27.03	22.9	23.01	23.85
Am × adult plantation	20.03	26.51	24.5	22.77	23.86
LSD		0.46	0.76	0.36	0.80
P content					
Aa × young plantation	0.090	0.080	0.063	0.058	0.057
Aa × adult plantation	0.090	0.078	0.064	0.057	0.055
Am × young plantation	0.150	0.125	0.110	0.085	0.062
Am × adult plantation	0.150	0.128	0.111	0.083	0.067
LSD		0.011	0.012	0.013	0.012
K content					
Aa × young plantation	1.07	0.944	0.636	0.391	0.198
Aa × adult plantation	1.07	0.799	0.618	0.468	0.211
Am × young plantation	1.19	0.951	0.549	0.240	0.191
Am × adult plantation	1.19	1.092	0.742	0.379	0.098
LSD		0.057	0.091	0.012	0.009
Mg content					
As × young plantation	0.190	0.182	0.177	0.174	0.173
As × adult plantation	0.190	0.180	0.175	0.173	0.172
Am × young plantation	0.221	0.194	0.182	0.172	0.172
Am × adult plantation	0.221	0.201	0.183	0.172	0.171
LSD		0.006	0.002	0.001	0.001

Aa *Acacia auriculiformis*, Am *Acacia mangium*

Table 2 Decomposition rate constant k (day^{-1}) and half-life time $T^1/_2$ (days) decomposition of dry matter litter of *A. auriculiformis* and *A. mangium*

	Young plantation		Adult plantation	
	A. auriculiformis	A. mangium	A. auriculiformis	A. mangium
k (day^{-1})	−1.571	−1.592	−1.582	−1.492
T12 (days)	286	283	284	301
R^2 (k vs time)	0.8	0.95	0.96	0.95
SD	0.221	0.092	0.089	0.092

coconut plantation was heavier (788 g) than that from the mature plantation (757 g). Likewise, the weight of remaining litter of *A. auriculiformis* was higher than that of *A. mangium*. A similar trend was observed at 180 days. The weight of remaining litter of *A. mangium* averaged 600 and 640 g and that of *A. auriculiformis* 649 and 669 g under the mature and young coconut plantations, respectively. Litter weights of the two *Acacia* species were similar at 270 and 360 days under the two coconut plantations (Table 1). This suggests that weight loss of the two *Acacia* species occurred according to the same pattern.

The calculated decomposition parameters, i.e., the constant k and $T^1/_2$ values for the experimental treatments are shown in Table 2. The estimated decomposition values revealed the highest k value (−1.492 day^{-1}) and $T^1/_2$ value (301 days) for *A. mangium* under the 20-year-old coconut plantation, although these were not statistically different from the values recorded under the 3-year-old plantation. The other treatments yielded similar k values, ranging from −1.592 to −1.571 day^{-1}, and $T^1/_2$ values, from 283 to 286 days (Table 1).

The N content of *A. auriculiformis* and *A. mangium* litter decreased from day 0 to day 180 in the two coconut plantations. On the average, the decrease was 23% for *A. auriculiformis* and 18% for *A. mangium* (Table 1). Positive linear correlations were found between N content and litter weight at day 90 [N content=0.001 litter weight+1.1333 (R^2 0.709)] and day 180 [N content=0.0009 litter weight+ 1.2083 (R^2 0.577)]. After 180 days, N content of the litter of the two *Acacia* species ranged from 1.75 to 2.2%.

Similarly, C/N ratio decreased from 27 to 28% at day 0 to about 23% at day 270–360.

The analysis of P, K, and Mg contents of the litter at the different dates indicated a steady decline in the contents of these elements from day 0 to day 270 for the two *Acacia* species (Table 1). The initial content of those elements was higher in *A. mangium* than in *A. auriculiformis*. Likewise, the decrease from each element was higher for *A. mangium* than for *A. auriculiformis*. The decreases from the initial values of P, K, and Mg contents were 37 and 57%, 81 and 88%, and 10 and 22% for *A. auriculiformis* and *A. mangium* litter, respectively.

