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Termite Control of Leaf Litter Decomposition of Eight Selected Plant Species of Sudano-guinea Savannahs of Ngaoundere, Cameroon

A. Ibrahima[1*], S. Kalba Sirzoune[1], P. Badakoa[1], A. A. Mang A. Menick[1] and P. Souhore[2]

[1]*Laboratory of Biodiversity and Sustainable Development, Department of Biological Sciences, Faculty of Sciences, The University of Ngaoundere, P.O.Box 454, Ngaoundere, Cameroon.*
[2]*Regional School of Agriculture of Maroua, P.O.Box 237, Maroua, Cameroon.*

Authors' contributions

This work was carried out in collaboration among all authors. Author AI designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors SKS, PB and AAMAM managed the analyses of the study. Author PS managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Few studies on effects of termites on litter decomposition have been done in African savannahs, particularly in the Adamawa savannahs of Cameroon. In the framework of management of resource quality to restore or improve soil fertility of farming systems of Sudano-guinea savannahs of Ngaoundere, Cameroon, study on termites' control of leaf litter decomposition of eight plant species was conducted on the field. The selected plant species are *Bixa orellana*, *Erythrina sigmoïdea, Ficus polita*, *Maytenus senegalensis*, *Mucuna stans*, *Piliostigma thonningii*, *Vitex madiensis* and *Vitellaria paradoxa*. Leaf litter samples were incubated *in situ* using litterbags of 2 mm mesh during 24 weeks in two plots out of canopy, corresponding to two treatments, with and without termites. Experimental design was *split-plot* with three replications. Collected data was carried out on litter dry mass remaining (LMR). Results showed total mass loss at the end of

**Corresponding author: E-mail: aibrahima@hotmail.com;*

incubation time (24 weeks) and decomposition rate constants (k) differed significantly among plant species for the two treatments. The values ranged respectively from 23.05% and 0.012 week^{-1} in *V. madiensis* to 61.93% of initial dry mass and 0.046 week^{-1} in *P. thonningii* for treatment without termites and from 43.88% and 0.022 week^{-1} in *B. orellana* to 91.51% and 0.095 week^{-1} in *P. thonningii* for treatment with termites. These macro organisms fasted litter decomposition in all plant species, with intensity variation according to species. Litter mass loss and decomposition rate constant (k) correlated with litter thickness, density, area and specific area mass, and these relationships were influenced by the presence of termites. Globally litter decomposition was influenced by termite activities and resource quality. These results contributed to understand litter decomposition process in the sudano-guinea savannahs of Ngaoundere in order improve soil fertility, nutrient cycling and some plant species domestication.

Keywords: Litter decomposition; litter quality; termites; Sudano-guinea savannahs; Ngaoundere; Adamawa, Cameroon.

1. INTRODUCTION

Litter decomposition is an important process in the nutrient cycles and soil fertility of agro-ecosystems, especially those of tropical savannahs where soils are poor. Indeed, it is a stage in the nutrient cycles during which mineral elements are released from litters and made available to soil organisms and vegetation for their growth [1,2]. The intrinsic mechanisms of litter decomposition process are therefore influenced by abiotic factors such as climate and soil type, as well as by biotic factors including the physicochemical quality of litter, soil organisms including termites [3,4,5].

In Tropical ecosystems, termites represent the most abundant soil macrofauna, especially during the dry season. Their density in these ecosystems ranged from 192 to 592 individuals per square meter [6] and their biomass can be greater than 100 kg (fresh weight) per hectare [7,8], which is much larger than the biomass of many groups of vertebrates in the savannahs of Africa [9]. Termites are important biological component of the tropical ecosystems. Their well-known roles as agricultural pest alone highlight the importance but their other roles are no less important. In fact, termites with other soil macroorganisms (>2 mm), including earthworms and macroarthropods can stimulate litter decomposition via litter fragmentation, and through altering the activities and composition of the microbial communities [10,11]. By the processes of fragmentation and comminution, termites can influence litter decomposition through their pedological effects: modification of soil structure through the construction of burrows and enhancing the decomposition of plant debris through the burial of litters [12,13]. Termites feed on a diverse range of resources, including live and dead wood, litter, humus, lichens, fungi, grass, manure and animal corpses [14]. Wood consumption by these insects is apparently determined by properties related to their ability to masticate, digest, and assimilate it. As such, wood properties such as density, nitrogen concentration, the presence of phenols and quinones, and its level of litter decomposition, can all affect consumption rates [15,16]. Estimates of the consumption of plant necromass have demonstrated that termites are important elements in the dynamic processes of litter decomposition and nutrient cycling [15,17]. In different tropical ecosystems, these insects can consume from 14 to 50% of the annual production of plant necromass [8,18]. In some deserts, termites can consume up to 100% of the plant necromass produced [19,20]. Their high number and diversity, and their habit of feeding on organic materials confirm their function as providers of various ecosystem services including organic decomposition, soil nutrient and carbon cycling, and soil ecosystem engineering [21,22]. These imply that decrease in termite diversity would have negative impact on ecosystem function through changes in termite-mediated ecological process [23]. According to other authors, termites contribute to the improvement of the physico-chemical properties of tropical and sub-tropical soils through their influence on the litter decomposition process and their mineralization [24,25,26].

