Original Research paper

Leaf litter decomposition in the sudano-guinea savannahs of Ngaoundere Cameroon: Patterns of decay rate as related to litter traits?

Abstract: Litter decomposition processes are poorly studied in the savannahs. Leaf litter decomposition of the following twe~~i~~nty-four contrasting plant species was studied in the sudano-guinea savannahs of Ngaoundere, Cameroon : *Aframomum latifolia*, *Callistemon regidus*, *Carica papaya, Chromolaena odorata*, *Combretum molle*, *Dacryodes edulis, Hymenocardia acida, Hyparrhenia involucrata, Imperata cylindrica, Lannea schimperi, Lophira lanceolata, Mucuna stans, Pennisetum purpureum, Protea madiensis, Pseudarthria hookeri, Psidium gajava, Securidaca longepedunculata, Senna javanica, Syzigium guineense* var. *guineense, Terminalia glaucescens, Terminalia macroptera, T~~h~~ithonia diversifolia, Uapaca togoensis* and *Vitex doniana*. The litterbags technique was used to assess litter mass loss and single exponential model was adopted to estimate decay rate constants. During the 52 weeks of the field experiment, mean dry mass remaining of litter samples was significantly between 8.05 and 75.22% of initial litter dry mass for *C. papaya* and *C. regidus* respectively. Decomposition rate constant (k) significantly ranged from 0.003 (*C. regidus*) to 0.121 %.week^{-1} (*C. papaya*). Litter mass remaining (LMR) was positively related to thickness (R^2 = 0.605, P<0.01), IS (R^2 = 0.446, P<0.05), SM (R^2 = 0.569, P<0.001), lignin (R^2 = 0.631, P<0.01) and PC (R^2 = 0.618, P<0.001). The decomposition rate constant (k) was negatively related to thickness (R^2 = 0.602, P<0.01, n=12), IS (0.542; P<0.05), SM (0.419; P<0.05) and PC (0.530; P<0.01). It can be concluded that litter decomposition is affected by plant species diversity, plant groups and physico-chemical traits of litter in the sudano-guinea savannahs of Ngaoundere, Cameroun.

Key- words: Litter decomposition, decay rate, plant species diversity, Sudano-guinea savannahs, Ngaoundere, Cameroon.
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1. INTRODUCTION

In the Sudano-guinea savannahs of Adamaoua, where the local population derives most of their livelihood from livestock, agriculture and, to a lesser extent, forest products, the social and environmental situations are worrying for this population [1,2]. These traditional anthropogenic activities were already enough to carry out the seeds of the destruction of the natural environment, with the practice of bush fires, uncontrolled logging, the increase of non-timber forest products for trade and traditional medicine [3,4].

Human activities, natural hazards and the extention of cities at the expense of savannahs, due to the demographic pressure, the poorly adapted traditional practices of agriculture and the related ecological disturbances have led to a more or less complete disappearance of arable land reserves and a significant decrease in agricultural and forestry production [3,5,6]. Production systems based on traditional agriculture can no longer satisfy population demands [7]. In this context, cropping systems must integrate judicious soil management in order to improve and maintain their productivity. Therefore, the addition of organic or mineral fertilizers could help to meet the nutrient requirements of crops [8]. However, organic fertilizers are poorly used because agriculture is not systematically integrated with livestock and mineral fertilizers are inaccessible to average farmers [9]. It is therefore necessary to find other ways to increase agricultural production and diversify farmers' sources of income while protecting the natural environment. The most accepted alternative currently is agroforestry [10]. One of the functions of this technique is the maintenance or improvement of soil fertility through the introduction into production systems of plant species whose litter is an important source of organic matter.

Decomposition and mineralization of these litters are key processes in which organic matter and nutrients are incorporated into the soil and provide a reserve of available nutrients for plants and soil biological activity. According to Swift et al.[11], litter decomposition rate is mainly controlled by three groups of factors: soil organisms such as microorganisms and invertebrates, litter physicochemical traits such as N, P, Lignin, C ratio / N, litter thickness and hardness, and environmental conditions, especially climate to temperature and humidity, and soil type [12,13]. The importance of each variable varies with the study sites, the type of litter and the ecosystems considered. The understanding of these processes and the factors that control them is an essential step for the selection of plant species to domesticate in the Sudano-Guinean savannahs of Adamaoua.

Despite their importance in the sustainable management of Ngaoundere savannahs, very little information exists on litter decomposition processes, except those on the influence of litterbag mesh size on the litter decomposition of agroforestry species [14]), on leaf litter leaching of nine agroforestry species [15, 16], on litter decomposition of J*atropha curcas* L. and *J. gossypifolia* L. along altitudinal gradient [13] and on synergistic effects of earthworms and soil microorganisms one litter decomposition in sudano-guinea savannah zone of Ngaoundere, Cameroon [17]. All these studies were carried out for a short period, at most 24 weeks, with few species. In this study, contrasting litters of 24 species were used to determine patterns of litter decomposition of sudano-guinea savannahs of Ngaoundere, and relationships between litter traits and their decomposition constants.

2. MATERIALS AND METHODS

2.1 Study site

The study site located in Adamawa region (6-8N, 12-15E, altitude 1200 m asl). This geographical situation gives at this region a humid climate according to Suchel [18], with one dry season (November - March) and one rainy season (April - October). The rainy season extends from July to September, registering maximum amounts in August. The dry season stretches from November to March. The mean annual rainfall is about 1500 mm, with a variation coefficient of 9.8. The mean annual temperature is approximately 22°C and the mean relative humidity about 69% [19]. The seasonally arid situation of Adamawa region is due to the influence of the Harmattan (dry wind) which recalls the harsh climatic conditions of the Sudano-sahelian savannahs, while its rainfall and its thermal amplitude recall the humid subequatorial regions [20]. The ferralitic soils are the dominant type [21], with rich clay (40-60%), low organic matter (less than 1%), low soil exchange capacity from 15 to 20 meq/100g and the pH about 4.7 to 5.6 [22]. Hydromorphic soils are found in the marshy depressions. The vegetation of Ngaoundere savannahs is constituted of meadows, shrubby and woody savannahs, with predominance of *Daniellia oliveri* and *Lophira lanceolata* [23] Degraded fallow lands and savannahs occasionally used as grazing land and composed of *Acacia hockii* and *Afzelia Africana* [23]. The vegetation aspects are maintained by zoo-anthropic factors such as bush fires and grazing [24].

The experimental site is located at the University of Ngaoundere (7°26' Northrd~~d~~, 13°31'East and altitude 1114 m) situated at the village Dang, about 15 km from North~~d~~ of Ngaoundere city. Plot was chosen under canopy of trees including *mangifera indica* L. (Anacardiaceae) and *Daniellia oliveri* (Rolfe) Hutnch and Dalz (Caesalpiniaceae).

2.2 Leaf litter selection

In this study, only fresh fallen leaf litters of twinty-four socio-economic and contrasting plant species of the Sudano-guinea savannahs of Ngaoundere were used. The experiment involved twelve deciduous broad-leaved including seven trees (*Combretum molle*, *Lannea schimperi*, *Lophira lanceolata*, *Senna javanica*, *Terminalia glaucescens*, *Terminalia macroptera* and *Vitex doniana)* and five shrubs (*Chromolaena odorata*, *Hymenocardia acida*, *Mucuna stans*, *Protea madiensis and Thitonia diversifolia)*, six evergreen board-leaved including five trees (*Carica papaya*, *Dacryodes edulis*, *Psidium gajava, Syzigium guineense* var. *Guineense* and *Uapaca togoensis*) and one shrub (*Callistemon regidus*), one semi-deciduous shrub (*Securidaca longepedunculata*), two herbs (*Aframamum latifolia* and *Pseudarthria hookeri*) and three grasses (*Hyparrenia involucra*, *Imperata cylindrica* and *Pennisetum purpureum*). The biological characteristics of these species are found in **table 1**. The distribution area of *Syzigium guineense* var. *guineense, Vitex doniana* and *Dacryodes edulis* is forest gallery, while others species is savannahs land, fallows or degraded forests. The twenty-four plant species play a great socio-economic role in the area. They are a source of income, food, firewood, medicinal products and soil fertility indicators for the farmers of this region [24-28].

