FALL AND DECOMPOSITION OF LITTER IN FOREST AND PLANTING: CASE OF THE CLASSED FOREST OF PAHOU IN BENIN

Short title: litter fall plant formation Benin

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Abstract

Description of the subject. The fall and decomposition of litter are two major phenomena on which the functioning of forest ecosystems depends.

Purpose of the research. The quantity. the fall dynamics and the decomposition of the litter are studied within the semi-deciduous dense forest (FDSD) of Pahou in southern Benin.

The methodology used is litter production is measured through traps of 1 m2 disposed in the forest while the decomposition rate is evaluated by the litterbag technique. By way of comparison. these measures were taken both in the natural forest and in a plantation of Acacia auriculiformis.

The results showed that the natural forest litter contains more leaves (70 to 97%) and that of the plantation. leaves (phyllodes) and reproductive organs respectively 50% and 46%. The maximum falls are recorded in December for natural forest (1.375 t / ha) and in January in the plantation (3.150 t / ha) and minimal falls in the months of April to October. The total annual fall is 16.16 t / ha in the plantation but 11.67 t / ha in the natural forest. In general. litter decomposition is faster in the wet season than in the dry season in both forests. However. the rate of decomposition within the natural forest (k = 0.72) is higher than that of the plantation (k = 0.63). Deposits of abundant biomass on the ground and their moderate rate of decomposition. litters studied have shown promise for a good restoration of degraded ecosystems and the maintenance of soil fertility.

Conclusion. In short. the rapid decomposition of the litter in the vegetative formations is at the origin of the dynamics of the flora in general and particularly of the fungi which appear more abundant in the natural forest. Weaknesses have been identified and research and development axes have been suggested for further studies.

Keywords: Decomposition. Formation vegetation. decomposition coefficient and Benin.

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1. Introduction

One of the most important roles of forest litter is the return to the soil of nutrients essential for soil structure and fertility and the transfer of energy through biogeochemical cycles. Litter constitutes all of the organic matter (OM) that has been little transformed (Mangenot. 1980) or fresh (Duchaufour. 1991) coming from the leaves. wood. Twigs, fruit. seeds which return to the soil and which provide both food and habitat for underground organisms (Chapin *et al*. 2002). Litter is the most abundant source of carbon renewal on earth (Geethanjali and Jayashankar. 2016). Forest litter varies according to its quantity and composition in relation to the climate and the diversity of the plant species that compose it (Triadiati *et al*.. 2011). The decomposition of forest litter is an essential process in the mineralization of organic matter. thus allowing the recycling of many chemical elements essential to forest productivity. This rotation of organic matter is under the control of biotic and abiotic factors. temperature and humidity. soil type. quantity and quality of organic matter (Quentin. 2018). Many studies have been carried out on soil enrichment by nutrients from litter fall and decomposition (Goma-Tchimbakala *et al*.. 2005; Quingkui *et al*., 2007; Becker *et al*.. 2015; Dawoe *et al*., 2009); but little attention is paid to a comparative measurement of these two processes between a natural forest and an exotic tree plantation (Triadiati *et al*.. 2011). The general objective of this study is to assess the fall and the rate of litter decomposition in a natural forest and an Acacia auriculiformis plantation growing under similar climatic conditions within the Pahou FDSD. Specifically. it involves (i) measuring the production of litter within the two formations studied; (ii) estimate the rate of litter decomposition at the two formations and (iii) measure the biochemical parameters and their influence on the decomposition of the litter.

2. Materials and methods

2.1. Study framework

The Republic of Benin is located in West Africa between the parallels 6 ° 20 and 12 ° 30 north latitude and the meridians 1 ° and 3 ° 40 east longitude. The Pahou forest is located in Benin. In the District of Ouidah. southwest of the Atlantic Department. between 6 ° 22 and 6 ° 27 North latitude and 2 ° 8 and 2 ° 14 East longitude. It is located at the edge of the national inter-state road N ° 1 (RNIE 1) Cotonou-Lomé which divides it into two portions. The city of Pahou is located in the Guinean-Congolese zone characterized by the bimodal annual rainfall distribution typical of the subequatorial domain. The great rainy season goes from mid-March to mid-July with a maximum in June. The short rainy season lasts from mid-September to mid-November with a maximum in October. These two rainy seasons are interspersed by two dry seasons which are also unevenly distributed: mid-July to mid-September (short dry season) and mid-November to mid-March (long dry season). Annual precipitation averages 1280 mm (ASECNA. 2016).