However, in spite of the importance of macro-invertebrates, particularly termite communities on litter decomposition processes and carbon release, information concerning termite control of litter decomposition processes of indigenous plant species of the Sudano-guinea savannahs of Ngaoundere, particularly potential agroforestry plant species which have likely, in the future, to be integrated in farming systems in order to improve or restore soil fertility, is very limited, excepting that of Ibrahima et al. [4]. Their study was carried out on the synergistic effects of earthworms and soil microorganisms on litter decomposition of the agroforestry plant species of these savannahs. In order to understand the functional role of termites in the ecological processes of litter decomposition and nutrient recycling, it is necessary to study the consumption rates of a given species (or assemblage) of termites in a given environment. Thus the objective of the present study was to determine the effects of termites on leaf-litter decomposition of eight multipurpose plant species of the sudano-guinea savannahs of Ngaoundere, Cameroon.

2. MATERIALS AND METHODS

2.1 Study Site

The study site located in Adamawa region (6-8N, 12-15E, altitude 1200 m asl) in central of Cameroon. This geographical situation gives at this region a humid sudano-guinea climate according to Suchel [27], with one dry season (November - March) and one rainy season (April - October). 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%. 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 [28]. The ferralitic soils are the dominant type [29], with low organic matter (less than 1%), low soil exchange capacity from 15 to 20 meq/100 g and the pH about 4.7 to 5.6. The vegetation of Ngaoundere is constituted of meadows, shrubby and woody savannahs, with predominance of *Daniellia oliveri* and *Lophira lanceolata* [30]. The vegetation aspects are maintained by zoo-anthropic factors such as bush fires and grazing [31].

In the experimental site located at Dang where two plots were chosen at The University of Ngaoundere (7°26,269' Nord, 13°31,988' Est and altitude 1114 m) out tree canopy. One plot was termites free and it was treated with antitermite product (Dorsban*4) that was spread at the edges of plot a day before litter incubation and after twelve weeks to eliminate termites of plot (plot termites free, TF). The other plot was not treated with antitermites (WT) that is a control.

2.2 Plant Species

In this study, only fresh fallen leaf litters of socio-economical plant species of the sudano-guinea savannahs of Ngaoundere were used. The experiment involved eight plant species: *Buxa orellana* L. (Buxaceae), *Erythrina sigmoidea* Hua and *Mucuna stans* Baker (Fabaceae), *Ficus polita* Vahl *(Moraceae), Maytenus senegalensis* (Lam.) Exell (Celastraceae), *Piliostigma thonningii* (Schumach.) Milne-Redh. (Caesalpiniaceae), *Vitex madiensis* Oliv. (Verbenaceae) and *Vitellaria paradoxa* Gaertn f. (Sapotaceae). They are herbaceous (*M. stans*,) and deciduous broad-leaved including three shrub species (*B. orellana*, *M. senegalensis* and *P. thonningii*) and four tree species (*E. sigmoidea*, *F. polita, V. madiensis* and *V. paradoxa*). The distribution area of all plant species is an upland savannah. *P. thonningii* can also find in fallows and degraded forests, and *F. polita* in the forest gallery. They are a source of income, food, firewood, medicinal substances and soil fertility indicators for the farmers of this region [32,33,34]. The farmers start now to conserve some of these plant species in their farms. New litter fall samples were collected directly from forest floor in the Ngaoundere humid savannahs, next to the University of Ngaoundere, during maximum leaf fall period (November – January). This period corresponds to dry season and soil was very dried; no leaching was occurred from new litter. Litter was sorted, air-dried and stored in the laboratory before use.

2.3 Litter Decomposition Experiment *in situ*

In order to determine effects of termites on litter decomposition, a study was conducted *in situ* in the savannah near the University of Ngaoundere, with eight plant Species. A litterbags experiment was carried out in two pots, termites free (TF) and with termites (WT), corresponding to two treatments. Litterbags used in this study consisted of nylon material with a 2 mm mesh [35]. 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 other studies of litter decomposition [2,4,33].

In total, two hundred and eighty-eight (288) litterbags (2 treatments x 8 Species x 6 sampling dates x 3 replications) were each filled with 7±0,01 g of the leaf litter and placed on top soil of each of the two plots, during 24 weeks, from May 21 to November 5, 2016. The litterbags were lightly covered with of litter. The experimental design was a *split-plot* with 3 replications. Plots were mean treatments and litter types or plant species were under treatments. Three litterbags per species and per treatment were collected at 2, 4, 6, 10, 16 and 24 weeks, 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 dry mass.

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 dry mass. The dry litter mass remaining was calculated per sample date, per species and per treatment. To avoid fragmentation, leaf-litter was moistened again, spread out and then the corresponding leaf areas were calculated using equation of Payne *et al.* [36]: Area = 0.68 x (litter length x litter maximum width) - 0,114. Thickness was measured on the same leaf litter by calliper. Specific area mass (SM) or area per unit mass was calculated from their area and dry mass (SM=A/DM), the sclerophyllous index (SI) was also calculated from their dry mass and area (IS=DM/A) and leaf litter density (D) was calculated from their dry mass, area, and thickness (D=DM/(A x T). Where SM is specific area mass ($cm.g^{-1}$), A, area (mm^2), DM, dry mass (g), IS, sclerophyllous index ($mg.mm^{-2}$), D, density ($g.cm^{-3}$), and T, thickness (mm).