2.3 Litter decomposition experiment *in situ*

New litterfall samples were collected directly from forest floor in the Ngaoundéré humid savannahs, next to the University of Ngaoundéré, during maximum leaf fall period (November 2006 – January 2007). This period corresponds to dry season and soil was very dried. Grasses have been cut to the ground. No leaching ~~was~~ occurred from new litter which was sorted, air-dried and stored in the laboratory before use.

A study was conducted *in situ* in the savannahs near the University of Ngaoundéré. A litterbag technic was used according to Bocock and Gilbert [29] method, and consisted of nylon material with a 2 mm mesh [11]. The bags were of different sizes according to litter type to avoid compressing the material and thus creating artificial conditions in the litterbags. The choice of the litterbags and mesh size was based on previous studies of litter decomposition [30]. The 2 mm diameter mesh is considered by Sundarapandian and Swamy [31] to be small enough to prevent litter loss and large enough to allow access to mesofauna such as some termites and glass of soil. In total, five hundred and seventy-six (576) litterbags (24 species x 8 sampling dates x 3 replications) were each filled with 7±0,01g of the leaf litter and placed on soil top, during 52 weeks. The litterbags were lightly covered with vegetation

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litter to avoid destruction litterbags by animals. The experimental design was a randomized complete block with species as treatment. Three litterbags per species were collected at 2, 4, 6, 10, 16, 24, 36, and 52 weeks intervals, brought to the laboratory where all roots, fauna, and soil particles were manually removed from the litter samples. The dry mass of the litter samples in each litterbag was determined after it was oven-dried at 60°C to constant mass for 48h.

To determine initial dry mass, three other litter samples of each species not including in the above mentioned were weighed and dried at 60°C to constant mass. The litter dry mass remaining was calculated per sample date and species. To avoid fragmentation, leaf-litter was moistened again, spread out and then the corresponding leaf areas were measured using a planimeter (Area meter, MK2). The leaf specific mass (SM) or mass per unit area was calculated from their dry mass and area. The Sclerophyllous index (SI) was also calculated from their dry mass and area. Thickness was measured on the same leaves by calliper. The leaf litter density was calculated from their dry mass and area, thickness.

2.4 Chemical analysis

The initial litters were analysed chemically after passing through a cyclone mill with a l-mm mesh. Ash content was measured after combustion in a muffle furnace at 550°C for 3h. The concentration of phenolic compounds, cellulose, lignin and NDF were respectively determined by Dubois *et al.* [32] method, by Folin-Ciocalteu reagent[33], by colometric method [34] and by van Soest's [35] and detergent method.

2.5 Statistical analysis

The oven dried litter mass remaining will hereafter be denoted as LMR. The LMR values for each species were fitted to several mathematical models assuming that the litters were composed of one, two, or three compartments with different rates of decomposition [36]:

$$LMR = Ae^{-k_1 t} \qquad \text{Eq1}$$

$$LMR = Ae^{-k_1 t} + C \qquad \text{Eq2}$$

$$LMR = Ae^{-k_1 t_1} + Be^{-k_2 t_2} \qquad \text{Eq3 (where A+B = 100)}$$

$$LMR = Ae^{-k_1 t} + Bt + C \qquad \text{Eq4}$$

Where A, B and C are the compartments of water soluble and resistant substances (lignin and other compounds). k_1 and k_2 are the decomposition rate constant over time t for components A and B respectively, and LMR is expressed as a percentage of the initial mass and the time in weeks. Best model was selected according to high coefficient of determination and low standard deviation or error. A multiple comparison among the fitted decomposition constants (k) was carried out using the *T' – method* [37].

Before forming any analysis, all variables was tested for normality and if necessary, log transformed. Using a one-way ANOVA, following by *Scheffe*'s mean comparison test at 5% (if ANOVA was significant), we compared LMR among litter types (or species). We used also ANOVA to test the effects of treatments on LMR at each sampling time (2, 4, 6,8, 16,24, 36 and 52 weeks). *Student*t test was also used to compare LMR at 4 and 52 weeks of incubation *in situ*. Pearson's correlation coefficients were used to determine relationships between decomposition rate constants (k), LMR at 4 and 52 weeks and physico-chemical traits of initial litter. These tests were conducted through software package SX for DOS, version 4.0. (Statistix, 1992).

3. RESULTS

3.1 Initial litter traits

The 24 litters studied belonged to 15 different botanical families and to four major groups: 12 species of broad-leaved deciduous trees and shrubs, 6 species of broad-leaved evergreen trees and shrubs, 1 species of broad-leaved semi-deciduous tree and 5 grasses (Table 1). Five physical traits of initial leaf litter (thickness, area, sclerophyllous index, density and specific mass) of 23 species, except *A. latifolium*, have been determined (Table 2). These plant species differed significantly (P < 0,001) among them according to each physical trait. Their mean thickness varied from de 0.02 mm in *P. purpureum* to 1.11 mm in *T. macroptera*, their area from 4.27 in *C. regidus* to 245.89 mm^2 in *T. macroptera*, their sclerophyllous index from 0.01 in *T. diversifolia* to 1.75 $mg.mm^{-2}$ in *P. purpureum*, their density from 0.21 in *D. edilus* to 87.50 $mg.mm^{-3}$ in *P. purpureum*, and their leaf-specific mass from 0.57 in *P. purpureum* to 185.46 $mm^2.mg^{-1}$ in *T. Diversifolia*.

The litters also differed significantly (P<0.01) in each of their four chemical traits (cellulose, lignin, NDF and total phenolic compounds) which have been detremined in 20 species, except *C. odorata*, *P. purpureum*, *P. gojava* and *T. glaucescens* (Table 2). Their cellulose content varied from 3.79 in *A. latifolium* to 11.84% in *V. doniana;* lignin from 2.84 in *S. g. guineense* to 8.12% in *V. doniana*; NDF from 21.35 in *S. g. guineense* to 80.41% in *V. doniana*; and total phenolic compounds from 0.47 in *V. doniana* to 17.76% in *A. latifolia*.

3.2 MSR at 4 and 52 weeks of incubation *in situ*

The litter dry mass remaining (LMR) varied significantly (P <0.05) among species at 4 and 52 weeks of incubation (Table 3). LMR ranged from 47.03 in *C. papaya* to 96.94% in *S. g.* var. *guineense* 4 weeks after incubation, and 8.05 in *C. papaya* to 76.22% in *C. regidus* 52 weeks after incubation. That is, a litter mass loss corresponding to 52.97 and 3.06% at 4 weeks after incubation and 92 and 23.78% after 52 weeks of incubation in the same species. For all species, LMR after 4 weeks of incubation were significantly different from those after 52 weeks of incubation, with the exception of *A. latifolia* and *L. schimperi* (Table 3). For the latter species, the standard deviations are large, suggesting that the deviations of the values around the averages were high.

3.3 Comparison of the various decomposition models and decay rate constant

To compare the mass loss and the parameters of decay in different species, we needed to find the mathematical function that fitted the data best. Among the tested functions, the equation Eq2 and Eq4 did not adjust to the LMR of all litters, in particular *L. lanceolata* and *S. g.* var. *guineense* for model Eq2 and *C. odorata*, *P. gojava*, *T. glaucescens* and *U. togoensis* for equation Eq4 (Table 4). On the other hand, the simple (Eq1) and double (Eq3) exponential functions fit well to the LMR of all litters with highly significant coefficients of determination. The double exponential function has coefficients of determination generally higher than those of the simple exponential model (Table 4), but the parameters (A, B, k_1 and k_2) of the model were not generally significant. Because most of the standard errors of these parameters were higher than the estimated parameters (Appendix 1). The simple exponential function was therefore adopted to fit the LMR of the litters (Figure 1) because the coefficients of determination are significant and the parameters of the regression model were well estimated with low standard errors for all litters (Appendix 2).

The litter decomposition constant differed significantly among species (Figure 2). It ranged from 0.003 to 0.120 week^{-1}. The litter decomposition constants of *C. papaya* (0.121 week^{-1}) and *T. diversifolia* (0.119 week^{-1}) were the highest. That of the litter of *C. rigidus* (0.003 week^{-1}) was the lowest and did not differ significantly from that of *D. edulis* (0.006 week^{-1}) and *H. acida* (0.006 week^{-1}). *C. papaya* and *T. diversifolia* had litter decomposition constants 2 to 40 times higher than those of other species, particularly of *C. rigidus*.