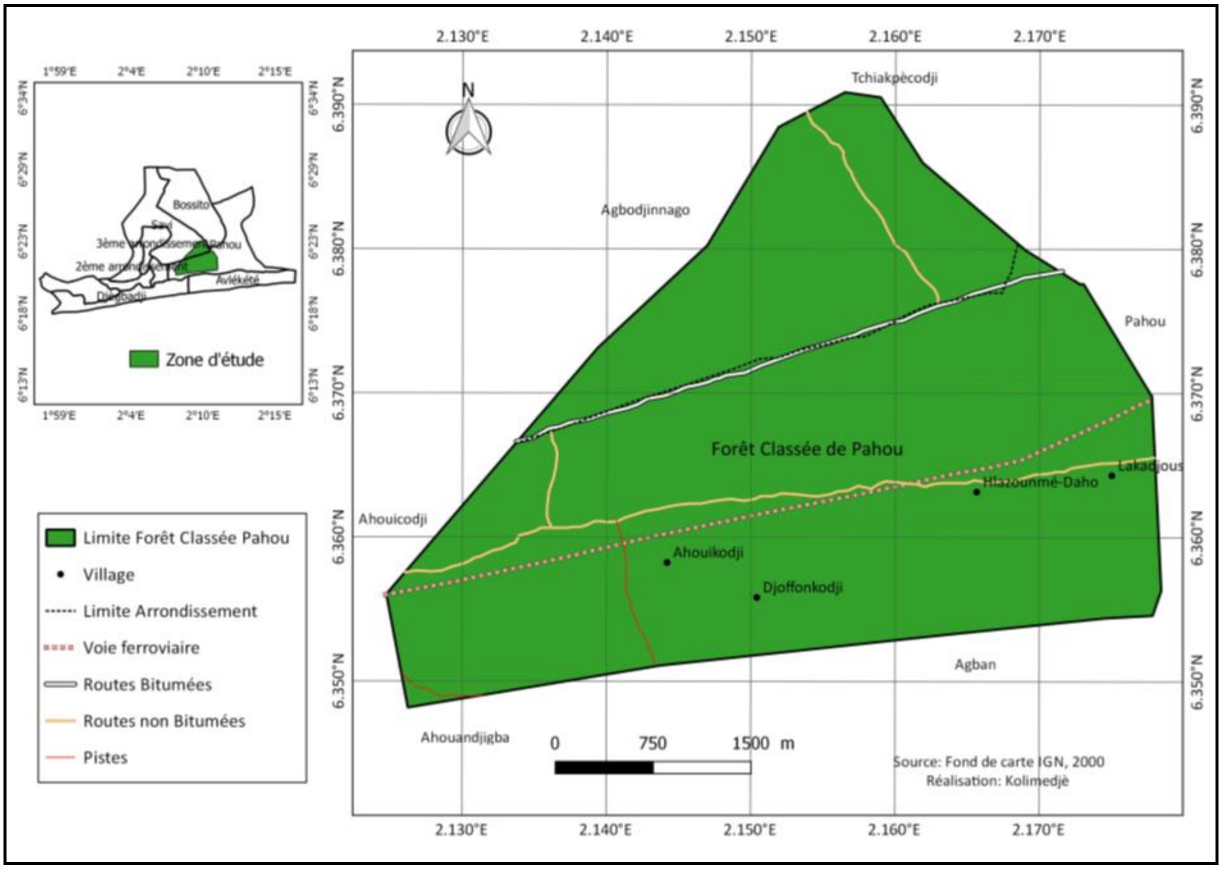

Figure 1: Geographical location of the dense semi-deciduous forest of Pahou (PAP. 2010)