2.4 Statistical Analysis

The contribution of termites to the litter decomposition (or mass loss) was calculated according to following formula: TC = WT – TF, where TC is a termite contribution (% of original mass), WT is the mass loss from termite-infested plot and TF is the mass loss from termite-free plot.

The litter mass remaining (LMR expressed as a percentage of the initial mass) of each species for each treatment in relation to litter incubation time (in weeks) was fitted to the following simple negative exponential decay [37]: LMR = A*exp(-kt), where k is the decomposition rate constant, A, the compartment of water soluble substances and other compounds. The model is widely used, particularly for the litters of sudano-guinea savannahs of Ngaoundere Cameroon [2,4,38] and enables easy comparison with other studies among parameters.

Before forming any analysis, all variables was tested for normality and if necessary, log transformed. Using a one-way ANOVA (species or treatment), following by *Scheffe*'s mean comparison test at 5% (if ANOVA was significant), we compared LMR among litter types (or species). Two-ways ANOVA (species and treatments) was used to compare the combined effects of litter types and treatments. *Student* t test was also used to compare treatments (with and without termites). Pearson's correlation coefficients were calculated between litter decomposition rate constants (k), LMR at 24 weeks and physical properties of initial litters. Multiple regression models (stepwise) were also used to determine relationships between these parameters. A multiple comparison among the fitted litter decomposition constants (k) was carried out using the *T' - method* [39] to compare for each species the effects of soil termites on litter decomposition rate. These tests were conducted through software package SX for DOS, version 4.0 (Statistix, 1992).

3. RESULTS

3.1 Initial Litter Traits

All initial litter traits presented in this study differed significantly among plant species (Table 1). The highest values of litter thickness (0.90 mm) and area (223.43 mm^2) were found in *F. polita* and the lowest ones in *B. orellana* (0.22 mm) for thickness and in *M. stans* (17.46 mm^2) for area. Sclerophyllous index (SI) and density varied significantly from 0.07 $mg.mm^{-2}$ and 0.32 $g.cm^{-3}$ in *M. stans* to 0.62 $mg.mm^{-2}$ and 6.23 $g.cm^{-3}$ in *V. paradoxa*. While the specific area mass (SM) was significantly the highest in *M. stans* (152 $cm^2.g^{-1}$) and the lowest in four species, *M. senegalensis* (42.13 $cm^2.g^{-1}$*), F. polita* (48.07 $cm^2.g^{-1}$), *P. thonningii* (48.73 $cm^2.g^{-1}$) and *V. paradoxa* (49.03 $cm^2.g^{-1}$), which were not differed significantly among them.

3.2 Litter Mass Remaining (LMR)

The dynamics of litter mass loss of the treatment without termites was slowed at the beginning of the litter decomposition experiment and fasted over time, except for *V. madiensis* and *B. orellana* (Fig. 1a), while with termites, the dynamics of litter mass loss was fasted at the beginning of the litter decomposition experiment and slowed over time, except for *B. orellana*, *F. polita*, *M. stans* and *V. madiensis* (Fig. 1b). The patterns of LMR dynamics differed among plant species in each of the two treatments. They were the fastest in *P. thonningii* for both treatments and the slowest in *V. madiensis* and *B. orellana* for treatment without termites and in *B. orellana* with termites (Fig. 1a and b). The mean Patterns of dynamics of LMR including all plant species varied between treatments and were slower in treatment without termites than that with termites (Fig. 2). In each of eight plant species, patterns of LMR dynamics differed significantly between treatments according to sampling date (Fig. 3). For each of these sampling dates, the litter mass remaining was significantly lower for treatment without termites than that with termites only in *P. thonningii* and *V. paradoxa*.

At the end of the experiment, the mean litter mass remaining including all plant species differed significantly (F = 8.88, P<0.005) between treatments. The value was lower for treatment without termites (36.45%) than that with termites (54.80% of initial dry mass). The corresponding mass loss values were 63.55% and 45.20%. According to each plant species, this litter mass remaining varied from 38.07% of initial dry mass to 76.95% for treatment without termites and from 8.49% to 56.12% for treatment with termites (Table 2). Thus, the corresponding mass loss was between 61.93 and 23.05% and between 91.51 and 43.88% respectively for treatments without and with termites. The plant species differed significantly among them according to their litter mass remaining. The highest value was found in *V. madiensis* and the lowest in *P. thonningii* and *E. sigmoidea* for treatment without termites, while for treatment with termites, the highest value was observed in *B. orellana* and the lowest in *P. thonningii*. The litter mass remaining differed significantly between treatments except for *E. sigmoidea* and *M. stans* (Table 2) and the value was significantly higher in treatment without termites than that with termites for each plant species excepting for the two previous species.

