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IMPACT OF ANTS ON THE GROWTH AND PRODUCTIVITY OF LAMTO SAVANNA PERENNIAL GRASSES (COTE D'IVOIRE)

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ABSTRACT

Lamto savanna soil known to have low agronomic value paradoxically has one of the highest grasses biomass productions in the world. During recent surveys, ant nest were encountered under some grass tufts and it as suggested that ants are able to influence the availability of resources for these grasses and also other organisms. An interaction is suspected between these savanna grass tufts and their associated ants. Three grasses species *Andropogon schirensis*, *Hyparrhenia diplandra* and *Loudetia simplex* were chosen to inventory ant communities associated with grass tufts and to assess the influence of ant communities on growth and productivity of perennial grasses. Three study sites were chosen and each was subdivided in two experimental plots of 2500 m². By systematic digging out method we were collected 38 ant species under grass tufts. They belong to 19 genera and 7 sub-families. Lamto herbaceous stratum was dominated by *Camponotus acvapinensis*. Diameter measures of grass tufts base at ground level, have allowed establishing the link between the size of ant nest and grass tufts size. Pearson coefficient r ranged no correlation between the size of ants nest and grass tufts size. The association rate with ants of one of the grasses *Hyparrhenia diplandra* was greater than for two other grasses studied *Andropogon schirensis* and *Loudetia simplex* (54.208 % versus 49.433 %, and 38.496 % respectively). Parameters such as grasses height, diameter (at ground level, and 10 cm above), dry biomass and seeds production were assessed. The results showed that *Hyparrhenia diplandra* with ant nest recorded the best results of growth and productivity. Association with ants nest is beneficial for the growth and productivity of Lamto perennial grasses.

Keywords: Lamto savanna; perennial Grass tufts; Ant nests; Growth; productivity

1. INTRODUCTION

Tropical soils are highly leached and impoverished, requiring the ecosystem to develop nutrient conserving mechanism. West Africa humid savanna, is particularly characterized by a low level of fertility (Riou, 1974; Koné, 2009), specifically in the savanna of Lamto Scientific Reserve where the soil is known to have a low agronomic value (Le Roux and Mordelet, 1995). However, according to Le Roux and Mordelet(1995), the primary production of grasses in this savanna is among the highest in the world. Abbadie (1990) showed that 77 kgN/ha/year of nitrogen is necessary for the normal growth of the herbaceous stratum. However, only 2-5 kgN/ha/year are available through organic matter mineralization. Investigating on the cause of this surprisingly remarkable high primary production in Lamto, Abbadie (1990) found that additional nitrogen was provided following another nitrogen cycle other than organic matter mineralization under grass tufts.This nitrogen cycle was shorter and consisted to the decomposition and mineralisation of dead roots under the grass tufts.

Recent investigations in Lamto savanna showed that many grass tufts were asssociated with ant nests. Ants are recognized as ecosystem engineers because of their ability to influence resources availability for other organisms (Jones *et al*., 1994; Hairiah *et al*., 2006). Through their nesting habits, these insects can improve soil physical (bioturbation, horizons mixing) and chemical properties “nutrients concentration arround the nest” (Levieux, 1976; Folgarait, 1998; Cammeraat *et al*., 2008). Their nests architecture (tunnels and chambers) also contributes to water and gas exchange in the soil (Folgarait, 1998). Ants can also affect directly plants by seeds transportation (Folgarait, 1998).

In this study, we hypothesize that ants contribute to the growth and productivity of Lamto savanna grass tufts. Ant nest associated with three grasses species; *Andropogon schirensis* ,*Hyparrhenia diplandra*, and *Loudetia simplex* were studied. Specifically, the objectives of this study were i) to inventory the ant communities associated with grass tufts in Lamto savanna; ii) to assess the influence of ant communities on the growth and the productivity of grasses in this savanna.

2. MATERIAL AND METHODS

Study site

The study was carried out in the Lamto Scientific Reserve located in Côte d’Ivoire at the southern edge of the “V Baoulé”. The climate is intertropical type with an annual temperature around 27.8°C. The annual rainfall average of 1200 mm is distributed on four seasons including two wet seasons from Mars to July, from September to November and two dry seasons, the first one is in August while the second on spans from December to February (Lamotte and Tireford 1988). The vegetation is a mosaic of forest-savanna dominated by the palmyra palm trees (*Borassus aethiopum*) and perennial grasses on three soil types: red tropical ferruginous soil; ochre tropical ferruginous soil and hydromorphic pseudo gley soil (Menaut *et al*., 1979; Vuattoux *et al*., 2006). The research was conducted on three different sites of 5000 m² each, all located in savanna. These sites are described as follow:

Site 1 (N 06 12’54.3’’and W 005 01’06.4’’) is a shrubby savanna dominated by grass species *Andropogon schirensis (*Hochst), *Andropogon canaliculatus*, *Hyparrhenia diplandra* (Hack.), *Hyparrhenia smithiana (Hook. f.)* and *Loudetia simplex* (Nees). The shrubby stratum consisted of *Piliostigma thonningii* (Schum.), *Crossopteryx febrifuga* (Afzel.), *Borassus aethiopum* Mart., *Cochlospermum planchoni* and *Tephrosia elegans*;

Site 2 (N 06 12’19.3’’and W 005 00’17.8’’) is a grassy savanna with scattered palmyra palm trees (*Borassus aethiopum* Mart). It is dominated by grass species *Andropogon ascinodis* C. B. Cl, *Andropogon schirensis* Hochst. *Hyperrhenia smithiana* (Hook.); *Hyparrhenia chrysargyrea* and also *Loudetia simplex* (Nees);

Site 3 (N 06 12’26.3’’and W 005 00’30.4’’) is a grassy transition savanna dominated by species such as *Andropogon schirensis* Hochst, *Hyparrhenia diplandra* (Hack) and *Loudetia simplex* (Nees). The shrubby stratum consisted of Palmyra palm trees and woody species such as *Bridelia ferruginea (*Benth), *Crossopteryx febrifuga* (Afzel) and *Tephrosia elegans.*

These three study sites were represented on the map (figure 1).Each study site has been subdivided in two experimental plots of 2500 m² on which different types of sampling were realized. The plot 1 is used to monitor the grass tufts growth with and without ant nest, the collect of seeds and biomass measurements at the end of seasonal cycle.

On the plot 2, a systematic digging out of the grass tufts of the three grasses species has been done on 2500 m² on each study site.