The average annual temperature of the study environment varies little and hovers around 27 ° C. The annual average of the maxima is 31 ° C and that of the minima is 24.6 ° C (ASECNA. 2016). The hottest period covers the months of February. March and April with relatively strong amplitudes: cool nights (23 ° C to 24 ° C) followed by hot sunny days (31 ° C to 33 ° C). July and August are the coolest months with a temperature of 25 ° C (ASECNA. 2016). The various thermal variations observed are linked to the duration of sunstroke and the maritime influence (Djègo. 2006). Relative humidity or relatively high hygrometry throughout the year is close to 80% (Agbahungba. 2000). Within the FDSD of Pahou. the natural forest is established on ferralitic soil (bar land) and the plantations on leached tropical ferruginous soils or coastal soils (Volkoff & Willaime. 1976). Natural vegetation includes two main types of formations: forest formations within which the study took place and savannahs (DGFRN; 2010). The forest formations include the forest with Pycnanthus angolensis and Chrysobalanus icaco and that with Dialium guineense and Antiaris toxicaria (DGFRN. 2010). The plantation chosen is that of Acacia auriculuformis because this exotic species occupies 78.22% of the surface. This artificial plant formation being in pure stand is chosen in order to carry out the comparison between it and the natural vegetation which is multispecies.

2.2. Data collection and processing methods

2.2.1. Physico-chemical characteristics of the studied soils

The soil is taken from a depth of 10 cm and packed in a plastic bag; three samples were taken from each formation. Soil moisture, total carbon, total nitrogen, assimilable phosphorus. exchangeable cations (Ca. Mg. K and Na) and cation exchange capacity (CEC) were determined at the Soil Science Laboratory of the FSA (Table 1).

Table 1. Physico-chemical characteristics of the studied soils

Soils	**C**	**N**	**pH**		**P (as)**	**Ca**	**Mg**	**K**	**Na**	**CEC**	**H%**
	%		eau	Kcl	ppm	meq/100g					%
Natural forest	1.10	0.08	4.89	4.44	13.26	0.46	0.11	0.96	1.08	14.38	2.09
Planting	0.82	0.04	4.34	3.79	35.51	2.60	1.60	0.87	0.71	11.88	4.63

2.2.2. Litter drop

The litter fall is evaluated using density squares or traps of 1m x 1m placed on the ground in plots installed within the two formations. at the rate of four traps per plot and a total of five plots per site. The litter is harvested over a period of one year (April 2016 to March 2017) with monthly readings. During each reading. The different fractions of the litter are cleaned. dried in the laboratory and weighed. The monthly litter falls were accumulated to obtain the annual productions. Two (02) collections of litter are carried out within 20 quadrats of 1m2: arranged in each of the formations studied. in order to quantify the stock of litter on the ground at a given time (Djego. 2006).

2.2.3. Weight loss and rate of litter decomposition

Decomposition tests were carried out by incubating litter in the forest. This method consisted in collecting freshly fallen surface litter in March 2016. drying it in an oven at 120 ° C for 6 hours and distributing it in small bags of 20 cm X 20 cm called litterbags. In the context of this study. The litterbags used are fine mesh (5 mm). In order to prevent the loss of litter during transport and to facilitate the access of decomposers (Attignon. 2004; Lecerf. 2005). Each oven-dried litterbag is filled with 10 g of dry litter and placed on the ground at the rate of 120 litterbags per plot. Every month. and over a year. 10 litterbags are removed from each plot. The remaining litter of each of them is cleaned. dried at 105 ° C in 24 hours and then weighed. These weighings made it possible to measure the weight loss and therefore to estimate the rate of decomposition of the litter.

2.2.4. Initial chemical composition of litter

Biochemical analyzes were performed on freshly fallen litter. collected. air dried and powdered. The organic constituents of the litter were determined by sequential digestion of the fibers according to the method of Van Soest. 1963. The cellulose and lignin content was determined

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from the residue insoluble in the acid detergent ADF (acid detergent fiber) and ADL. (acid detergent lignin). The cellulose content is equal to ADF minus ADL. and the lignin content is equal to ADL minus the ash contained in ADL. Total nitrogen is measured by the Kjeldahl method. phosphorus by spectrophotometry. All chemical analyzes are done three times on the same samples. The initial nitrogen. lignin. and cellulose levels. C / N and lignin / N ratios are used in predicting the rate of litter decomposition.

2.2.5. Statistical analyzes

Average monthly decomposition rates (V) were calculated by the formula:

$V = \frac{Mi-Mr}{t}$ Mi: initial mass of litter (g)

Mr: remaining mass of litter (g)

t: duration of incubation in the month considered (months)

The rate of decomposition k is indirectly calculated according to the formula of Olson (1963): K = L / L + X; or

L is the annual litter fall and X is the mass of litter on the ground at a given time. The turnover time (t) is calculated by t = 1 / K (Lamnganbi Devi and Jadu Singh. 2017).