The LMR of each of the eight plant species was fitted to negative exponential model, with highly significant coefficient of correlation for all species in the both treatments (Table 3). A multiple comparison of litter decomposition rate constants (k) by *T'-method* showed that the rate constants (k) of litter decomposition varied among plant species and between treatments (Fig. 4). *P. thonningii* had the highest litter decomposition rate constant for the both treatments, and *B. orellana* and *V. madiensis,* the slowest ones. The litter decomposition of all plant species was faster for treatment with termites than that without termites.

3.3 Correlations between LMR, Decomposition Rate Constants and Initial Litter Traits

Pearson coefficient correlations showed relationships between the mean of LMR at the end of the experiment, litter decomposition rate constants (k) and the mean values of initial litter traits (Table 4). These relationships varied according to treatment. Litter thickness was correlated significantly with LMR, and litter decomposition rate constants (k) only at the treatment without termites. This correlation was negatively with LMR, and positively with litter decomposition rate constants (k).

Table 1. Physical properties of initial litters of eight plant species of Ngaoundere savannahs of Cameroon

Species	Thickness (mm)	Area (mm^2)	IS ($mg.mm^{-2}$)	Density ($g.cm^{-3}$)	SM ($cm^2.g^{-1}$)
B. orellana	0.22 (0.08) d	45.31 (7.75) bc	0.59 (0.17) ab	5.88 (1.70) ab	91.10 (15.58) b
E. sigmoidea	0.84 (0.04) ab	51.03 (4.98) bc	0.20 (0.03) bc	2.03 (0.26) bc	69.21 (6.75) bc
F. polita	0.90 (0.12) a	223.43 (35.27) a	0.30 (0.06) abc	2.97 (0.64) abc	48.07 (7.59) c
M. senegalensis	0.62 (0,14) bc	27.75 (5.25) bc	0.51 (0.17) ab	5.11 (1.73) ab	42.13 (6.23) c
M. stans	0.24 (0.03) d	17.46 (0.98) c	0.07 (0.001) c	0.32 (0.04) c	152.69 (1.85) a
P. thonningii	0.79 (0.08) ab	74.47 (7.59) b	0.33 (0.09) abc	3.26 (0.92) abc	48.73 (5.95) c
V. madiensis	0.41 (0.02) cd	33.42 (7.28) bc	0.50 (0.15) ab	4,99 (1.48) ab	64.97 (14.15) bc
V. paradoxa	0.35 (0.03) d	49.93 (5.62) bc	0.62 (0.12) a	6.23 (1.21) a	49.03 (5.52) c
F	35.04***	29.30***	18.19**	15.21**	42.09***

*** p<0.01, *** p<0.001. Numbers in parentheses indicate standard deviation. Different letters indicate significant differences among different species*