Discussion

In this study, a significant interaction between plantation age and *Acacia* species on litter weight was observed at day 180 of the experiment. However, the general evolution in litter weight over time was identical for the two *Acacia* species (Table 1). Moreover, the decomposition parameters of the two *Acacia* litters, characterized by their k and $T^1/_2$ values, were not significantly different between the two plantations. The litterbags contained a mixture of leaves and fine stems in equal proportion, thus making it impossible to differentiate decomposition rates between the two types of litters.

Nitrogen is one of the main limiting factors of litter decomposition. It determines microbial activity and influences mineralization of organic C (Heal et al. 1997). The mineralization rate of an organic substrate can generally be predicted by its C/N ratio or its N content. When the C/N ratio is less than 20 or the N content greater than 2.5%, N is mineralized and the litter decomposition is fast. In contrast, N tends to be immobilized when the C/N ratio is higher than 20 while the litter decomposition is retarded (Heal et al. 1997). This study shows that the C/N ratio of the two *Acacia* species was higher than 20 but the litter N contents varied throughout the experimental period. However, at day 90 and 180, a positive correlation was found between N content and litter weight on one hand, and between C/N ratio and litter weight, on the other hand. A positive correlation was also found between the litter weight and decomposition rate constant. Xuluc-Tosola et al. (2003) reported a similar correlation between decomposition rate and C/N ratio of *Croton lundelli* Standl., *Metopiumbrownie* Jacq and *Manilkara zapota* L. in a tropical forest of Mexico. Those studies demonstrated that N content and C/N ratio are good parameters of plant residue decomposition rate in tropical regions. However, many tropical plants contain other compounds that may greatly influence their decomposition rates (Palm and Sanchez 1991; Tian et al. 1992). Frey et al. (2003) recently indicated that part of the C is lost by respiration, whereas N is microbially immobilized with an increase in litter N content (Table 1). This may perhaps explain the increase in N contents of the *Acacia* litter observed in this study after 180 days.

The decrease in P content of the litter during the first 180 days of this study depended on the *Acacia* species. After 180 days, P release occurred from *A. mangium* litter unlike *A. auriculiformis* litter that showed a trend to immobilize P. In a litter decomposition study in Zimbabwe, Musvoto et al. (2000) reported a first phase of release followed by an immobilization phase. Stevenson (1986) found that P mineralization occurs when the C/P ratio is below

300. However, other authors reported that P mineralization occurred with a C/P ratio ranging from 360 to over 1,000 (Gosz et al. 1973; Musvoto et al. 2000). It was then also shown that the critical C/P ratio varies according to climatic conditions (Blair 1988). In this study, the C/P ratio of *Acacia* litter from the coconut plantation varied from 334 to 1,052.

More than 80% of the initial K content of the acacia litter was released during the experimental period under the two coconut plantations. Similar results were reported by Zakra et al. (1996). The authors concluded that K is the most mobile element of *A. auriculiformis* and *A. mangium* litter. Working with leaves of *Gliricidia sepium*, Zaharah and Bah (1999) found that K was completely released from the litter during the first 30 days of decomposition in an Ultisol of Malaysia.

Unlike K, Mg content of the *Acacia* litter was released very slowly. Only 10% of the initial Mg content of *A. auriculiformis* was released by the end of the trial. This result is also consistent with the report from Zakra et al. (1996).

In conclusion, *A. auriculiformis* and *A. mangium* had the same decomposition rates under open (3-year-old coconut plantation) and closed (20-year-old coconut plantation) vegetation cover. The rates of nutrient release were different for the nutrients studied (N, P, K, and Mg) and for the type of *Acacia* litter. In practice, some 3–6 months were required for the release of N from the *Acacia* litter, whereas for the other nutrients some 6–9 months would be needed. Further studies are needed to better characterize the quality of the *Acacia* litter and understand the dynamics of their decomposition and release of nutrients in the coconut plantation. The management of nutrient release from organic residues to meet crop demand in the *Acacia*–coconut system still remains a major challenge.

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