The Shapiro-Wilk test was performed on monthly fall and litter decomposition data to test for normality. The Kruskal-Wallis test was used to compare the monthly variation in litter fall and that in litter decomposition in natural forest. The one-sample Student's t-test or the one-sample Wilcoxon test was used to compare the litter fall in natural forest to that of the plantation and then the monthly rates of litter decomposition in the natural forest to that of the plantation. All these analyzes were performed in software R3.2.3 at the significance level of 5%. A correlation is established between the coefficient k of decomposition and the initial chemical composition of the litter.

3. Results

3.1. Production and composition of bedding

The annual litter fall is greater within the plantation: 16.16 t / ha/year than in the natural forest: 11.67 t / ha/year. Concerning the different litter fractions. The difference between the two formations is significant ($p < 0.05$). both at the level of the leaves. stems and fruits. The weight contribution of organs to litter is dominated by leaves. As for the other deciduous organs. The litter of Acacia auriculiformis contains more fruit. a characteristic specific to the species. while that of the natural forest contains more stems (Table 2).

Table 2: Quantity (t / ha / year) and weight contribution (%) of litter

Formations	leaf	stem	Fruits	Total
Planting	8.07±0.33 (50%)	0.64±0.14 (4%)	7.45±0.54 (46%)	16.16±0.82 (100%)
Natural forest	9.80±0.26 (84%)	1.23±0.03 (10.5%)	0.64±0.003 (5.5%)	11.67±0.41 (100%)

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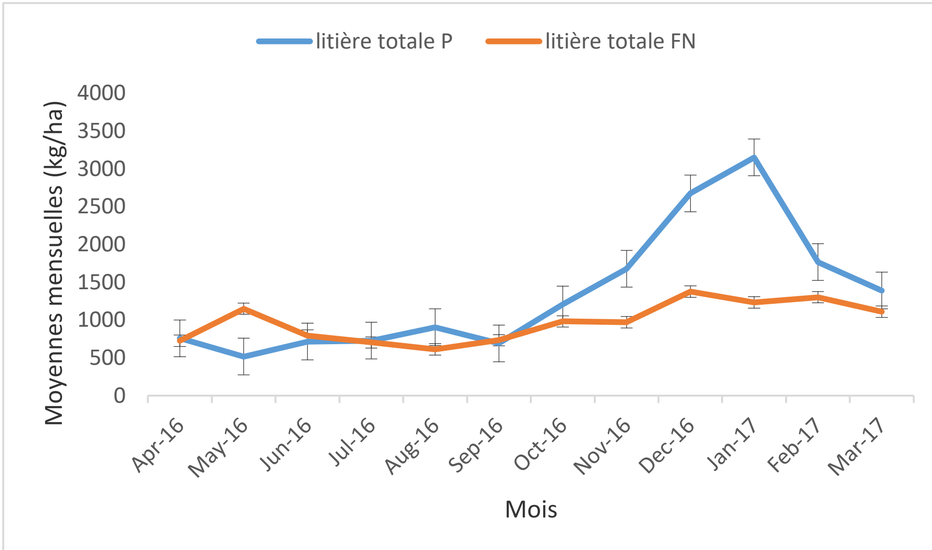

Figure 1: Seasonal evolution of litter fall in plantating and natural forest (P: plantating. FN: natural forest)

The litter fall has a unimodal distribution and occurs throughout the year in both formations (Figure 2). The highest values are recorded during the dry season and the peak is obtained in December in natural forest (1.375 t / ha) then in January under planting (3.150 t/ha). The wet periods are characterized by less significant falls and the lowest are recorded from May to October in the two formations. The maximum leaf litter is obtained in December and January respectively in natural forest and in plantation (figure 3). while the maximum in fruits and others is collected in September and December respectively in natural forest and in plantation (figure 4).