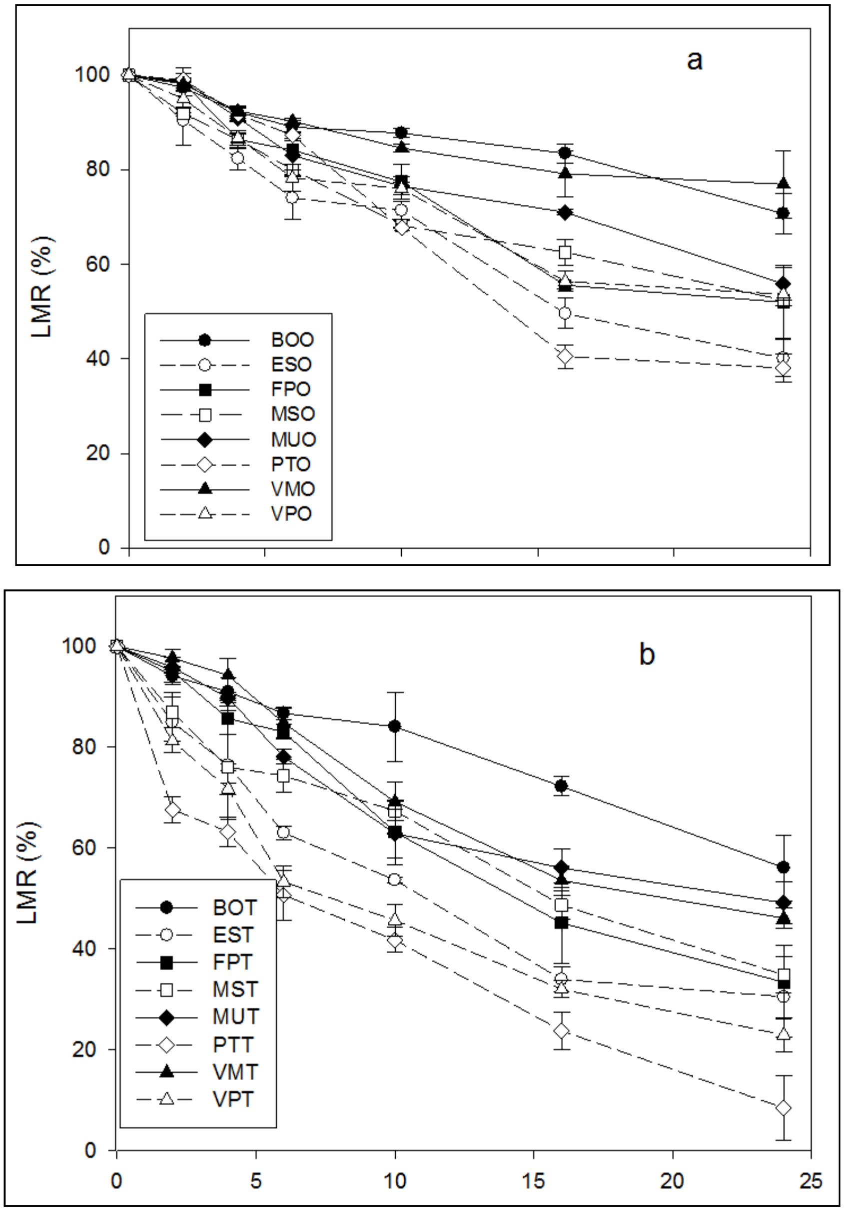

Fig. 1. Changes of LMR of eight plant species at the treatments without (a) and with termites (b) during the course of incubation time *in situ*. *B. orellana* (BO), *E. sigmoidea* (ES), *F. polita* (FP), *M. senegalensis* (MS), *Mucuna stans* (MU), *P. thonningii* (PT), *V. madiensis* (VM) and *V. paradoxa* (VP)

The stepwise model showed the relationships between LMR at the end of litter incubation time, litter decomposition rate constant (k) and associations of litter traits at each of the both treatments (Table 5). These relationships between LMR and litter traits were explained more than 70% by the association of two physical parameters (area and SM) for treatment with termites, or three physical parameters (thickness, density and specific area mass) for treatment without termites. The number of litter traits involved in the relationships between litter decomposition rate constant (k) and litter traits, which explained more than 90%, was decreased from three parameters (Area, density and SM) for treatment without termites to two parameters (Area and SM) for the treatment with termites.

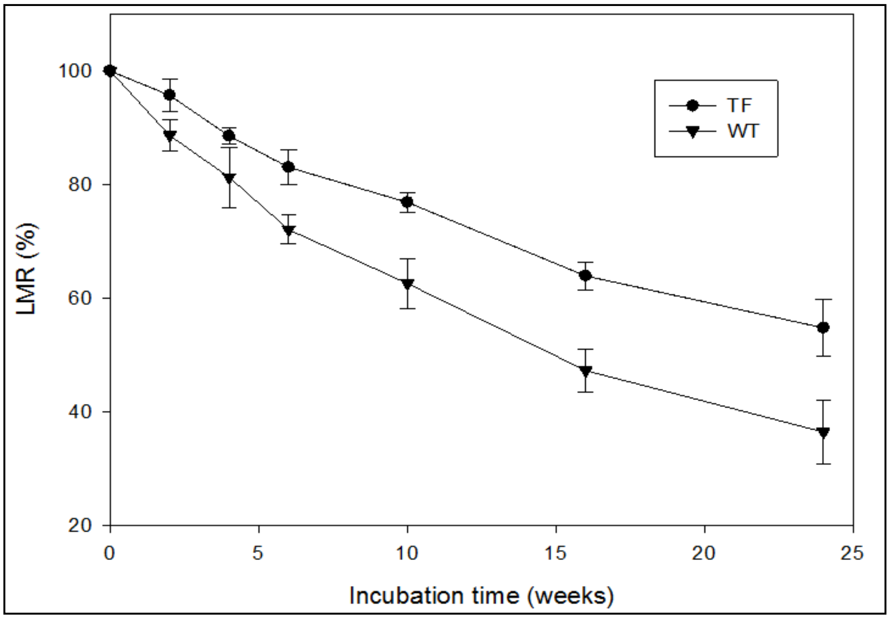

Fig. 2. Changes of LMR mean of eight plant species of treatments with (WT) and without (TF) termites during the course of incubation time *in situ*

Table 2. Litter mass remaining (LMR in %) at the end of incubation time *in situ* (24 weeks) of the eight plant species at each of the two treatments (With and without termites). Termite contribution (TC)

Plant species	Without termites	With termites	t *Student*	TC(%)
B. orellana	70.69 (4.26) ab	56.12 (6.54) a	7.09*	14.57
E. sigmoidea	40.11 (3.92) c	30.55 (7.91) bc	3.83ns	9.56
F. polita	52.01 (7.73) bc	33.42 (7.38) abc	8.67*	18.59
M. senegalensis	52.42 (0.69) bc	34.87 (3.65) abc	48.08**	17.55
M. stans	55.88 (3.37) abc	49.18 (4.16) ab	4.05ns	6.70
P. thonningii	38.07 (2.91) c	8.49 (6.45) c	16.19*	29.58
V. madiensis	76.95 (7.15) a	46.13 (1.96) ab	66.07***	30.82
V. paradoxa	53.67 (2.42) abc	22.99 (3.42) bc	101.23***	30.68
F	14.05***	16.35***		

** P<0.05, ** P<0.01, ***P<0.001. Numbers in parentheses indicate standard deviation. Different letters in columns indicate significant differences among different species*