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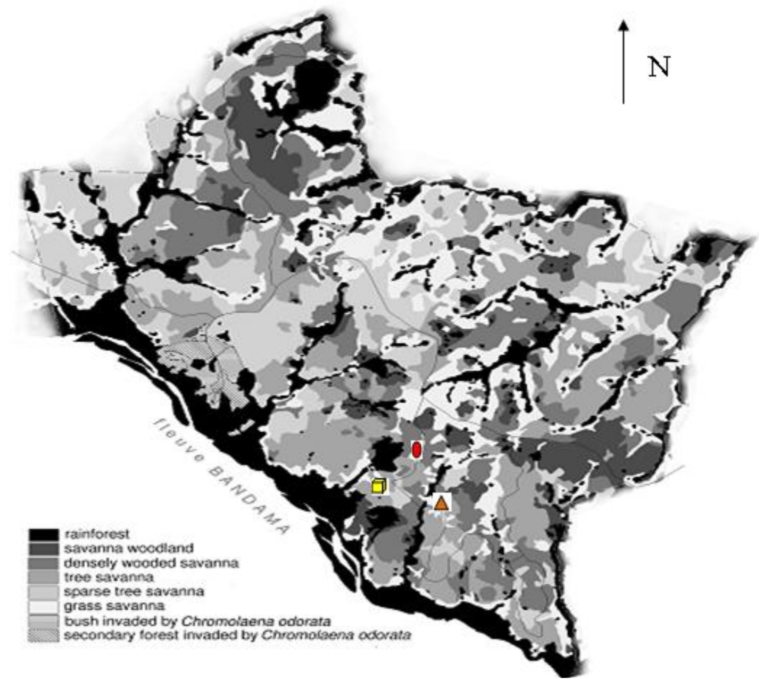

Figure 1: Vegetation map of Lamto Scientific Reserve: 2500 ha (modified from Gauthier, 1990) and localization of sampling sites.

Study site 1; Study site 2; Study site 3

The research was focused on ant communities under three grass species *Andropogon schirensis (*Hochst), *Hyparrhenia diplandra* (Hack.) and *Loudetia simplex* (Nees). We measured tufts variables in order to examine whether selected grasses species primary production was related to the presence or absence of ant nest under tufts. We quantified four tufts variables that are supposed to influence primary production: the growth by; i) height and ii) the circumference of the tuft); iii) the biomass; iv) the seed production.

Measurements were made on 150 grass tufts (75 tufts with ant nests and 75 tufts without ant nests) on each study site. So, 450 tufts were recorded in the three studies sites.

Ant sampling and identifications

Sampling of ant was conducted on the plot 2 of each study site. All Tufts were dugout and all ant workers beneath were collected and stored in labelled vial containing alcohol 96°. Ants were identified to genus using the key of Bolton (1994) and Fisher & Bolton (2016). Species were named, when possible, using identification key of Bolton (1976, 1980, 1982, and 1987) and a reference collection deposit at Lamto Ecology Station (Yeo, 2006).

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Undetermined species were assigned code within genus (sp. 1, sp. 2, etc). Voucher specimens of all species are deposited at Lamto Ecology Research Station.

Data analysis

Our data set was a site-by-species abundance matrix, with the frequency of occurrence used as measure of abundance because of the patchy distribution of ants due to great differences in colony sizes (Longino 2000). For statistical analysis, Relative abundance, Species richness and species composition were considered. Also Simpson diversity index and Evenness was determined as a measure of the alpha-diversity using Ecological Methodology version 6.1 software (Krebs, 2002). Sampling efficiency was then assessed calculating expected number of species with the non parametric estimator (Chao 2). EstimateS 8.0.software was used to perform these analyses.

To assess the similarity of ant assemblages between study sites and also between grass species, we used the Jaccard dissimilarity index using the EstimateS software (Colwell, 2006).We also used the Unweighted Pair-Group clustering method using arithmetic Averages (UPGMA) with the software Statistica version 7.1 (Statsoft, 2005).

The correlation r of Pearson has been determinate with Statistica software version 7.1. It allowed measuring the proportional relationships between the size of grass tufts and the size of ant nest. Overwise, it allowed examining the relationship between measured variables (Tufts diameter at ground level and individual numbers in the ant nest) on grass tufts and ant fauna characteristics. We used Statistica version 7.1 (Statsoft, 2005) to create the graphic that showed the range of points around the straight line with 0.95 % as confident interval.

The compute of the means of the measurement parameters (high and diameter at soil level) of grass tufts allowed tracing the growth curves on Microsoft office Excel (2007). A pair wise comparison of Student (t test) compute with Statistica software version 7.1, allowed to show the significant different between the growth of grass tufts with and those without ant nest.

The association rate of ant with grasses, the biomass quantity and productivity, have been compute by the following formulas:

$$X \text{ (association rate)} = \frac{\text{number of tufts with ant nests (colonies)}}{\text{total number of tufts}} * 100 \qquad (1)$$

Biomass and seeds production

$$Y \text{ (biomass)} = \frac{\text{total weigth of tufts with or without ant nest}}{2500 \text{ m}^2 \text{ (total surface)}} \qquad (2)$$

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$$Z \text{ (productivity)} = \frac{\text{total weigth of seeds with or without ant nest}}{2500 \text{ m}^2 \text{ (total surface)}} \quad (3)$$

3. RESULTS AND DISCUSSION

1-Ant communities that living in association with grass tufts in Lamto savanna

1.1 Inventory of ant living under grass tufts

A total of 38 ant species belonged to 19 genus and 7 sub-families were collected during the study. The sub-family are: Aenictinae, Cerapachynae, Dolychoderinae, Dorylinae, Formicinae Myrmicinae and Ponerinae. This result consistent with Yeo (2006) and Yeo *et al*.,(2017) who found that the litter and soil of Lamto savanna were dominated by the same sub-families and those of Dorylinae, Dolichoderinae and Proceratinae. Figure 2 shows the distribution of ants under three grass tufts according to their abundance in each sub-family.44.58 % of the ants associated with A. schirensis were Formicinae, 26.21 % were Ponerinae and 23.91 % were Myrmicinae. That associate with *Hyparrhenia diplandra were* 52.85 % Formicinae, 30.48 % Ponerinae and 14.69 % Myrmicinae. Under *Loudetia simplex*, the Ponerinae (41.34 %) were more abundant than Formicinae (34.27 %) and Myrmicinae (19.80 %).