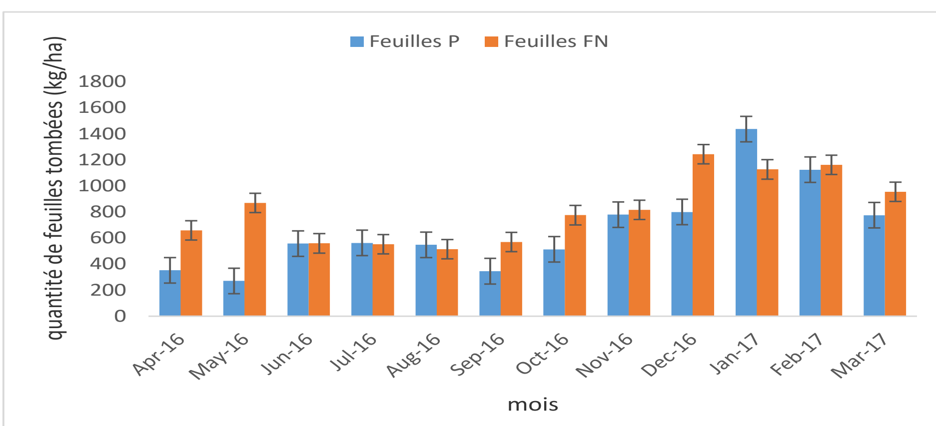

Figure 2. Monthly leaf fall in plantating and natural forest

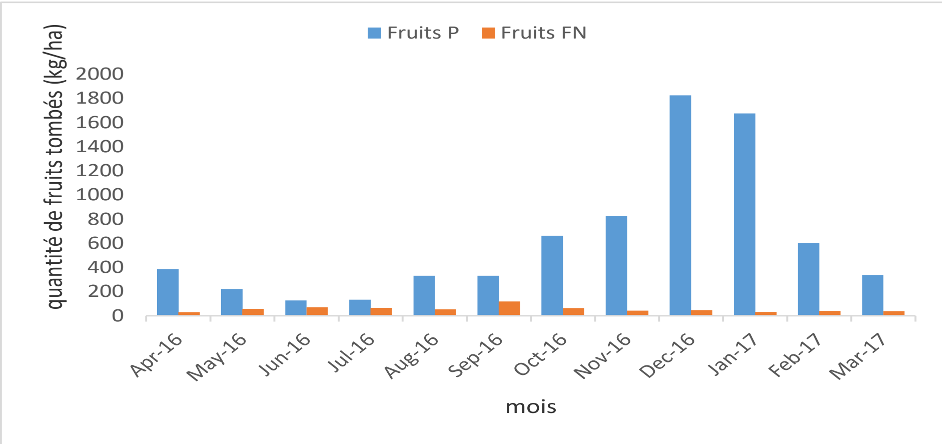

Figure 3. Monthly fruit drop in plantating and natural forest

3.2. The decomposition of the litter

The table tree summarizes the monthly rates of litter decomposition in natural forests and in plantations. The average speed decreases over time. the difference being significant ($P < 0.05$). The highest value is obtained in April at the start of the experiment and the lowest in March after 12 months of incubation. The monthly speed is always higher in natural forest than in plantation for the same month ($P < 0.05$). However. for the months of June. October and November the difference is not significant.

Table 3. Monthly rates of decomposition in natural forest and in Planting (g / month)

Month	Duration of the experiment (month)	VFN	VP	P
April	1	3.20±0.77	1.7±0.32	0.002
may	2	1.50±0.47	0.83±0.11	0.002
June	3	1.40±0.60	1.16±0.19	0.10
July	4	1.75±0.21	1.22±0.28	0.0002
August	5	1.20±0.16	0.84±0.06	<0.0001
September	6	1.00±0.20	0.85±0.05	0.03
October	7	0.92±0.16	0.83±0.09	0.08
November	8	0.82±0.17	0.75±0.05	0.18
December	9	0.81±0.13	0.67±0.06	0.007
January	10	0.80±0.07	0.62±0.04	0.01
February	11	0.72±0.05	0.58±0.05	<0.0001
March	12	0.72±0.07	0.54±0.04	0.00861

V = monthly rate of decomposition

The rate of litter decomposition within the two formations is greater than 50%, but a little higher in natural forest (81%) than in plantation of exotic species (65%). Figure 5 shows that the litter weight loss follows a gradual development, slow in the dry season and more rapid in the wet season. Also, the litter in natural forest lost 50% of its weight in for months (51% of remaining mass in July) while that of the plantation spent 8 months (52% of remaining mass in November) to lose the same weight. . It should also be noted that the total decomposition is generally spread over more than a year in the two formations studied: t = 1.53 years (about 19 months) in plantation and t = 1.23 years (15 months) in natural forest.