Table 3. Coefficient of correlations (R) of exponential regression equations (y = exp(-kt)) describing changes in LMR with incubation time (in weeks). All are highly significant at P< 0.001, n = 21

Plant species	Without termites	with termites
B. orellana	0.9507	0.9639
E. sigmoidea	0.9799	0.9703
F. polita	0.9684	0.9835
M. senegalensis	0.9859	0.9851
M. stans	0.9810	0.9729
P. thonningii	0.9732	0.9806
V. madiensis	0.9365	0.9834
V. paradoxa	0.9770	0.9847

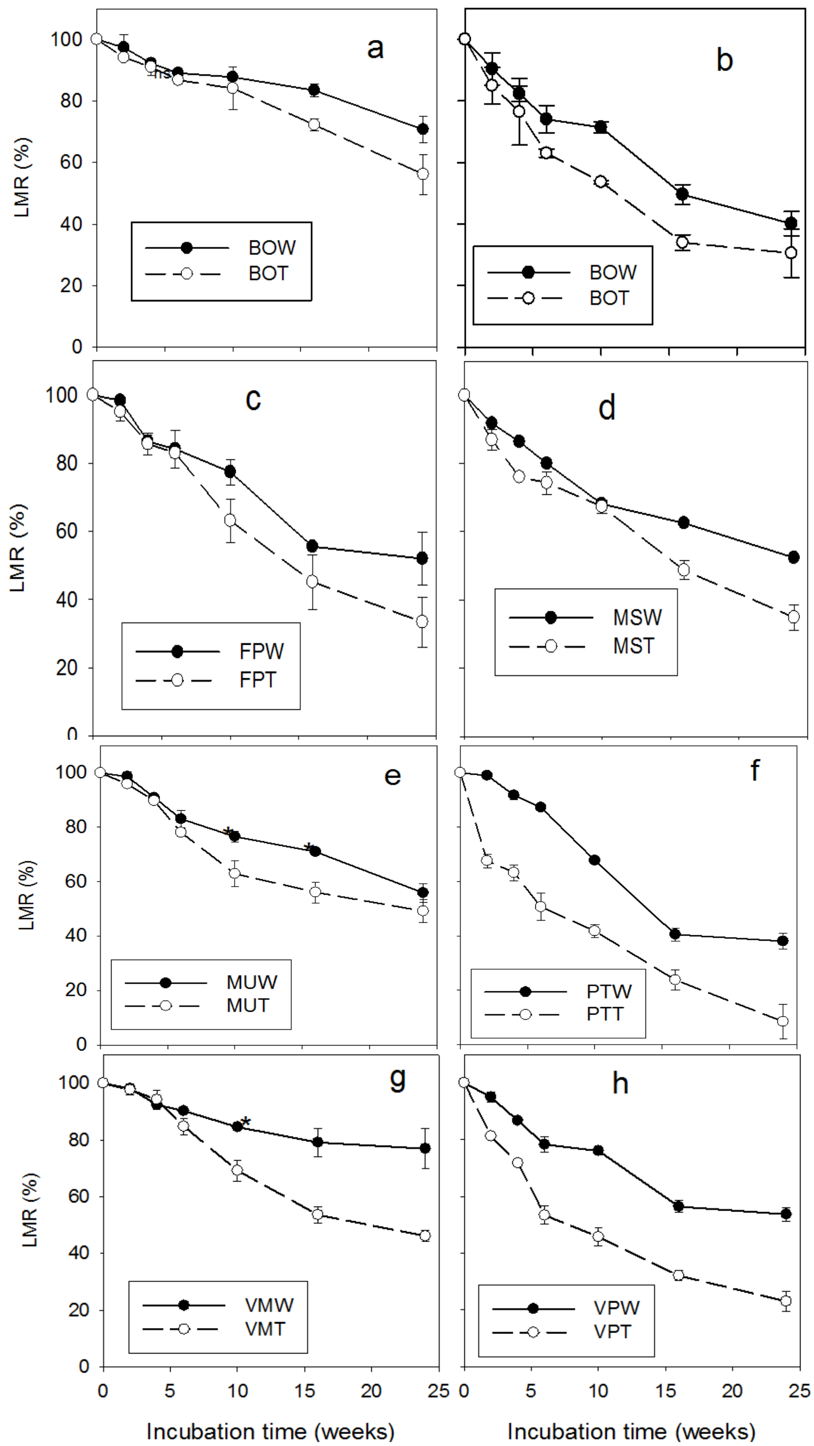

Fig. 3. Comparison of LMR (%) changes between treatments with (T) and without (W) termites of each of eight plant species during the course of incubation time *in situ*. ns, non-significant, significant at * p<0.05, ** P<0.01 and *** P<0.001. *B. orellana* (BO), *E. sigmoidea* (ES), *F. polita* (FP), *M. senegalensis* (MS), *Mucuna stans* (MU), *P. thonningii* (PT), *V. madiensis* (VM) and *V. paradoxa* (VP)

Table 4. Correlation coefficient of Pearson (n=5) calculated between LMR and k and initial litter traits (Thickness, area, sclerophyllous index, density and specific area mass) at each of the two treatments (with and without termites). n=6, Significant at * P<0.05