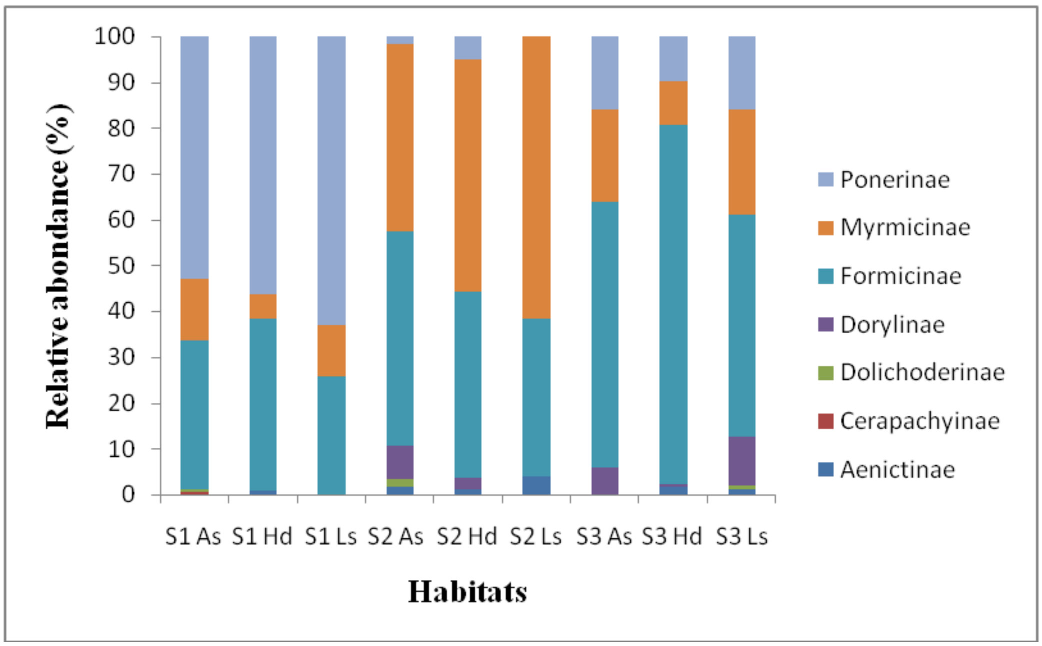

Figure 2: Relative abundance (%) of ant sub-families associated with grass species within the three study sites. S= study site; As = *Andropogon schirensis*; Hd= *Hyparrhenia diplandra*; Ls = *Loudetia simplex*

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The dominant ant sub-family was represented by some species such as *Camponotus acvapimensis*, (34.58 %) for the Formicinae. It occupied on average 34.58 % of the herbaceous stratum. The study of Levieux (1971) showed that a total of 55 individual females of this species were collected on 400m² that correspond on average one female per 7 m².

Camponotus acvapinensis recognized among the indicator species of savanna (Yeo, 2006 and Yeo *et al*., 2017). Specifically, study site 2 was richest (30 species) than study site 1, (26 species) and study site 3 (25 species). That could be due to the edaphic parameters of area and the micro-climate conditions created by each grass species. The high relative abundant of Myrmicinae sub family observed in study site 2 could due to sandy aspect of soil. According to Dostal *et al*., (2005), the size of the soil particles transported by ants depends of the size of the mandibles and thus of the ant species. According to Yeo *et al*. (2017), Myrmicinae sub family were numerically dominant in forest habitats. Savanna also recorded a good number of Mymicinae, which depend only to the soil structure.

1.1.1 Ant species stand parameters and diversity under grass tufts

The table 1 shows the observed and expected species richness under each grass species and study sites. Sampling coverage comprises 62.5 % and 92.8 %. *Andropogon schirensis* recorded the high species richness (35 species) followed by *Loudetia simplex* (27 species) and *Hyparrhenia diplandra* (23 species), there is a significant difference in species richness under the grass tufts (ANOVA: F= 0.34; dl = 8; p= 0.71). Student t test has shown a significant difference only between the species richness under *Andropogon schirensis* and *Loudetia simplex* in the three study sites (S1 As # S1 Ls: p= 0.05; S1 As # S2 Ls: p= 0.01; S2 Ls # S2 As: p= 0.02 and S2 Ls # S3 As: p= 0.02).

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Table 1: Summary statistic of ants collected under grass species in the three types of savanna

As= *Andropogon schirensis*; Hd= *Hyparrhenia diplandra*; Ls= *Loudetia simplex*

	Study sites:	**Study site 1**			**Study site 2**			**Study site 3**		
parameters	**Grasses :**	**As**	**Hd**	**Ls**	**As**	**Hd**	**Ls**	**As**	**Hd**	**Ls**
Total No. of samples		145	265	270	227	172	112	245	264	283
No. of samples with ants		107	165	141	88	69	24	110	146	91
Relative abondance		173	212	162	112	78	26	150	166	95
S(obs)		20	12	14	23	16	11	15	13	13
Chao 2		32	14	16	29	19	14	18	14	16
Sampling coverage (%)		62.5	85.71	87.5	79.31	84.21	78.57	77.78	92.86	81.25
Uniques species		9	3	5	8	6	5	5	3	5

At the field, a difference between the roots aspect of *Andropogon schirensis* has been remarked. In presence of ant nest, the roots are well dress, alive and airy. Without ant nest, the roots have a compact and condense aspect.

The studies of Kovarova *et al*., (2001) and Dostal *et al*., (2005) suggest that ant's environment can favour a rapid increase of the roots or a higher of the rhizomes.

Hyparrhenia diplandra had the high association percentage by *Camponotus acvapinensis* (42.32 %). That could be due equally to the roots aspect of grasses species. The roots of this grass were hardy, long, large and light up. That could allow to the large ant species to do some vertical and horizontal rummage. The vertical rummage (from soil to the base of the stubble) is to search the resources. At the field, during the digging sampling (July to November), rain period, queen and major part of ant nest were located between the stubbles annulus and the base of the roots. The central area of the nest was located in the soil depths which the dimension depend of the nest size. In November, a decomposition of the roots (abundance of the root litter) was observed. The workers must rummage horizontally between the roots hair. The Camponotus (genus) move generally in the soil digging fine galleries or using the natural penetration roads (dead roots) to hunt (Levieux, 1971). *Mesoponera ambigua* (30.48 %) live essentially in the soil and rummage at the time between the roots hair. The well aeration of roots hair of *Hyparrhenia diplandra* could allow him to give good life conditions especially to the large ant species.

Loudetia simplex had the great percentage of ponerinae (41.34 %) represented by *Mesoponera ambigua* (30.39 %) at the savanna stratum scale. At the small scale in study site 2, *Loudetia simplex* was dominated by Myrmicinae sub-family (61.538%).

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The results of *Loudetia simplex* tufts sampling with ant nest (table 1) showed that grass species shelter fewer ant nests than the two other grass species. That could be due to roots aspect which seems condensed. The dominance of *Mesoponera ambigua* could be due to the fact that the roots aspect confers him a best life conditions. The nests of this species were collected in major part in the soil.

The mean species richness (figure 4) under the three grasses species which were studied in this work: *Andropogon schirensis*: 14.89 ± 1.5 *Hyparrhenia diplandra* : 10.40 ± 0.98 and *Loudetia simplex* 9.56 ± 117.

The results indicated that there are no significant difference between the species living under the tufts of *Andropogon schirensis* in the three types of savanna F = 0.56 and P = 0.65 > 0.05. It is a same for *Hyparrhenia diplandra* (F = 1.06 and P = 0.36) and *Loudetia simplex* (F = 1.15 and P = 0.33).

The values (F = 0.68 and p = 0.52 > 0.05; n= 3) showed that there are no significant effect between ant species under grass tufts (Figure 5A). Figure 5B showed the evolution of the mean specific richness in the different faces of andropogonae savanna.