3.4 Relationships between physico-chimical traits of initial litières, LMR and k

Relationships between initial litter traits and their LMR at 4 and 52 weeks of litter decomposition were determined (Figures 3, 4 and 5). Positive and highly significant correlations ($P < 0.01$) between sclerophyllia index ($R^2 = 0.568$), NDF ($R^2 = 0.523$) and phenolic compounds ($R^2 = 0.598$) and LMR at 4 weeks of incubation (LMR4) were found (Figure 3). Similarly, LMR at 52 weeks of incubation (LMR52) were positively and significantly correlated with the three physical traits of litter: the thickness ($R^2 = 0.605$, $P < 0.01$), the sclerophyllia index ($R^2 = 0.446$; $P<0.05$) and SM ($R^2 = 0.569$, $P < 0.001$) (Figure 4a) and two chemical traits: lignin ($R^2 = 0.631$, $P < 0.01$) and phenolic compounds ($R^2 = 0.618$, $P < 0.001$) (Figure 4b). On the other hand, the litter decomposition constant (k) was negatively and significantly correlated with the three physical traits of the litter: thickness ($R^2 = 0.602$, $P < 0.01$), IS ($R^2 = 0.542$, $P < 0.05$) and SM ($R^2 = 0.419$; <0.05) and one chemical traits, phenolic compounds ($R^2 = 0.530$, $P < 0.01$) (Figure 5).

4. DISCUSSION

4.1 Initial litter traits

The litter studied came from a varied range of plants, *i.e.*, grasses, herbaceous, shrubs and broad-leaved deciduous and evergreen plant species. The physical traits within the initial litters studied ranged from 0.02 to 1.11 mm for thickness, from 0.04 to 2.46 mm^2 for area, from 0.01 to 1.75 $mg.mm^{-2}$ for sclerophyllous index, from 0.21 to 87.50 $mg.mm^{-3}$ for density and from 0.57 to 185.46 $mm^2.mg^{-1}$ for specific area. Regarding the initial organic compounds, they varied from 3.79 to 11.84% for cellulose content, from 2.84 to 8.12% for lignin content, from 21.35 to 80.41% for NDF content and from 0.47 to 17.76% for phenolic compound content. The following studies used various types of litters to investigate the influence of the initial traits on litter decomposition: Mapongmetsem [38], who used seven types of litters of Ngaoundere savannahs with a thickness varying between 0.12 and 0.36 mm, area between 0.19 and 1.26 mm^2, sclerophyllous index between 0.27 and 1.05 $mg.mm^{-2}$, density between 0.67 and 14.21 $mg.mm^{-3}$. He also found out cellulose content ranged from 1.26 to 3.28%, lignin content from 1.05 to 5.37% and phenolic compound content from 1.48 to 7.48%; Ibrahima et al. [17] using six types of litters including deciduous and evergreen leaf litter with thickness varying between 0.34 and 0.78 mm, area between 22.78 and 58.98 mm^2; sclerophyllous index between 0.15 ana 0.25 $mg.mm^{-2}$; cellulose content between 1.14 and 2.89%; lignin content between 2.84 and 6.03% and phenolic compound content between 1.16 and 6.90%; Anguessin et al. [13], using jatropha leaf litters with thickness varying between 0.21 and 0.36 mm, area between 108.64 and 246.40 mm^2, sclerophyllous index between 0.045 and 0.051 $mg.mm^{-2}$; Bayala et al. [39], using deciduous leaves with cellulose between 16.26 and 18.90%, lignin between 15.74 and 20.78% and polyphenol content between 5.51 and 5.91%; Taylor et al. [40], using litters of conifers, broadleaved trees, shrubs, and grasses with lignin varying between 3.4 and 20.5%. Compared with that of other litter decomposition studies, the range of variation in initial physical and chemical traits in the litters in this study was at least of the same order of magnitude, exception of the results of Bayala et al. [39] on cellulose and lignin contents which were higher values than ours. Gillon et al. [41] reported the results of physico-chemical litter traits of 34 Mediterranean plant species. Their values varied from 0.10 to 0.94 mm for theckness; from 0.04 to 0.20 $mg.mm^{-2}$ for LSM and from 0.13 to 0.75 $mg.mm^{-3}$ for density. They reported also the cellulose and lignin content varied from 5.8 to 34.90%, and from 4.5 to 36.50% respectively. In general, the physico-chemical traits of leaf litters of twenty-four plant species in the soudano-guinea Savannahs of Ngaoundere were within the range of published data [13,17,38,39,40,41].

4.2 Mass loss at 4 and 52 weeks of incubation

Litter decomposition varied among study sites and species composition. Indeed, Mapongmetsem [38] reported that mass losses of eight litter types ranged from 10.83 to 41.79% after 1 month (4 weeks) and from 38.00 to 69.85% after 9 months (39 weeks) of field incubation at the similar type of savannah (Sudano-guinea of Ngaoundere) with different types of litters. According to Oladoye et al. [42] who worked in the Nigerian savannah, this loss, for *Leucaena leucocephala* litter reached about 32.32% of initial mass after 40 days (≈6 weeks) of field incubation while Jamaludheen and Mohan Kumar [43] found the litter mass loss of nine species ranged from 13 to 35% after 1 month~~e~~ (≈4 weeks) and from 82 to 99% after 12 months (52 weeks) of field incubation in traditional agroforestry systems of Kernataka, southern India. In our study the average litter mass loss varied significantly from 3.06 to 52.97% after 4 weeks and from 23.78 to 92.00% after 52 weeks of litter incubation *in situ*. These values were from the lower to upper range reported in the literature and showed wide spectra of litter mass loss in the Sudano-guinea Savannah of Ngaoundere [14,38], due to existing of various plant species of different behevours in this savannah. It could play an important role in the adaptation mechanism of species of this savannah to eventual and environmental changes, due to natural or anthropogenic pressures, as have shown by Ibrahima et al. [44] in Ebom Tropical Forest.

4.3 Mass loss dynamics

Numerous mathematical models were found in the literature to describe litter mass loss with time [36,45]. These models vary according to leaf litter traits, short or long-term litter incubation, soil organisms of study sites and laboratory or field experiments [36,46,47]. In our study, depending on the litter type, the four models are well suited to describe the litter mass loss during their decomposition. This suggested that for the studied litters, several models can describe the mass loss dynamics and could be explained in part by a wide range of the initial physico-chemical traits of these species. For example, *T. diversifolia* lost more than 92% of its initial dry mass in one year. This loss corresponds to more than 4.5 times that of *D. edulis* (25.11%). These 2 species differed widely in their physico-chemical litter traits and their ecology. The litter thickness (0.15 mm), sclerophyll index (0.01 $mg.mm^{-2}$), lignin (5.63%) and phenolic compounds (1.21%) of *T. diversifolia* were 1 to 5 times lower than those of *D. edulis*, which were respectively 0.73 mm, 0.16 $mg.mm^{-2}$, 7.27% and 3.48%. On the other hand, the cellulose content was higher in *T. diversifolia* (9.98%) than in *D. edulis* (6.48%). In addition, *T. diversifolia* is a fast growing pioneer, while *D. edulis* is a slow-growing evergreen shade tree.

To compare litter decomposition rates of 24 studied species, the single-exponential decay model, most commonly used to describe mass-loss with time [45, 48] was adopted. Indeed, although the coefficients of determination of the adjustments are weak, it is the only model among the four tested which fitted well for all the litters. On the other hand, the double-exponential model, although had the highest significant coefficient of determination, the three parameters of this model (A, k_1 and k_2) were estimated with greater error than estimates. In other respects, the coefficients of determination of the single exponential decay model were less than the double exponential decay model, but still quite highly significant. The parameters of this model have been estimated with reasonable standard error.