Parameters	Without termites		With termites	
	LMR	K	LMR	K
Thickness (mm)	**-0.8357***	**0.8457***	-0.6592	0.6201
Area (mm^2)	-0.6230	0.6832	-0.7015	0.8057
IS ($mg\ mm^{-2}$)	0.6775	-0.6642	0.4289	-0.4680
Density ($g.cm^{-3}$)	0.6747	-0.6636	0.4292	-0.4703
SM ($cm^2.g^{-1}$)	0.4970	-0.5834	0.7306	-0.5976

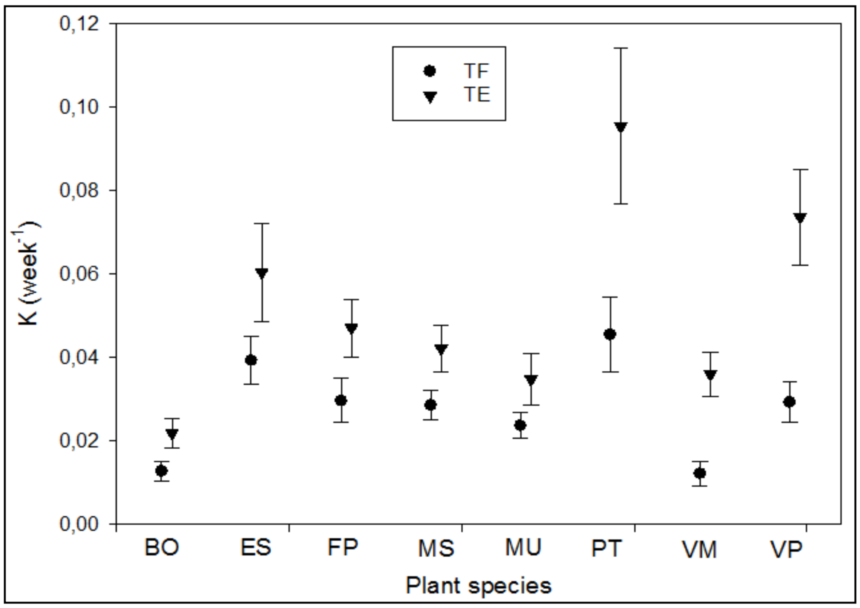

Fig. 4. Comparison of decomposition rates constant (k) between treatments with (TE) and without (TF) termites of each of eight plant species after 24 weeks of litter incubation time *in situ*. *B. orellana* (BO), *E. sigmoidea* (ES), *F. polita* (FP), *M. senegalensis* (MS), *Mucuna stans* (MU), *P. thonningii* (PT), *V. madiensis* (VM) and *V. paradoxa* (VP)

Table 5. Multiple regressions (Stepwise) between LMR at the end of incubation time (24 weeks), k and initial litter traits (Thickness, area, sclerophyllous index, Thickness, density and specific area mass) at each of the two treatments (with and without termites). n = 6

Treatments	Stepwise regression	R^2
	Litter dry mass remaining (LMR)	
With Termites	LMR = 25.990 - 0.683*Area + 0.6456*SM	0.9730
Without termites	LMR = 171.721 – 113.156*Thickness – 9.166*Density - 0.221*SM	0.7410
	Litter decomposition rate constant (k)	
With Termites	k = 0.0449 + 0.0013*Area – 8.62310^{-4}*SM	0.9568
Without termites	k = -0.056 + 4.488 10^{-4}*Area – 0.0043*Density – 4.777 10^{-4}*SM	0.9160

4. DISCUSSION

Few studies determined the effects of termites on litter decomposition process were found in the literature, particularly for African savannahs [40,41,42,43]. In fact, Dosso et Kone [44] have shown that the litter decomposition of three grass species (*Andropogon sp.*, *Hyparrhenia diplandra* and *Loudetia simplex*) of Ivory-Coast savannahs due greatly to termite feeding activities varied from 24 to 39% of original litter mass. Ohiagu and Wood [45] reported that 69% of grass litter have been loss by after 4 months dry season in Nigerian savannahs and indicate that this loss was due largely to consumption by fungus-growth termites. In extremely arid east Africa, fungus-grower dominated termite assemblages decompose up to 50% of grass litter [46]. In the Southwestern United States of America, Bodine and Ueckert [19] observed that all of the blue grama (*Bouteloua gracilis*) grass litter had disappeared from the litterbags on the soil surface in termite-infested rangeland, while 55% of the original still remained in the bags on the soil surface in termite-free rangeland. Thus the desert termite, *Gnathamitermes tubiformans*, accounted for 45% of the disappearance of litter from the soil surface. In Asia, Nakagami et al. [47] have found that grass litter of *Zoysia japonica* had loss 50% of original mass over a 1 year incubation period in Japan. Ashton et al. [48] reported that termite activities and abundance increased during drought in a Bornean forest and accelerated litter decomposition process.