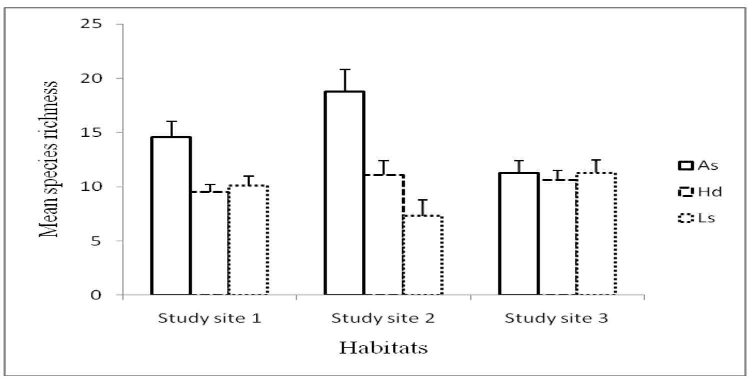
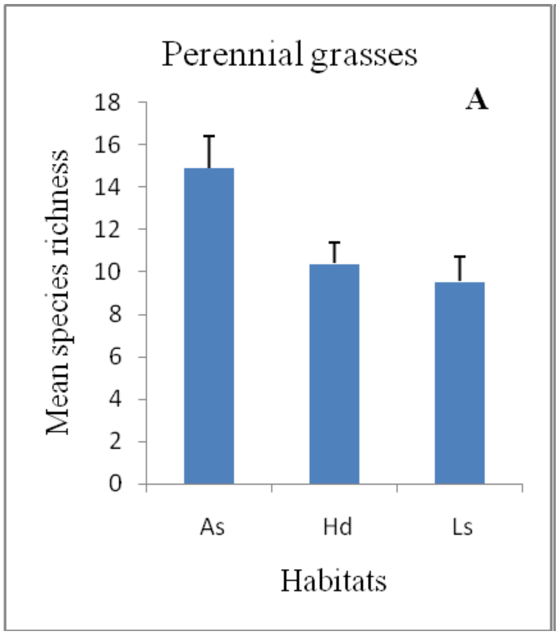


Figure 4: Mean species richness of ant living under perennial grass tufts per study site



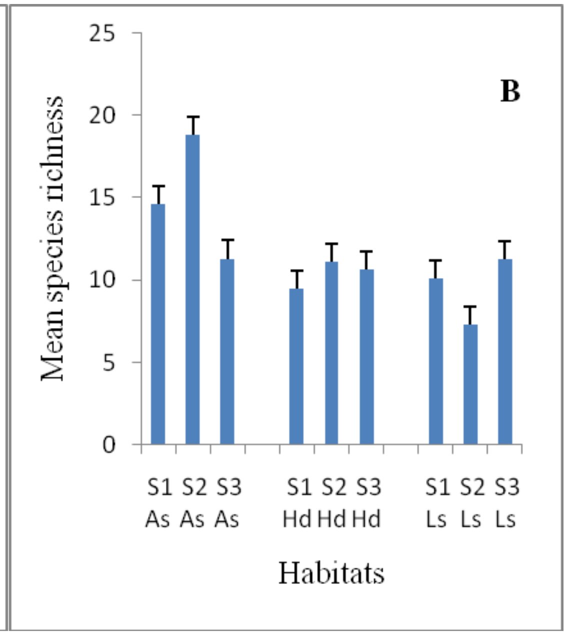


Figure 5: Comparison of Mean species richness of ants in the habitats type: (A) in all Andropogoneae savanna strata, (B) between the three study sites of Andropogoneae savanna.

Ant communities differed according to the habitats structure within Lamto savanna (Table 2). The values of Simpson diversity index is high under A. *schirensis* (0.86) followed by L. *simplex* (0.81) and H. *diplandra* (0.77). The values of Evenness were low under grass tufts and ranged inter 0.18 to 0.20.

Table 2: Ants diversity under grass tufts species

Ants parameters;	**Grasses species**			
	Andropogon schirensis	***Hyparrhenia diplandra***	***Loudetia simplex***	**Total**
Species richness	35	23	27	38
relative abundance	435	456	283	1174
Simpson diversity index (D)	0.86	0.77	0.81	0.82
Evenness (1/D)	0.21	0.19	0.19	0.15

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Ants' species composition under grass tufts

Andropogon schirensis and *Loudetia simplex* presented Jaccard similarity = 0,324. *Hyparrhenia diplandra* and *Andropogon schirensis* indicated Jaccard similarity = 0,432.
The cluster analysis traduces the low similarity observed between ant species composition living under *Andropogon schirensis* and *Loudetia simplex* (Figure 6 and 7). But these two species have a great similar with *Hyparrhenia diplandra*.

The results indicated two major groups: one concerning ant community living under *Andropogon schirensis* on the two first study sites 1 and 2 (sub-group1). Sub-group 1, consisting of only S1As and S2 As, indicated that there was a feeble similarity in the composition of the ant species living in these two habitats. The others included all remaining habitats (sub-group 2).

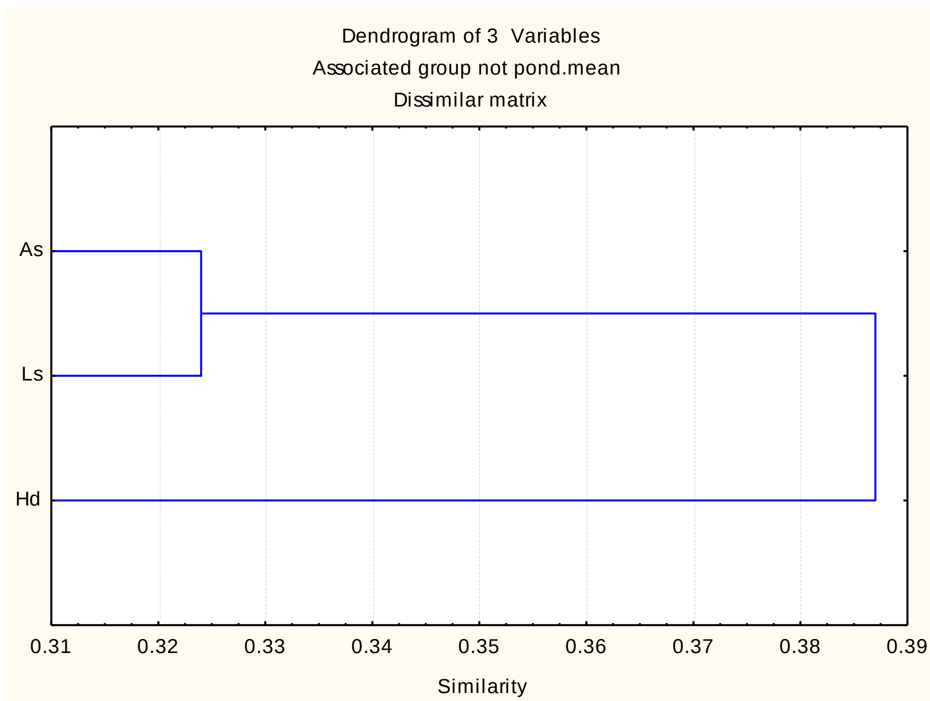

Figure 6: Comparison of the similarity of species composition between the three-grass species.