Litter decomposition constant (k) varied among plant species. Indeed, in their study on litter decomposition of a tropical vertisol forest of Lama reserve in Benin, Sabin Guendehou *et al.*[49] found that the litter decomposition constant varied among five plants species (*Afzelia africana*, *Anogeissus leiocarpa*, *Ceiba pentendra*, *Dialium guineense* and *Diospyros mespilifourmis*). Their values ranged from 1.69 to 4.67 $year^{-1}$ corresponding to 0.03 and 0.09 $week^{-1}$. According to Jamaludheen and Mohan Kumar [43], the litter decomposition constants of nine multipurpose trees in Kerala, India varied from 0.16 to 32 $year^{-1}$, corresponding to 0.04 and 0.079 $week^{-1}$. Many other studies synthetized by Ibrahima et al. [44] have shown that the litter decomposition constant (k) of tropical forets ranged from 0.21 to 8.58 $year^{-1}$, corresponding from 0.004 to 0.17 $week^{-1}$. Our study showed that the decomposition constants of leaf litter including the litter of tropical forest as *Dacryodes edulis* were in the lowest to highest part of the range reported in the literature for the litter of plant species of African

Savannahs [38, 49] and were in the lowest to middle part of the range reported in the literature for the litter of plant species of Tropical forest. In fact, in the present study the decomposition rate constants (k) varied from 0.003 to 0.0120 week^{-1}, with an average value of 0.027 week^{-1}.

4.4 Factors determining litter mass loss and k

Mass loss and litter decomposition constant (k) were generally influenced not only by the litter physical traits but also by its chemical quality [30,36,38,44,50,51,52]. The parameters retained varied according to ecosystems under consideration. With respect to the litter physical traits such as the thickness, sclerophylly index and specific area (SM), we found that the LMR at 4 weeks of incubation was influenced by the Sclerophylly index, whereas that at 52 weeks of incubation and the litter decomposition constant (k) were both under the dependence of the Sclerophylly index, the thickness and the specific area (SM). Like the physical traits, the litter chemical traits as the phenolic compound content was correlated with the LMR and the litter decomposition constant. Based on these results and those of the previous studies, we can affirm that the rate of litter decomposition of species of Sudano-guinean savannahs of Adamawa was controlled by the litter physico-chemical traits as were shown in this study and those of Mapongmetsem [38], Ibrahima et al.[15], but also by climate [13]) and soil organisms [17]. The importance of these parameters has not yet been studied as Lavelle et al. [53] for Tropical forest ecosystems.

4.5 Comparison between species groups

The litters in this study can be classified according to their distribution (native and exotic species), their biological type (deciduous and evergreen species), and vegetative type (tree, shrub, and herbaceous). The introduced plant species included the exotic cultivated (*C. papaya*, *D. edulus*, *C. regidus*, *S. javanica*, and *P. gojava*) and alien invasive species as *T. diversifolia* and *C. odorata*. If we exclude grasses with particular characteristics, litter decomposition constant (k) and litter mass loss of *T. diversifolia* (0.119 week^{-1} and 91.72%) and *C. odorata* (0.052 week^{-1} and 88.73%), two (2) exotic invasive herbaceous, and those of *C. papaya* (0.12 week^{-1} and 91.95%) were among the highest and that of 2 exotics cultivated, *C. regidus* (0.003 week^{-1} and 23.78%) and *D. edulus* (0.006 week^{-1} and 25.11%), were among the lowest compared to native species of Ngaoundere savanna. These differences between the native species and these two groups of exotic species can be explained by the physical and/or chemical litter ttraits as reported by Allison and Vitosek [54] and Godoy et al. [55]

comparing the litter decomposition of invasive and native species. Indeed, the 2 exotic invasive species are annual and deciduous species with lower thickness (0.15 and 0.20 mm), sclerophyllous index (0.01 0.14 mg.mm^{-2}) and phenolic compound content (1.21%), and higher cellulose content (9.49%). In addition, they are pioneers, fast-growing herbaceous plants adapted to various tropical climatic conditions. In contrast, cultivated exotic species (*C. regidus* and *D. edulus*) are evergreen, with higher litter thickness (0.22 and 0.73mm), density (0.21 and 0.91 mg.mm^{-3}), and lignin content (4.06 and 7.23%) and lower cellulose content (6.48 and 9.35%). In addition, they are slow-growing trees adapted to humid climatic conditions in tropical regions. Our results confirm those of the literature. Indeed, Faster litter decomposition from invasive alien species compared to native species has been reported when invaders were N_2-fixers and native species were not [56], when nutrient content in the exotic was higher than native one [54] and when the specific leaf area (SLA) of invaders was higher than that of native species [57,58]. By constrast, slower decomposition of invaders alien species leaf litter was found when it had a higher polyphenol content, higher lignin content or higher C/N ratio than native litter [55,59,60].

Some studies have shown that litter decomposition of evergreen species is slower than that of deciduous species [61,62]. However, in our study, the distinction between deciduous and evergreen species concerning litter decomposition is not clear. In fact, evergreen species (*C. regidus* and *D. edulus*) decomposed more slowly than deciduous species. On the other hand, *C. papaya*, which is an evergreen, decomposed very fastly like the deciduous species and has density (0.23 gm.mm-3) and phenolic compounds (4.51%) among the lowest such as those of deciduous species. In addition, *C. papaya* is fast-growth species and its litter is very friable in the dry state which breaks easily and increases the contact surface of microorganisms. This explains its litter decomposition is faster than that of the deciduous species and the shift of its behavior with the other evergreen ones.

5. CONCLUSION~~S~~

The 24 leaf litters studied showed a great variety in behaviours in their mass loss, litter decomposition rate constant (k) and equation model~~e~~ describing mass~~e~~ loss dynamics. In fact, the average litter mass loss ranged significantly from 23.78 to 92.00% after 52 weeks of litter incubation, while the decomposition rate constants (k) ranged from 0.003 to 0.120 week^{-1}, with an average value of 0.027 week^{-1}. The net difference between litters of evergreen and deciduous species did not seem to appear in our study as shown with litter of *C. papaya* (evergreen species) which decamped faster than~~e~~ the deciduous ones. These patterns of litter decomposition process were linked to variety of the physico-chemical traits of the leaf litter in the Soudano-guinea savannahs of Adamawa Cameroon. These finding suggested that the physico-chemical traits of the leaf litter in these savannahs seem to play a major role in leaf litter decomposition. ~~This is in agreement with one of the conclusions of the study by Mapongmetsem [38] on the decomposition of litters of Soudano-guinea savannahs species and those of Gillon et al. [36] in Mediterranean ecosystems.~~

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Table1: Leaf litters of 24 studied species.

Species	Families	Code	Statut	Habitat	Guilde
Broad-leaved deciduous trees					
Combretum molle R. Br. Ex G. Don	Combretaceae	CM	N	Savannah	
Lannea schimperi (Hochst. Ex A. Rich.) Engl.	Anacardiaceae	LS	N	Various	
Lophira lanceolata Van Tigh. Ex Keay	Ochnaceae	LL	N	Savannah	
Senna javanica L.	Fabaceae	SJ	E	Pre-forest	
Terminalia glaucescens Planch. Ex Benth.	Combretaceae	TG	N	Savannah	
Terminalia macroptera Guill. & Perr.	Combretaceae	TM	N	Savannah	
Vitex doniana Sweet	Verbenaceae	VD	N	Forest gallery	Shad tree
Broad-leaved deciduous shrubs					
Chromolaena odorata (L.) King & Robinson	Asteraceae	CO	E	Clearing	Pioneer
Hymenocardia acida Tul.	Hymenocardiaceae	HA	N	Savannah	
Mucuna stans Welw. ex Baker	Fabaceae	MS	N	Savannah	
Protea madiensis Oliv.	Proteaceae	PM	N	Savannah	
Thitonia diversifolia (Hemsl.) A. Gray	Asteraceae	TD	E	Open Savannah.	Pioneer
Broad-leaved semi-deciduous tree					
Securidaca longepedunculata Fres.	Polygalaceae	SL	N	Savannah	
Broad-leaved evergreen trees					
Carica papaya L.	Caricaceae	CP	E	Planted	
Dacryodes edilus (G. Don) H. J. Lam.	Burseraceae	DE	N	Forest gally	Shad tree
Psidium guajava L.	Myrtaceae	PG	E	Planted	Pioneer
Syzygium guineense var. *guineense* (Willd.) DC.	Myrtaceae	SG	N	Forest gallery	Shad tree
Uapaca togoensis Pax	Euphorbiaceae	UT	N	Forest gallery	Shad tree
Broad-leaved evergreen shrub					
Callistemon rigidus R. Br.	Myrtaceae	CR	E	Planted	
Grasses					
Aframomum latifolia K. Schum.	Zingiberaceae	AL	N	Grassland	Pioneer
Hyparrhenia Involucrata Stapf.	Poaceae	HI	N	Grassland	Pioneer
Imperata cylindrica (Linnaeus) Palisot de Beauvois	Poaceae	IC	N	Grassland	Pioneer
Pennisetum purpureum Schum.	Poaceae	PP	N	Grassland	Pioneer
Pseudarthria Hookeri Wright & Arn.	Fabaceae	PH	N	Grassland	Pioneer

Table 2: Initial leaf litter traits of 24 plant species studied. Standard deviation in parenthesis.