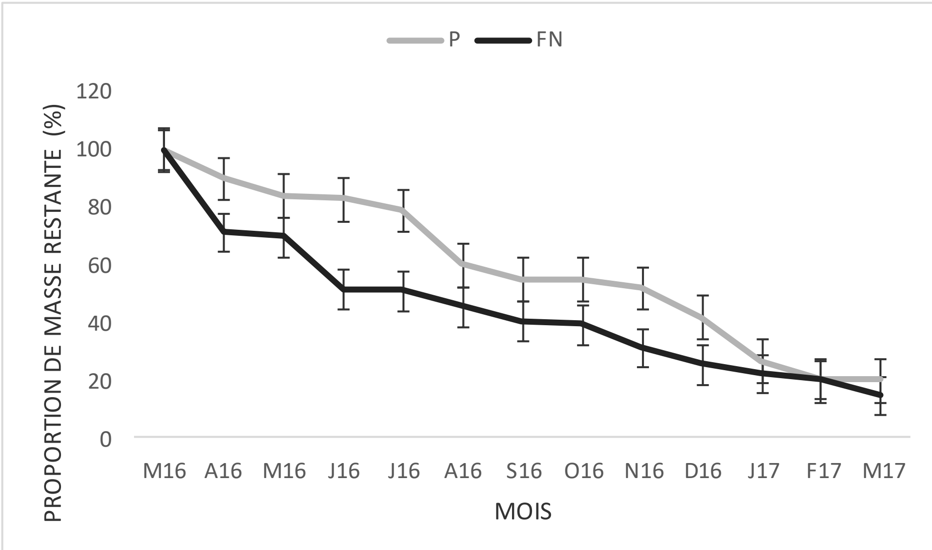

Figure 4. Litter weight loss in plantating (P) and natural forest (FN)

3.3. Litter quality

The analysis of the biochemical parameters (Table 4) only reveals a difference at the level of the fiber content of the two litters: the natural forest litter contains more cellulose (2%) and less lignin (4%) than that of the plantation. The differences between nitrogen and carbon levels are insignificant. In addition, the C / N ratio of the litter is higher in natural forests than in plantations, unlike the lignin / N ratio.

Table 4. Parameters related to the quality of the litter studied.

Litters	Lignine %	Cellulose	C	N	C/N	Lignine/N
Natural forest	17,5	39,4O	3,88	0,17	22,82	87,5
Planting	24,6	37,30	3,77	0,20	18,85	144,70

4. Discussion

4.1. Production and weight contribution of bedding

The quantity of litter fallen in natural forest (11.67 t / ha/year) relatively high compared to that obtained by Sokpon (1995) in Pobe (7.55 to 9.4 t / ha/year) and Djègo (2006) in the Lama (5.2 to 9 t / ha/year) are however comparable to values recorded in other dense semi-deciduous forests of the continent: 10.5 t / ha/year in Ghana (Nye, 1961); 12.88 to 14.1 t / ha/year in Cameroon (Songwe, 1984); 12, t / ha/year in Nigeria (Odiwe and Muoghalu, 2003) or elsewhere, 11.01 t / ha/year in China (Yang *et al*., 2004) and 13.67 t / ha/year in Indonesia (Triadiati *et al*., 2011). These observed variations may be due to the difference in species composition, to the phenology of these different species growing in these forests and to climatic conditions (Yang *et al*., 2004, Djego, 2006). Under the *Acacia auriculiformis* plantating, the annual litter fall is 16.16 t / ha/year. Lower values are recorded in the plantating of the Lama classified forest where the average is between 4.3 and 6.7 t / ha/year (Djègo, 2006); under a plantating of *Acacia auriculiformis* (7.3 t / ha/year) in Côte d'Ivoire (Gnahoua *et al*., 2013) and in Terminalia superba plantatiing in DRC where the highest value is 7.16 t / ha/year (Goma-Tchimbakala *et al*., 2005). These variations can also be linked to different climatic conditions, and to the phenology of the species (Yang *et al*., 2004, Djego, 2006). Litter production in plantating is higher than that of natural forest as in most tropical forest (Djego, 2006; Dawoe *et al*., 2010). However, Triadiati *et al*. (2011) reported greater litter fall in natural forest than under cocoa plantatings (4.98 t / ha/year). Leaves constitute the major part of the litter, as many other studies have shown (Goma-Tchimbakala *et al*., 2005; Djego, 2006; Dawoe *et al*., 2010). Indeed, several factors come into play concerning the amount of litter that has fallen in the natural forests and exotic species plantatings of southern Benin. These are the nature (mono or plurispecific) of the formation, the seasons, the specific diversity (Attignon, 2004; Djego, 2006) or the age of the population. (Dawoe *et al*., 2010) and even species-specific characteristics.