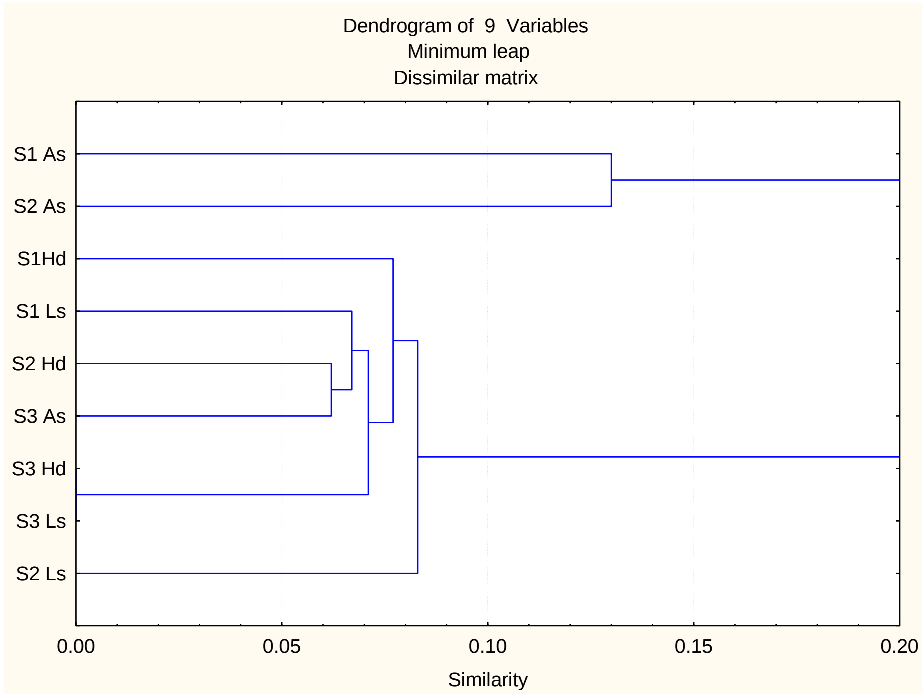

Figure 7: Comparison of the similarity of species composition between grass species and study sites

There aren't great similarities between ant species composition not only at the study sites level but also the grass species level. That could be due to the heterogeneity of the different study sites. This heterogeneity could be observed at the soil composition level, the type of vegetation associated, the microclimatic conditions and the disponibility of resources in the area. The results verified the assertion that both species richness and species composition usually vary strongly between localities (Andersen and Brault 2010; Jacquemin *et al*.2012). Vasconselos *et al*., (2003) demonstrated that soil texture, and clay content in particular, affects ant community composition and abundance in an Amazonian forest. Soil texture determines ease with which ants can tunnels the soil and construct chambers, and plays a significant role structuring the ant communauties (Boulton *et al*., 2005). In addition, local topography has been shown to promote heterogeneity in species distribution (Vasconcelos *et al*., 2003;Jacquemin *et al*.,2012). Moreover, ants select microhabitats with specific physicochemical conditions according to the species preferences for building their nest (Johnson, 2000).

1.2.Size of grass tufts in relation with the size of ant nests

The three graphics concerning the savanna grass tufts and ants nest size (Figure 8), indicated that the relationship between the two organisms type is not significant. They allowed understanding the independent character between them.

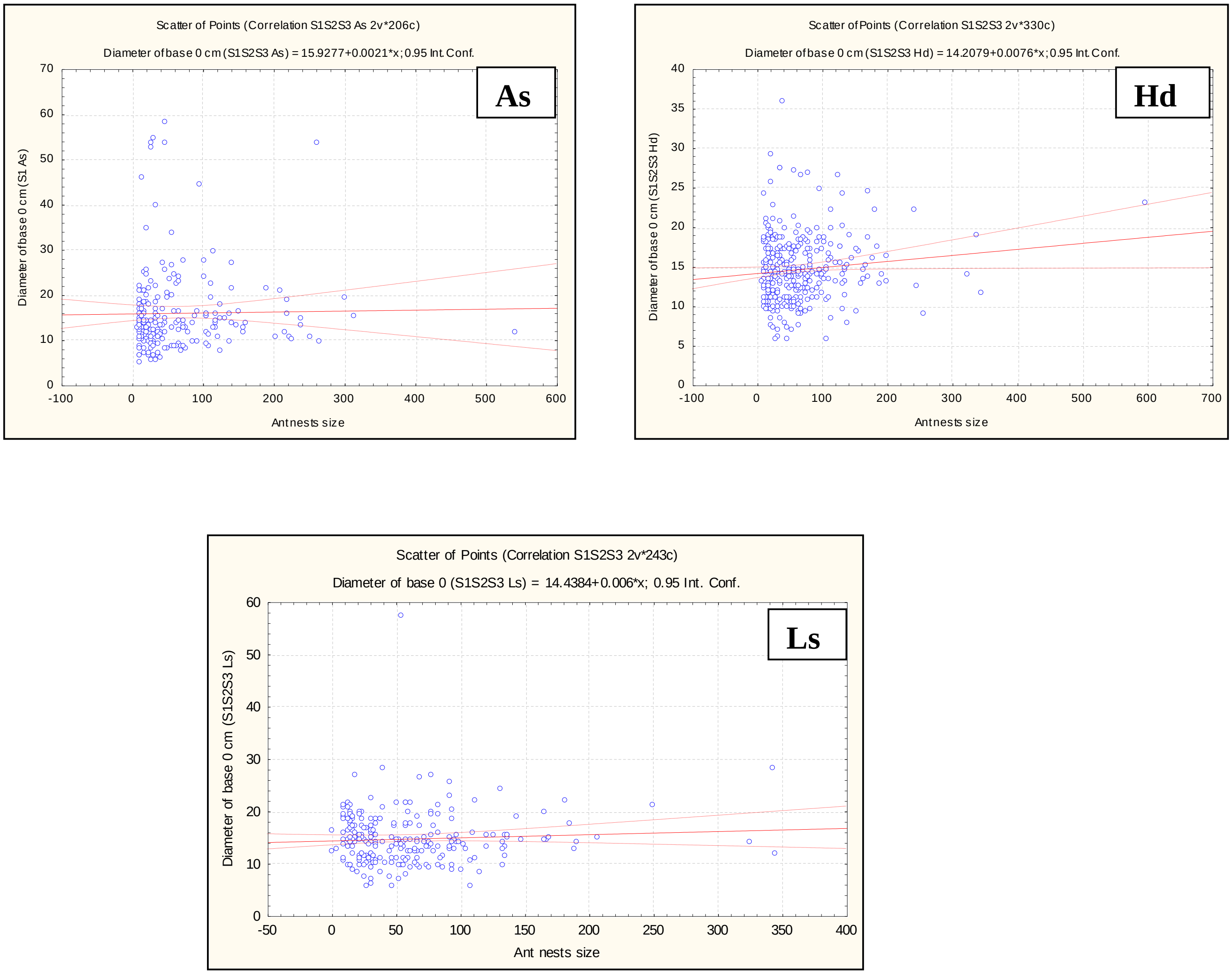

Figure 8: Relationships between the size of grass tufts and ant nest size in Lamto savanna