Species	**Thickness (mm)**	**Area (mm^2)**	**IS ($mg.mm^{-2}$)**	**Density ($mg.mm^{-3}$)**	**SM ($mm^2.mg^{-1}$)**	**Cellulose (%)**	**Lignin (%)**	**NDF (%)**	**Phenolic compounds (%)**
A. latifolium	ND	ND	ND	ND	ND	3.79 (0.51) e	4.40 (0.56) abcd	66.94 (21.71) ab	17.76 (12.78) a
C. regidus	0.22 (0.03) fg	4.27 (0.56) c	0.02 (0.003) e	0.91 (0.11) ef	50.73 (7.01) c	9.35 (1.13) abc	4.06 (0.09) abcd	62.84 (12.85) ab	11.28 (0.43) abcde
C. papaya[1]	0.44 (0.003)	48.82 (0.95)	0.10 (0.01)	0.23	10.00	7.16 (0.54) bcde	5.99 (0.42) abcd	52.12 (17.16) ab	4.51 (1.32) defg
C. molle	0.62 (0.03) bcde	42.97 (1.92) bc	0.18 (0.02) bcde	0.31 (0.02) f	59.68 (2.66) c	9.45 (1.39) abc	5.83 (0.08) abcd	63.43 (8.85) ab	16.11 (13.30) ab
C. odorata[1]	0.20	38.00	0.14	0.70	7.14	ND	ND	ND	ND
D. edulis[1]	0.73 (0.01)	42.89 (0.16)	0.15	0.21	6.67	6.48 (1.95) abcde	7.27 (2.36) ab	45.86 (1.48) ab	3.48 (1.06) efg
H. acida	0.40 (0.04) cdefg	12.63 (0.06) c	0.16 (0.001) bcde	0.40 (0.02) f	66.49 (0.34) c	5.44 (1.02) bcde	3.83 (0.55) bcd	76.43 (12.15) a	13.54 (9.12) abc
I. cylindrica	0.30 (0.10) defg	26.33 (1.15) c	0.03 (0.003) e	1.22 (0.42) def	29.57 (2.62) c	ND	6.34 (0.44) abcd	79.43 (3.78) a	9.79 (1.23) abcdefg
L. schimperi	0.64 (0.03) bcd	27.21 (2.51) c	0.26 (0.03) abcde	0.40 (0.05) f	41.23 (3.80) c	7.45 (1.90) abcde	5.43 (0.01) abcd	56.38 (12.96) ab	4.98 (2.83) cdefg
L. lanceolata	0.40 (0.03) cdefg	177.55 (76.16) abc	0.02 (0.01) e	0.46 (0.24) f	65.26 (31.46) c	6.48 (1.63) bcde	5.65 (1.30) abcd	60.63 (23.96) ab	1.00 (0.12) fg
M. stans	0.24 (0.03) fg	17.46 (0.98) c	0.07 (0.003) de	0.32 (0.04) f	152.60 (1.85) ab	8.57 (0.01) abcde	6.51 (0.24) abc	72.62 (8.83) a	5.33 (2.49) cdefg
P. purpureum[1]	0.02	36.26	1.75	87.5	0.57	ND	ND	ND	ND
P. madiensis	0.59 (0.08) bcde	61.97 (17.15) abc	0.02 (0.003) e	0.36 (0.06) f	48.02 (6.87) c	8.76 (1.93) abcd	4.89 (0.06) abcd	57.51 (18.68) ab	13.05 (0.39) abcd
P. hookerii	0.57 (0.04) bcdef	70.52 (0.91) abc	0.14 (0.02) cde	0.26 (0.03) f	89.01 (6.88) c	4.11 (0.3) de	4.29 (2.68) abcd	77.73 (6.57) a	8.71 (5.63) abcdefg
P. gojava	0.62 (0.05) bcde	25.63 (3.47) c	0.19 (0.02) abcde	0.32 (0.03) f	58.25 (7.88) c	ND	ND	ND	ND
S. longepedunculata[1]	0.42 (0.02	9.65 (0.08)	0.10 (0.04)	0.24	10.00	6.96 (0.54) bcde	5.43 (1.60) abcd	66.43 (0.24) ab	8.18 (0.08) abcdefg
S. javanica	0.28 (0.16) efg	29.00 (1.73) c	0.02 (0.002) e	1.09 (0.79) ef	45.71 (4.17) c	8.93 (1.40) abcde	5.59 (1.25) abcd	61.64 (16.10) ab	8.79 (2.29) abcdefg
S.g. var. *Guineense*	0.56 (0.03) bcdef	29.10 (0.52) c	0.20 (0.002) abcde	0.38 (0.02) f	53.51 (0.96) c	8.34 (0.19) abcde	2.84 (0.68) cd	21.35 (0.17) b	4.79 (0.35) cdefg
T. glaucescens	0.81 (0.03) ab	75.85 (2.05) abc	0.20 (0.03) abcde	0.27 (0.04) f	54.57 (1.48) c	ND	ND	ND	ND
T. macroptera	1.11 (0.05) a	245.89 (74.66) a	0.29 (0.11) abcde	0.26 (0.08) f	39.03 (11.85) c	9.30 (1.84) abc	4.56 (1.76) abcd	80.41 (4.47) a	10.76 (4.70) abcdef
T. diversifolia	0.15 (0.02) g	53.24 (22.73) bc	0.01 (0.002) e	0.40 (0.14) f	185.46 (83.09) a	9.49 (1.10) abc	5.63 (0.04) abcd	59.61 (17.14) ab	1.21 (0.38) fg
U. togoensis	0.38 (0.10) cdefg	176.63 (137.32) abc	0.29 (0.21) abcde	0.89 (0.77) ef	53.04 (41.24) c	5.38 (1.52) cde	5.16 (1.18) abcd	77.23 (10.91) a	13.25 (10.02) abcd
V. doniana	0.72 (0.02) bc	74.79 (16.47) abc	0.17 (0.04) bcde	0.24 (0.06) f	67.38 (14.84) c	11.84 (0.17) a	8.12 (1.12) a	63.72 (0.63) ab	0.47 (0.01) g
F	41.88***	9.88***	14.46***	12.78***	12.46***	5.08***	3.04**	2.63*	2.18*

[1]Excluded species from ANOVA test, because there is only one value. * *P*= 0.05; ** *P*= 0.01, *** *P*= 0.001. Different letters of the same colon indicate that the values were significantly different.

Table 3: LMR (%) of 24 studed species at 4 and 52 weeks of incubation *in situ*. Standard deviation in parenthesis.