Our findings have shown that the contribution of termites in litter decomposition varied from 20.88 to 29.64% of original litter mass and ranked among the middle values of savannah ecosystems. The differences between our results and these of previous authors can be explained by the fact that their experiments were carried out with grass litter and some of them occurred in plot not totally termite free, while our experiment was conducted on woody species leaf litters in termite free plot. In addition, the duration of experiments varied according to the studies. Thus, the studies of Dosso, et al. [44], Ohiagu and Wood [45], Nakagami et al. [47] and Bodine and Ueckert [19] were carried out during 27 days (or ≈ 4 weeks), four months (or ≈ 17 weeks), 12 months (or ≈ 52 weeks) and 14 months (or ≈ 61 weeks) respectively, while our experiment conducted during 24 weeks. The litter types and termites involved in the experiments differed also according to the studies. All the previous authors used in their experiments grass litters contrary to our study which carried out on woody specie leaf litters, excepting *M. stans* which is herbaceous species. According to Dosso, et al. [44], the mass loss of herbaceous litters caused by termites was higher (33% of original mass) than that of woody species leaf litters (11% of original mass) during 27 days (or ≈ 4 weeks) in fallows of Ivory-Coast. They concluded that there is an obvious difference between litters of woody and herbaceous species, which is related to the physio-chemical properties of litters of these plant species, the former being more resistant than the latter, and therefore naturally heavier whatever the activity of termites. Our results confirmed these findings, because the contribution of *M. stans* (6.70%), herbaceous species, was lower than those of others species (9.56–30.82%) which are all the woody species.

Our findings have also shown that leaf litter decomposition in termite-infested plot was significantly faster than that without termites globally and for each litter type, excepting for *E. sigmoidea* and *M. stans*. The difference of litter decomposition between treatments with and without termites was attributed to the consumption of termites, the majority of which consist of fungus-growth termites that are major consumers of plant debris as reported in the Lamto savannahs of Ivory-Coast as well by Dosso, et al. [44] than by Josens [49]. The latter has shown that there are three types of termites in one hectare of savannah, including the more numerous fungus-growth, represented by 5 million individuals incorporating in their burrows about 1.4 tons of dry litter per year. They are followed by forage termites consuming plants represented by 1.6 million individuals consuming from 30 kg to 50 kg of grass dry mass. In his study on the influence of soil organisms on litter decomposition in the savannahs of Ngaoundere Cameroon, Babe Ndara [50] estimated in square meter 1.2 individuals of termites (120800 individuals per hectare) in the plot where litter samples were incubated. These results suggest that termites ones of the fauna, particularly fungus-growth termites, that largely control litter decomposition process through breakdown of litter, transporting of the fragments of litter to underground chambers or fracturing litter, thereby increasing the surface area available to microbes [51,52]. This effect of termites modified also the influence of physical features of leaf-litter as litter thickness, density, area and specific area mass (SM) on litter decomposition process as showing by our study (Table 5). In fact, in the absence of termites, thickness and density largely control litter mass loss and decay rate (k), while with the presence of termites in plot, litter decomposition was driving by area and specific area mass (SM). These findings could be explained by the mechanism so called facilitation and resource partitioning which are widely discussed in the literature of plant diversity effects on net primary production and are thought to contribute to complementary in more diverse plant communities [53]. In fact, Ibrahima, et al. [4] have shown that the contribution of micro-organisms alone on the litter decomposition, in the absence of earthworms was very low for litters of the six plant species of Ngaoundere Savannah of Cameroon. Contrary, when the earthworms were present in plot, this contribution of microorganisms to the litter decomposition was wholly significant for the all previous litters. This confirms that the actions of microorganisms would be tributary of that of the soil macrofauna just like earthworms and termites.

Our finding suggested that the importance of contribution of termites in litter decomposition varied not only between herbaceous and woody species as suggested by Dosso, et al. [44] in fallows of Ivory-Coast, but also among deciduous broa-leaved woody species. The value of this contribution of woody species varied from 9.56 in *E. sigmoidea* to 30.82% in *V. madiensis* and significantly for all plant species except for *E. sigmoidea.* This type of results was found by Ibrahima, et al. [4] on synergistic effect of earthworms and soil microorganisms on the litter decomposition process. According to their findings, this effect was stronger on litters with low thickness, rich in cellulose and high capacity to release water soluble substance as *X. americana* and *A. occidentale*. They concluded that the physical features of leaf-litter as litter thickness, as well as their chemical quality as lignin and polyphenols seemed generally to play a great role in the faunal effects on litter decomposition process as also reported by De Oliveira, et al. [52], and Kaspari and Yanoviak [54] in tropical Forests. We found significant ($R^2 > 0.95$, $P<0.05$) correlations between the litter mass remaining (LMR), decay rate constant (k) and litter area, and specific area mass (SM) with the presence of termites, while when the plot was termite free, these correlations were modified.

5. CONCLUSION

As far as we know, this study indicated that termite activities speeded significantly the litter decomposition of eight contrasting multipurpose plant species of Ngaoundere savannahs of Adamawa region of Cameroon. These activities modified the effects of the quality of litters on their decomposition. These results suggested that termites provided a significant contribution to litter decomposition. They holds implication for the importance of preserving all termite diversity in the sudano-guinea savannahs of Ngaoundere Cameroon for assuring efficiently nutrient cycling and contributing to soil fertility management to order to a sustainable management of Savannah of Ngaoundere of Cameroon.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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