The absence of relationship could be due to the fact of perennial character of grass species. Ant occupied the habitat which confers there, best microclimatic conditions. The ant nest control and work his environment follow their needs. So they could occupy their habitats according to his availability. During the field work, it had been observed that a large colony such as *Camponotus acvapinensis* can occupy a small grass tuft and digging fine galleries with many chambers.
This ant species can extend his nest about 15 m² in the savanna (Lévieux , 1971). Thus, the young societies were composed only to some individuals and the olds populated by many workers.

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According to Lévieux, the total surface of *Camponotus acvapinensis* varied from 15 to 45 %, follow the society old and his importance. Besides, in the rich areas such as the ferruginous sandy of plateaux, a total number of 1200 nests per hectare of this ant species can be assess.

1.3. Association rate of the grass tufts with ant nest

A total of 1983 grass tufts have been sampled. 941 (47.45 % of association rate) tufts have been recorded with ant nest (Table 3).*Hyparrhenia diplandra* recorded the highest value (54.21 %) followed by *Andropogon schirensis* (49.43 %) and *Loudetia simplex* (38.49 %).

At the local scale, study site 1 recorded the best results of the association rate and study site 2 recorded the lowest values. *Hyparrhenia diplandra* gave the best response of association rate of Lamto savanna grass tufts with ant nest. A study of the competition between the development of Hyparrhenia and Loudetia genus has been made by Yves Monnier (eburnean studies, 1968). In an experience during four months he showed an insignificant covering of Loudetia and contrary a good development of Hyparrhenia. His results concluded that Hyparrhenia constitute a remarkable screem against the direct insolation and the flagellation rate drop. The vivacity aspect of Hyparrhenia development could be the origin of his appreciation by ants.

Table 3: Association rate of grass tufts with ant in the andropogonae savanna.

TAN= Tufts with Ant Nest;   TWN = Tufts Without ant Nest

Tufts parameters	Grasses species			
	As	**Hd**	**Ls**	**Total**
Tufts number	617	701	665	1983
TAN	305	380	256	941
% TAN	49.43	54.21	38.49	47.45
TWN	312	321	409	1042
% TWN	50.57	45.79	61.50	52.55

2-The benefit results to the relationships between grass tufts and ants (for grass tufts and for ants).

2.1. Effect of ant on the growth (height and diameter) of perennial grass tufts

2.1.1. Height growth of tufts according to grasses species

During the seasonal cycle, a reconstitution of savanna landscape, the herbaceous carpet increased in size and also in density**.** According to the measure of grasses species height, (*Andropogon schirensis, Hyparrhenia diplandra* and *Loudetia simplex*), a same evolution was observed follow the curves with and those without ant nests (figure 9). The pair comparison of the height of *A. schirensis* tufts (t = 2.87; p = 0.01) and *H. diplandra* tufts (t = 2.82; p = 0.01) showed a significant difference between the tufts associate with and those without ant nest during the sampling period (from February to November- December). The first stage of perennial grasses species evolution is a vegetative growth. It started in February (after the mi-seasonal fire and the end of dry season). In March the rapid increasing of grass tufts could be due to the reserve stopping in the roots after the fire and permit the growth of the vegetation.

A slow decreasing observed from April to May. That could be due to the rapid depletion of the roots resources that was allowed the new growth of epigenous organs. April-May-June, fall of the first rainy, moderate increasing of the biomass until July; that traduces the absorbant radicel formation. August, a weak decline of biomass was observed, decreasing of growth rate which could be due to the small dry season. That could induce the radicel dead (Cesar, 1971, Fournier, 1991).

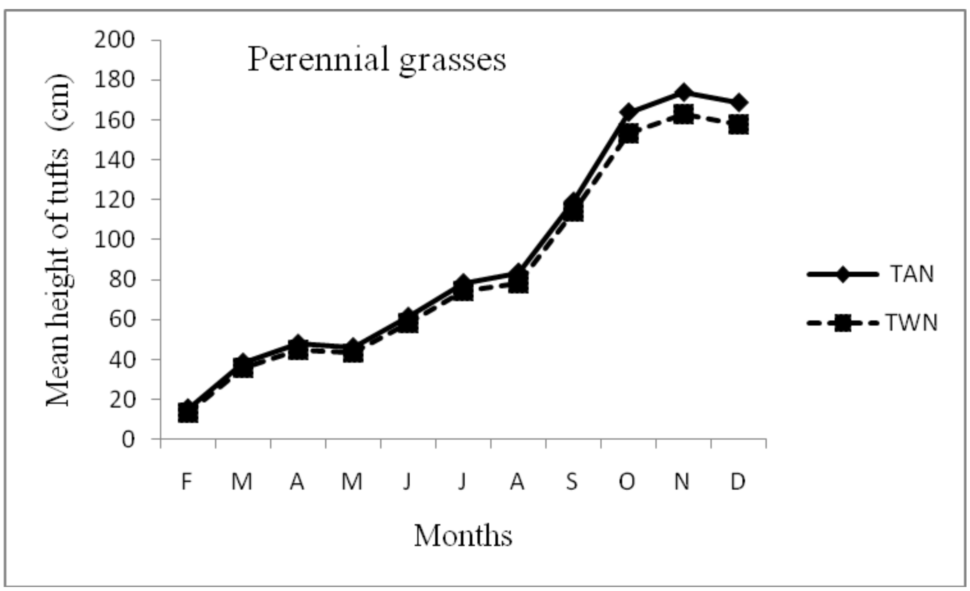

Figure 9: Mean height of perennial grasses (cm) per recording date (months) in Lamto savanna. TAN: Tufts with Ant Nest; TWN: Tufts Without ant Nest

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The growth curves of the tufts with ant nest increased rapidly from September to November than those without ant nest (figure 10). That is going to seed stage. It is well distinct on *Andropogon schirensis* (figure 10.a) and *Loudetia simplex* (figure 10.c) curves. The flowering stage of perennial grasses species showed the end of the axis extension. From October to November, the majority of perennial grasses species take the flowers and inter in fructification stage. From November to December, drying of epigenous biomass and his dead were observed. At this period, you need to attribute the increasing of root biomass to an accumulation of reserve substances (Cesar, 1971). Only *L. simplex* (t = 0.04; p = 0.96) does not showed significant differences between the two types of tufts (with and without ant nest). That was observed on the evolution curves. The tufts increased with a same allure.