Species	04 weeks	52 weeks	*t Student* t
A. latifolia	72.75 (1.97) abc	42.55 (37.46) abc	1.14ns
C. regidus	94.83 (4.94) ab	76.22 (0.39) a	5.04*
C. papaya	47.03 (2.57) c	8.05 (6.97) c	7.26*
C. odorata	76.17 (0.73) abc	11.27 (6.01) bc	20.19***
C. molle	93.73 (3.94) ab	59.32 (7.92) abc	6.74*
D. edulis	91.90 (0.32) ab	74.89 (2.93) a	8.17*
H. acida	91.22 (1.69) ab	72.86 (7.89) a	4.23*
H. involucrata	72.11 (0.005) abc	22.28 (7.88) abc	8.95*
I. cylindrica	90.14 (1.04) ab	26.78 (0.11) abc	85.91***
L. schimperi	72.03 (31.00) abc	30.31 (16.66) abc	1.68ns
L. lanceolata	89.98 (11.59) ab	53.66 (21.92) abc	2.54*
M. stans	87.40 (1,23) ab	66.54 (10.86) ab	3.60*
P. purpureum	86.98 (1,19) ab	36.83 (6.82) abc	9.70**
P. madiensis	87.11 (3,54) ab	36.21 (11.79) abc	7.16*
P. hookerii	81.21 (7,96) abc	51.29 (9.49) abc	3.42*
P. gajava	87.18 (2,24) ab	60.45 (1.64) abc	14.23***
S. longepedunculata	75.90 (0,26) abc	28.56 (7.26) abc	9.22*
S. javanica	87.91 (0,76) ab	46.38 (4.56) abc	15.55***
S.g. var. Guineense	96.94 (1,06) a	32.23 (39.39) abc	2.84*
T. glaucescens	95.56 (0,51) ab	51.02 (4.04) abc	15.46***
T. macroptera	81.71 (4,93) abc	53.86 (1.76) abc	7.35*
T. diversifolia	61.19 (9,68) bc	8.28 (3.21) bc	7.14*
U. togoensis	95.82 (2,46) ab	66.74 (2.15) ab	13.50***
V. doniana	84.46 (0,03) abc	45.57 (0.76) abc	71.95***
F	7.77***	4.17***	

* *P*= 0.05, ** *P*=0.01 *** *P*=0.001; ns: not significant. Different letters of the same colon indicate that the values were significantly different.

Table 4: Coefficients of~~de~~ détermination (r^2) of the regressions fitted to the different models for what?.

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Species	Eq1	Eq2	Eq3	Eq4
A. latifolia	0.7035	0.7036	0.8074	0.8293
C. regidus	0.7081	0.7948	0.8050	0.8051
C. papaya	0.9323	0.9655	0.9785	0.9732
C. odorata	0.9684	0.9710	0.9684	ND
C. molle	0.8611	0.9224	0.9339	0.9346
D. edulis	0.6019	0.9189	0.8219	0.9193
H. acida	0.5696	0.8761	0.8783	0.8783
H.involucra	0.8016	0.8896	0.9142	0.8870
I.cylindrica	0.9189	0.9190	0.9283	0.9427
L. schimperi	0.6693	0.7008	0.7008	0.7039
L. lanceolata	0.8166	ND	0.8166	0.8278
M. stans	0.7463	0.9017	0.9017	0.9018
P. purpureum	0.9355	0.9712	0.9712	0.9712
P. madiensis	0.8304	0.8583	0.8583	0.8591
P. hookerii	0.7483	0.8952	0.9116	0.9115
P. gojava	08432	0.9383	0.9383	ND
S. longepedunculata	0.8404	0.9174	0.9427	0.9412
S. javanica	0.7928	0.9349	0.9349	0.9353
S. g. var. *Guineense*	0.8126	ND	0.8126	0.8986
T. glaucescens	0.9091	0.9410	0.9410	ND
T. macroptera	0.6487	0.8976	0.9159	0.9170
T. diversifolia	0.9094	0.9468	0.9471	0.9472
U. togoensis	0,6683	0,8305	0.8305	ND
V. doniana	0,8378	0,9150	0.9150	0.9151

The four models were as follows: single-exponential decay function ($Eq1 = Ae^{-kt}$), single-exponential decay model with asymptote ($Eq2 = Ae^{-kt} + B$), double-exponential decay function (**$Eq3 = Ae^{-k_1 t_1} + Be^{-k_2 t_2}$**), $Eq4 = Ae^{-kt} + Bt + C$).

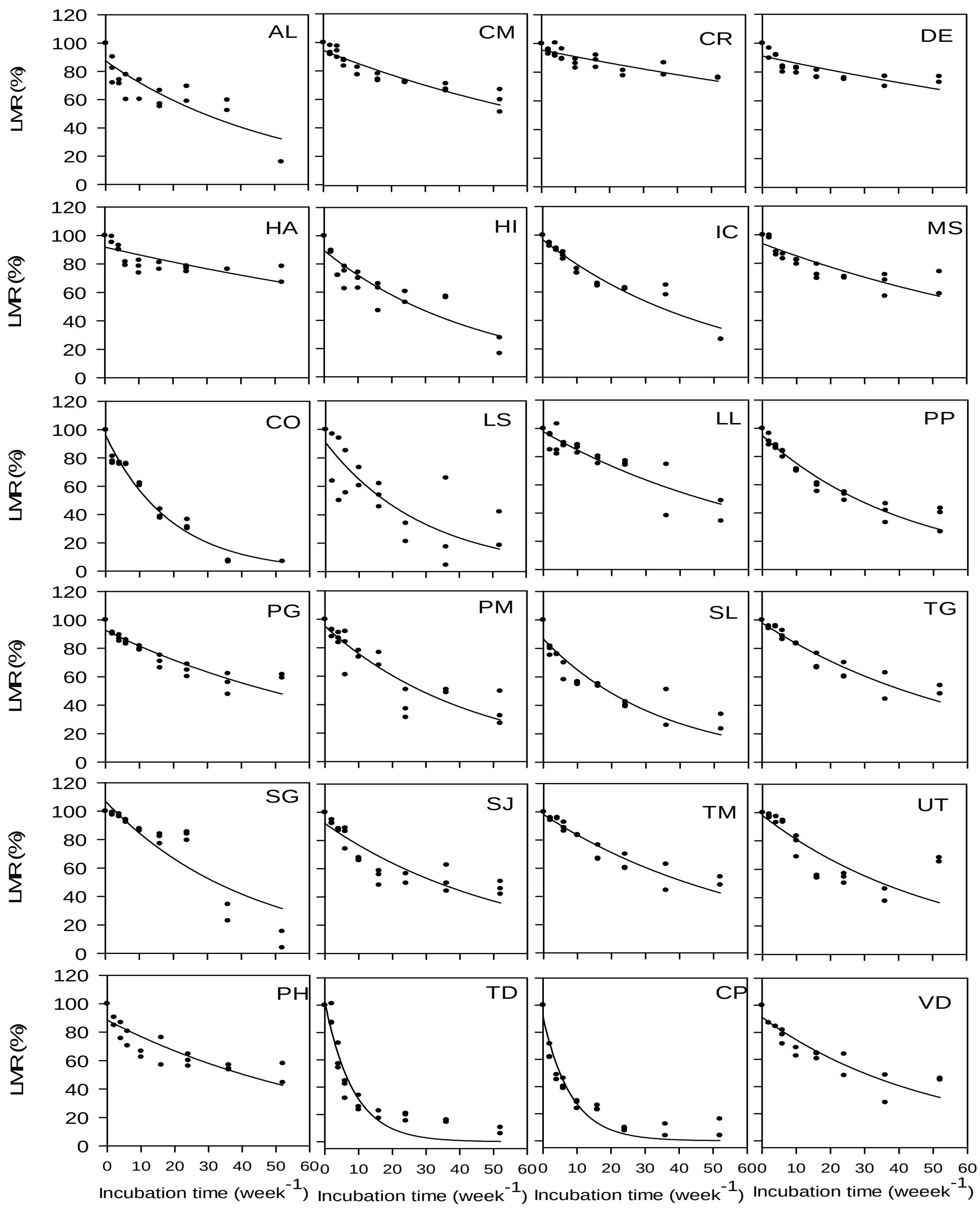

Figure 1: Measured values of litter mass remaining (LMR expressed as percentage of ash free original mass) with incubation time, and predicted single exponential decay regression lines (LMR = Ae^{-k}) of the 24 types of litter studied.

A. latifolium (AL), *C. molle* (CM), *C. regidus* (CR), *D. edulis* (DE), *H. acida* (HA), *H. involucra* (HI), *I. cylindrica* (IC), *M. stans* (MS), *C. odorata* (CO), *L. schimperi* (LS), *L. lanceolata* (LL), *P. purpureum* (PP), *P. gojava* (PG), *P. madiensis* (PM), *S. longepedunculata* (SL), *T. glaucescens* (TG), *S. g.* var. *guineense* (SG), *S. javanica* (SJ), *T. macroptera* (TM), *U. togoensis* (UT), *P. hookerii* (PH), *T. diversifolia* (TD), *C. papaya* (CP) et *V. doniana* (VD).