The litter fall in the two formations studied presents a unimodal distribution with a high production in the dry season. This phenomenon has already been observed by other authors (Sokpon, 1995; Djego, 2006; Odiwe and Muoghalu, 2003; Yang *et al*., 2004, Owusu-Sekyere *et al*., 2006; Diallo *et al*., 2016); can be explained by several factors including the phenology of the species; (Djego, 2006; Gnanhoua *et al*., 2013; Diallo *et al*., 2016); the availability of nutrients in the soil (Goma-Tchimbakala *et al*., 2005) and mainly the influence of water stress (Wieder and Wright, 1995; Lawrence and Foster, 2002; Gnanhoua *et al*., 2013) which promotes senescence and therefore the abscission of aerial plant organs mainly that of leaves (Lian and Zhang 1998, Sundarapandia and Swamy, 1999). Leaf abscission in the dry season seems to have a very important adaptive value as it constitutes a physiological response to the harsh conditions of this period. But the work of Goma-Tchimbakala *et al*. (2005) do not go in the same direction as those preceding because they underline that the peak of litter production in the rainy season is linked to attenuating features of the dry season such as wind, thunderstorms during the rainy season (Moraes *et al*., 1999; Dawoe *et al*., 2010).

4.2. The decomposition of the litter

The reduction in the mass of litter in the rainy season proves the favorable chemical activity of microorganisms found in the environment (Conn and Dighton, 2000; Padalia *et al.*, 2015). This also explains the large accumulation of litter in both types of formation during the dry season. Also this faster loss of mass at the beginning is due to the easier degradation of certain molecules such as carbohydrates and amino acids followed by the transfer of a large amount of soluble compounds (C and N) to the soil. On the contrary, the slowness of subsequent decomposition is linked to the more complex and slower humification of cellulose and lignin (Padalia *et al.*, 2015). The values of k show that the decomposition of litter in plantation is a little slower than that of natural forest (Djego, 2006; Owusu-Sekyere *et al.*, 2006; Triadiati *et al.*, 2011). This could be explained by several factors including the mono-specific nature of the plantation, the soil pH: the soil of the plantating being slightly more acidic than that of the natural forest, the availability of nitrogen, the resistance of cladodes or their low tearable character, the lignin richness of these phyllodes and biotic factors not studied here. The two parameters studied: the amount of litter fallen and the rate of decomposition explain the accumulation of litter on the ground (Dawoe *et al.*, 2010).

4.3. Coefficient of decomposition and litter quality

The nitrogen rate of the litter resulting from the plantation is higher than that of the natural forest because Acacia being a legume is able to fix the N of the soil. However, this difference is insignificant and does not confirm the influence of the N content of the litter on decomposition (Barrera *et al.*, 2000).

Many researchers have had to develop predictors of decomposition such as the rate of lignin, the lignin / N ratio (Aber and Melilo, 1982, Parton *et al.*, 1987; Bernhard-Reversat *et al.*, 2000), the C / ratio N (Nicolardot *et al.*, 2001). These are the values with which the rate of decomposition is inversely proportional. In the context of this study, only the level of lignin and the lignin / N ratio can explain the difference observed between the rates of litter decomposition; natural forest litter, which has a low lignin content and a low lignin / N ratio, decomposes more quickly than that of the plantation. The C / N ratio, a better predictor of decomposition (Taylor *et al.*, 1989; Edmonds, 1980) is therefore not validated here.

Conclusion

In the dense semi-deciduous forest of Pahou, the annual litter fall is seasonal and depends on climatic conditions and species phenology. This drop is lower in the natural forest than in the exotic essence plantation. The leaf biomass in the litter is greater in the natural forest than in the plantation where there is a greater drop in small stems and especially fruit. This also explains that among the possible mechanisms at the origin of the fastest turnover of decomposition in natural forest, is the greater contribution of leaves and the mixed character of the litter compared to the mono specific one of the planted forest. These results show that natural forests give more litter than mono-specific plantations and indicate a good state of regeneration of natural plant formation than that carried out by hand. Also, by the abundant deposits of biomass on the soil and their moderate decomposition rate, the litter studied can help meet the challenge of properly restoring degraded ecosystems and maintaining soil fertility.

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