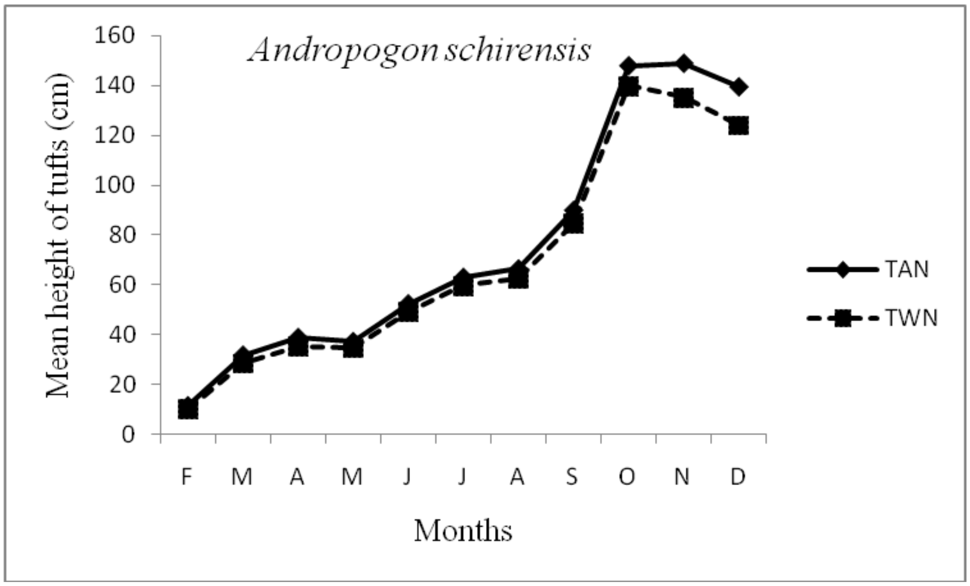

Figure 10.a: Mean height of *Andropogon schirensis* (cm) per recording date (months)

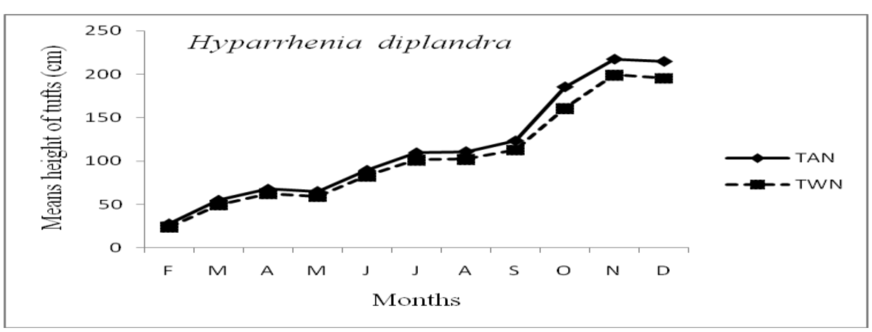

Figure 10.b: Mean height of *Hyparrhenia diplandra* (cm) per recording date (months)

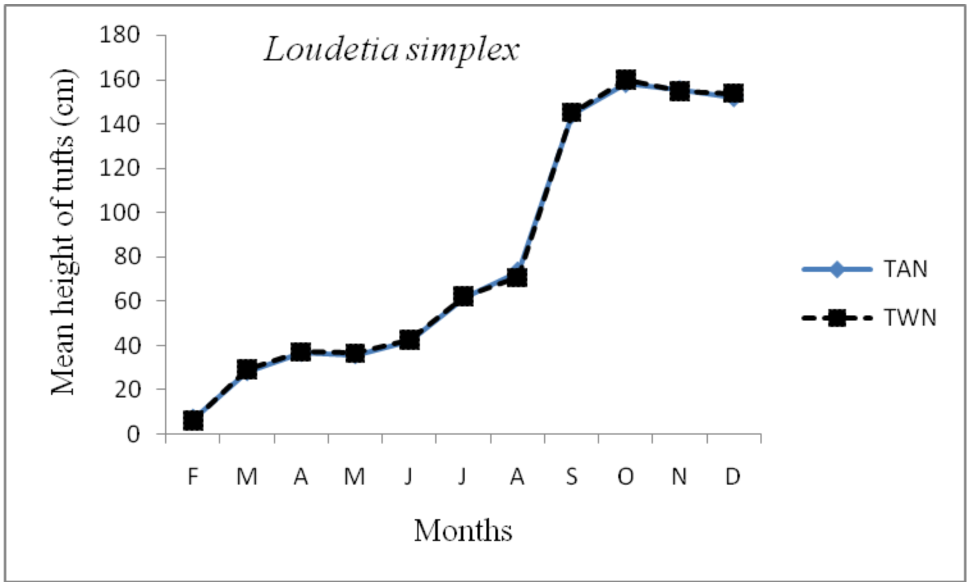

Figure 10.c: Mean height of *Loudetia simplex* (cm) per recording date (months)

2.1.2. Diameter growth of perennial grass tufts in Lamto savanna

The measure of grasses species diameter at 0 cm of ground level in Lamto savanna (Figure 11), the tufts associated with ant nest evolved between 14 cm and 15.5 cm at continue way. Whereas, those without ant nest evolved between 10.5 cm and 12.5 cm during the seasonal cycle (t = 22.03 and P = 0.00).According to the grasses species, the growth of*Andropogon schirensis* associated with ant nest was more important (between 11 cm and 12.5 cm) than tufts without ant nest (evolution interval: 8.5 cm and 10 cm) (t = 16.4; P = 0.00) (Figure 12.1a).

At 10 cm of the soil, the curve of tufts associated with ant nest, evolve above that without them. The t of Student value and the p associated: t = 2.22; P = 0.04 showed a significant difference between the grass tufts during the seasonal cycle. According to *Hyparrhenia diplandra*, for diameter of base 0 cm (figure 12.1b), the growth of tufts associated with ant nest varied enter 14 cm and 16 cm. Those without ant nest varied inter 10 cm and 11.5 cm. The test t of Student shown a significant difference (t= 36.29; p= 0.00) between the tufts associated with ant nest and those without them. At 10 cm of ground, the same evolution during seasonal cycle was observed with *Andropogon shirensis* (figure 12.2a). The test t of Student shown a significant difference between the two types of tufts (t= 2.89; p = 0.01).

Diameter at 0 cm of ground level, the curves (Figure 12 1a) varied between 15 cm-17.5 cm for the ant associated with ant nest and 13.5 cm- 16 cm for those without them. It existed a significant different between the two types of tufts (t= 8.28; p = 0.00).