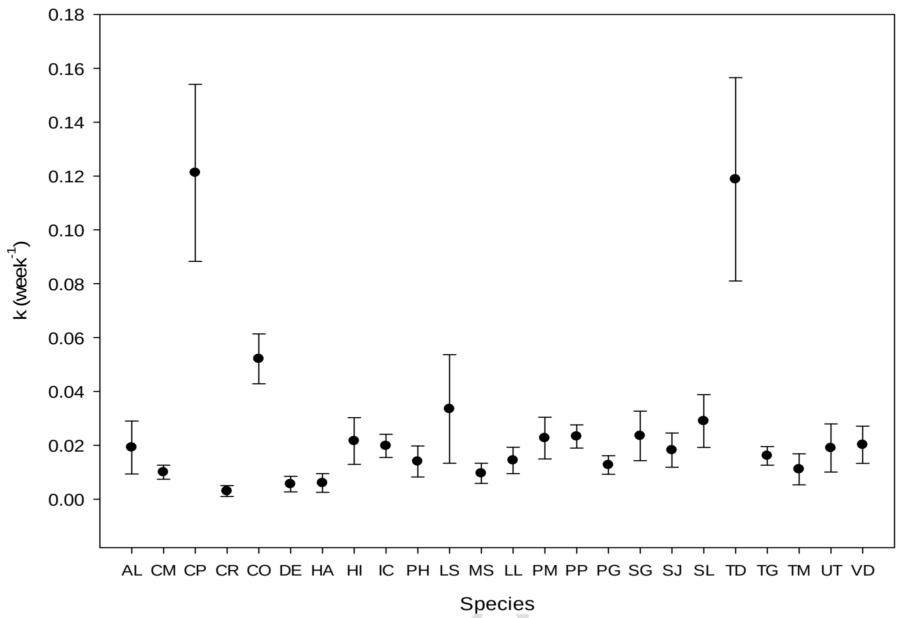

Figure 2: Ninety-five percent comparison intervals by the T'-method for litter decomposition constants (k) of 24 studied species during 52 weeks of incubation *in situ*.

A. latifolium (AL),*C. molle* (CM), *C. regidus* (CR), *D. edulis* (DE),*H. acida* (HA),*H. involucra*(HI), *I. cylindrica* (IC), *M. stans* (MS),*C. odorata* (CO),*L. schimperi* (LS),*L. lanceolata* (LL),*P. purpureum* (PP),*P. gojava* (PG),*P. madiensis* (PM), *S. longepedunculata* (SL),*T. glaucescens* (TG), *S. g.* var. *guineense* (SG),*S. javanica* (SJ), *T. macroptera* (TM),*U. togoensis* (UT), *P. hookerii* (PH), *T. diversifolia* (TD),*C. papaya* (CP). et*V. doniana* (VD).

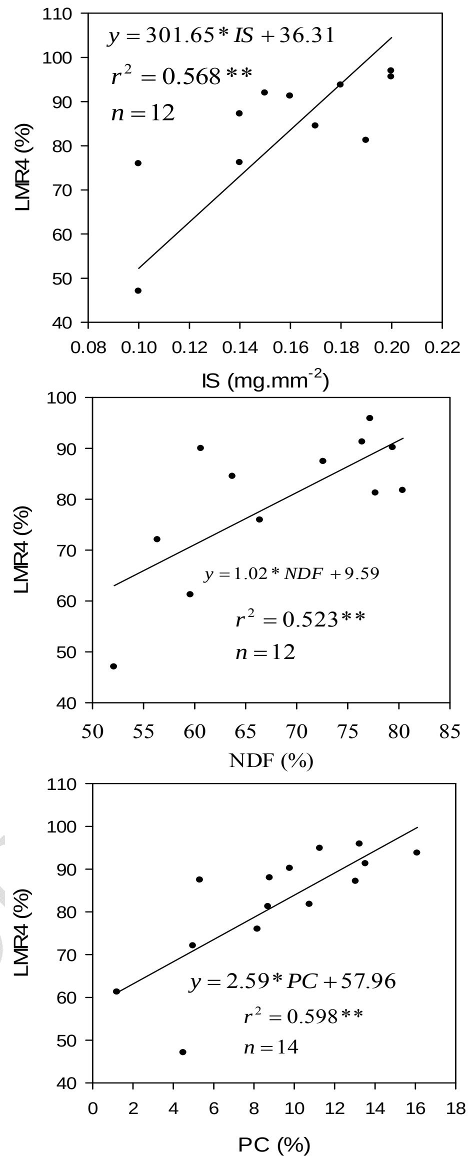

Figure 3: Linear regressions between LMR at 4 weeks of incubation (MSR4) and Sclerophyllous index (a), NDF (b) and Phenolic compounds (c). Sample number (n); ** P < 0.01.

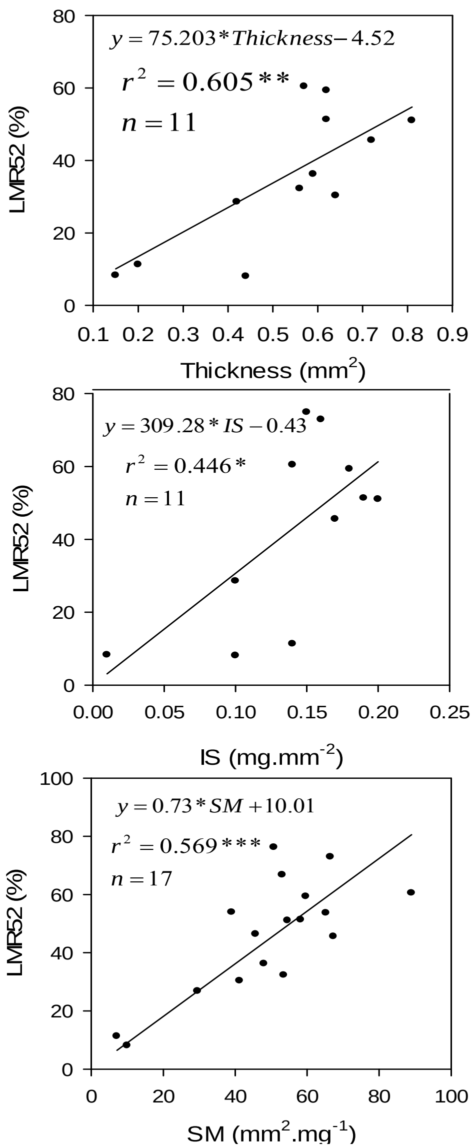

Figure 4a: Linear regressions between LMR at 52 weeks of incubation (MSR52) and physical traits of leaf litters (thickness, Sclerophyllous index (IS), SM). Samples number (n); * $P = 0.05$; ** $P = 0.01$; *** $P = 0.001$.

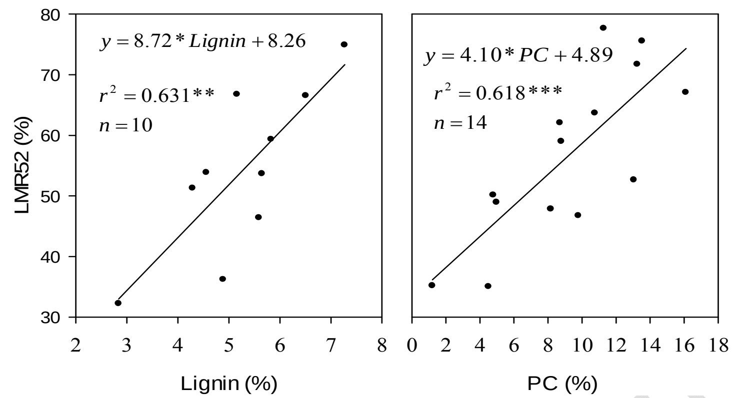

Figure 4b: Linear regressions between LMR at 52 weeks of incubation (LMR52) and chemical traits of leaf litters (Lignin and Phenolic compounds). Samples number (n); ** P = 0.01; *** P = 0.001.

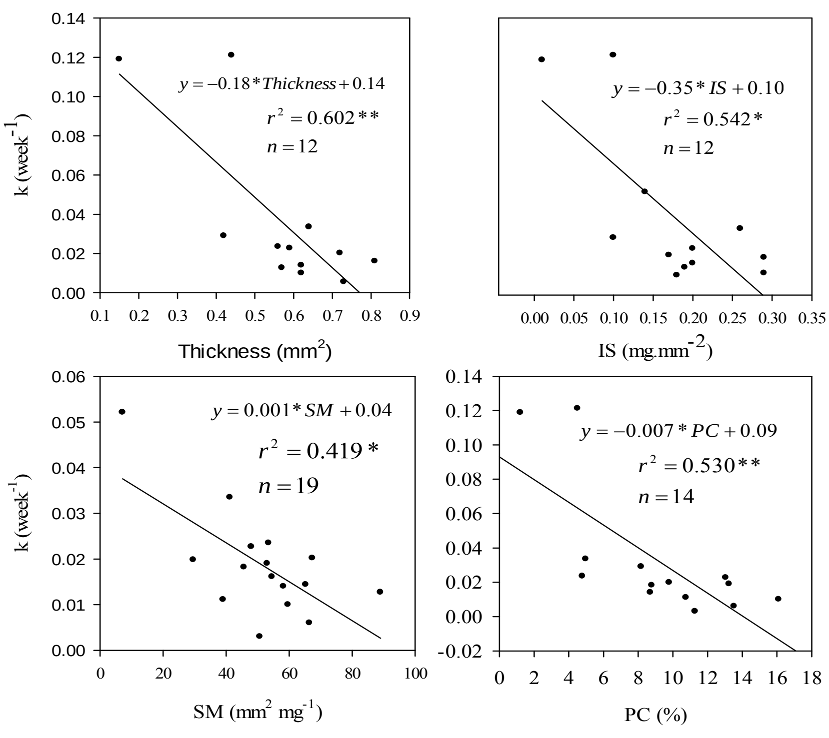

Figure 5: Linear regressions between litter decomposition constants (k) and physical litter traits (thickness, IS, SM) and PC. Sample number (n); * P = 0.05 and ** P = 0.01.

Appendix 1: Regression coefficients of single exponential function (Eq1): LMR (%) = Ae^{-kt} where LMR is litter mass remainng expresses in percentage of initial litter et t in weeks. Standard error in parenthesis.

Espèces	**A**	**k**	r^2	**n**
A. latifolium	87.30 (3.67)	0.19 (0.003)	0.7035	22
C. molle	94.34 (1.50)	0.01 (0.001)	0.8611	27
C. papaya	91.51 (3.90)	0.12 (0.01)	0.9323	25
C. regidus	95.46 (1.24)	**0.003 (0.0001)**	0.7081	24
C. odorata	95.86 (2.23)	0.052 (0.003)	0.9684	23
D. edulis	91.09 (1.84)	**0.006 (0.001)**	0.6019	23
H. acida	91.88 (2.10)	**0.006 (0.001)**	0.5696	22
H. involucra	89.48 (3.42)	0.02 (0.003)	0.8016	22
I. cylindrica	96.87 (1.97)	0.02 (0.002)	0.9189	24
P. hookerii	88.47 (3.04)	0.014 (0.002)	0.7483	21
L. schimperi	90.69 (6.79)	0.034 (0.007)	0.6693	21
M. stans	93.76 (2.06)	0.01 (0.001)	0.7463	24
L. lanceolata	97.78 (2.40)	0.014 (0.002)	0.8166	25
P. madiensis	95.09 (3.33)	0.02 (0.003)	0.8304	24
P. purpureum	94.97 (1.87)	0.023 (0.002)	0.9355	27
P. gojava	92.62 (1.81)	0.013 (0.001)	0.8432	26
S. g. var. *guineense*	106.97 (4.13)	0.02 (0.003)	0.8126	25
S. javanica	91.94 (2.92)	0.018 (0.002)	0.7928	26
S. longepedunculata	86.64 (3.30)	0.029 (0.003)	0.8404	23
T. diversifolia	102.38 (4.96)	0.119 (0.013)	0.9094	24
T. glaucescens	98.04 (1.76)	0.016 (0.001)	0.9091	24
T. macroptera	87.84 (2.81)	0.011 (0.002)	0.6487	22
U. togoensis	97.89 (4.00)	0.019 (0.003)	0.6683	25
V. doniana	91.22 (2.91)	0.020 (0.002)	0.8378	21

Appendix 2: Regression coefficients of double exponentialfunction (Eq3): LMR (%) = $Ae^{-k_1 t_1} + Be^{-k_2 t_2}$ where LMR is litter mass remainng expresses in percentage of initial litter et t in weeks. Standard error in parenthesis

Paramètres de la régression double exponentielle (Eq5): MSR = $a*e^{-bt} + c*e^{-dt}$ où MSR est exprimée en pourcentage de la masse initiale et t en semaine. Les erreurs types entre parenthèses.

Espèces	**A**	**Bc**	**K_1**	**K_2**	**r^2**	**n**
A. latifolium	21,39 (7,72)	78,69 (5,73)	**0,80 (0,82)**	0,014 (0,004)	0,8074	21
C. molle	19,43 (5,81)	81,24 (6,04)	0,14 (0,07)	0,01 (0,002)	0,9339	27
C. papaya	52,66 (8,56)	47,19 (8,41)	0,42 (0,011)	0,05 (0,01))	0,9785	25
C. regidus	11,38 (5,16)	88,28 (5,30)	0,16 (0,13)	0,003 (0,002)	0,8050	24
C. odorata	46,62 (3,59)	**49,23 (503,79)**	**0.05 (272,57)**	**0,05 (258,18)**	0,9684	23
D. edulis	**39,83 (96,53)**	**61,07 (97,81)**	**0,04 (0,09)**	**0,20 (20,02)**	0,8219	22
H. acida	24,32 (4,46)	77,27 (4,36)	0,19 (0,07)	0,001 (0,002)	0,8783	22
H. involucra	31,54 (7,29)	68,54 (7,07)	0,24 (0,10)	0,01 (0,004)	0,9142	24
I. cylindrica	**9,69 (81,45)**	90,75 (8,44)	**0,23 (0,34)**	**0,02 (0,003)**	0,9283	24
P. hookerii	30,91 (6,62)	69,19 (6,33)	0,23 (0,09)	0,01 (0,003)	0,9116	21
L. schimperi	**70,69 (91,60)**	**25,03 (94,50)**	**0,07 (0,10)**	**0,0002 (0,069)**	0,7008	21
M. stans	35,48 (13,89)	65,46 (14,53)	0,09 (0,05)	0,0002 (0,005)	0,9017	24
L. lanceolata	**47,11 (271,24)**	**50,66 (271,24)**	**0,01 (0,39)**	**0,01 (0,36)**	0,8166	25
P. madiensis	**63,36 (97,81)**	**31,97 (99,97)**	**0,05 (0,07)**	**0,0001 (0,048)**	0,8583	24
P. purpureum	67,30 (32,40)	**32,62 (33,23)**	0,06 (0,03)	**0,0002 (0,02)**	0,9712	26
P. gojava	43,05 (22,28)	55,22 (23,01)	0,07 (0,04)	0,0003 (0,007)	0,9383	26
S. g. var. guineense	**53,78 (472,32)**	**53,19 (472,32)**	**0,02 (0,73)**	**0,024 (0,75)**	0,8126	25
S. javanica	55,64 (14,90)	46,87 (15,67)	0,09 (0,034)	0,0003 (0,007)	0,9349	26
S. longepedunculata	33,50 (6,46)	65,90 (6,01)	0,32 (0,12)	0,02 (0,004)	0.9427	23
T. diversifolia	90,35 (11,97)	15,82 (12,17)	0,17 (0,039)	0,01 (0,02)	0,9471	24
T. glaucescens	**58,61 (78,58)**	**42,76 (79,57)**	**0,04 (0,05)**	**0,0008 (0,03)**	0,9410	24
T. macrptera	31,76 (5,15)	69,99 (4,89)	0,23 (0,07)	0,004 (0,002)	0,9159	22
U. togoensis	57,20 (2,78)	49,68 (34,33)	0,08 (0,06)	0,001 (0,01)	0,8305	25
V. doniana	56,26 (33,93)	41,51 (35,05)	0,07 (0,04)	0,0001 (0,015)	0,9150	21