At 10 cm of ground level, *Loudetia simplex* (figure 12.1c) growth rapidly from February to June with a decreasing in April. The t of Student value and the p associated: t=1.94; p= 0.07 not showed a significant difference between the grass tufts during the seasonal cycle. The growth rate curves showed the same evolution stage for the three grass species (*Andropogon schirensis*, *Hyparrhenia diplandra* and *Loudetia simplex*).

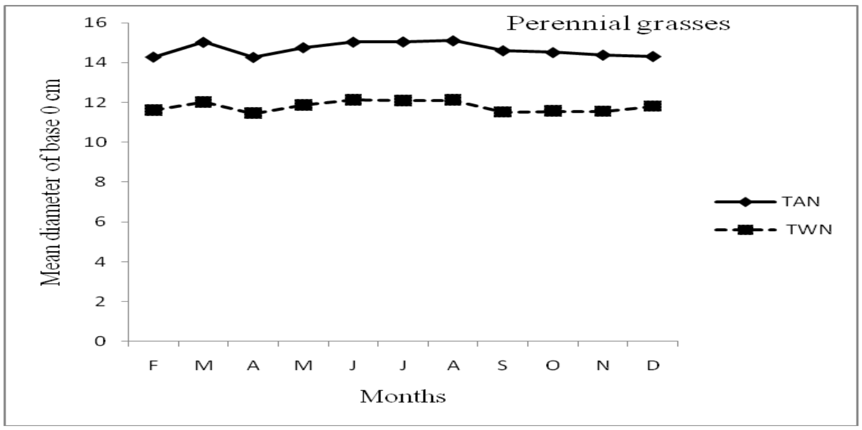

Figure 11.a: Mean diameter growth (0cm at ground level) of perennial grass tufts per recording period

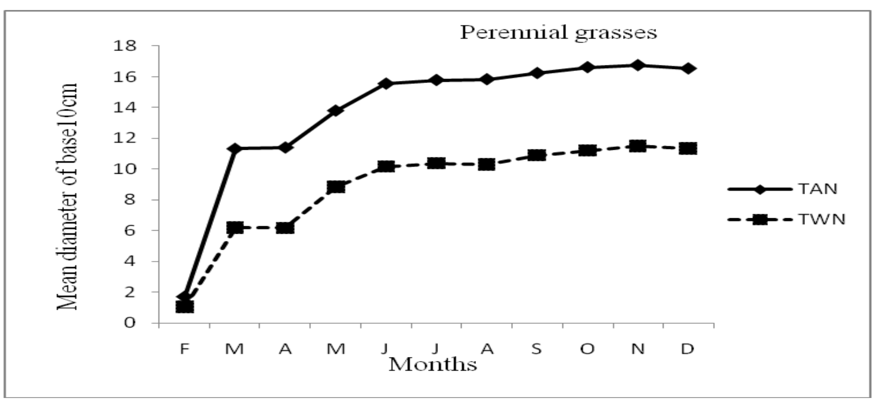

Figure 11.b: Mean diameter growth (10cm at ground level) of perennial grass tufts per recording period

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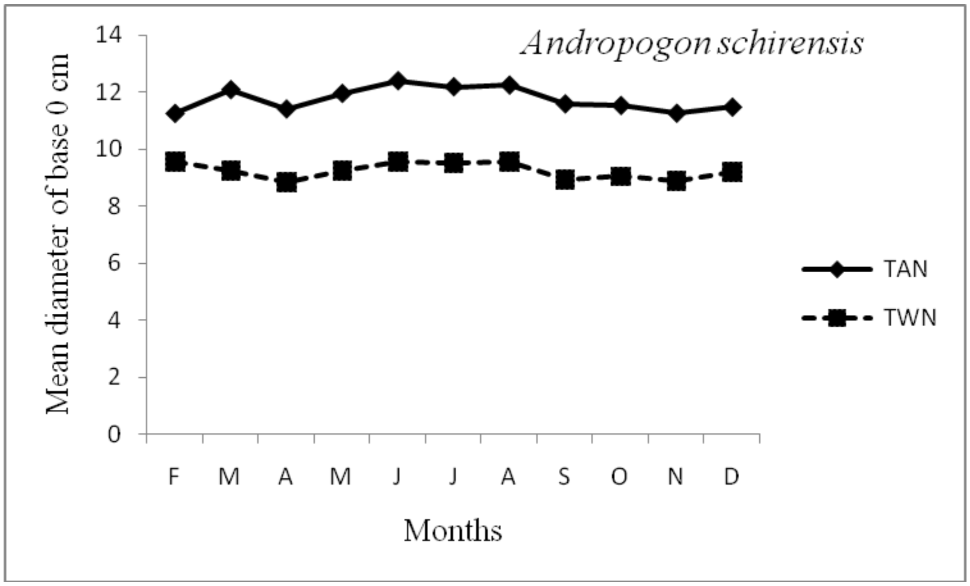

Figure 12.1a: Mean diameter growth (0cm at ground level) of *Andropogon schirensis* per recording period

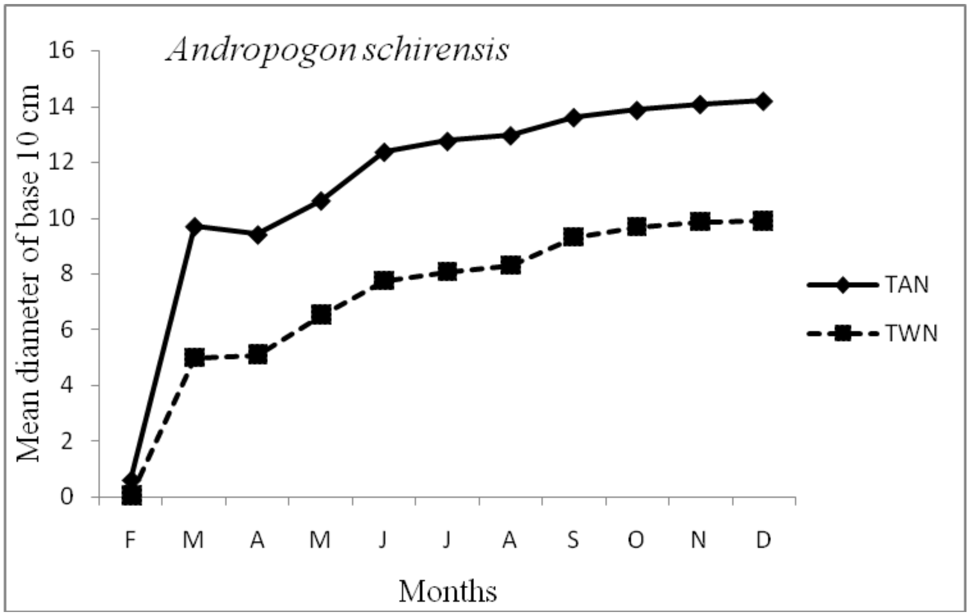

Figure 12.2a: Mean diameter growth (10cm at ground level) of *Andropogon schirensis* per recording period

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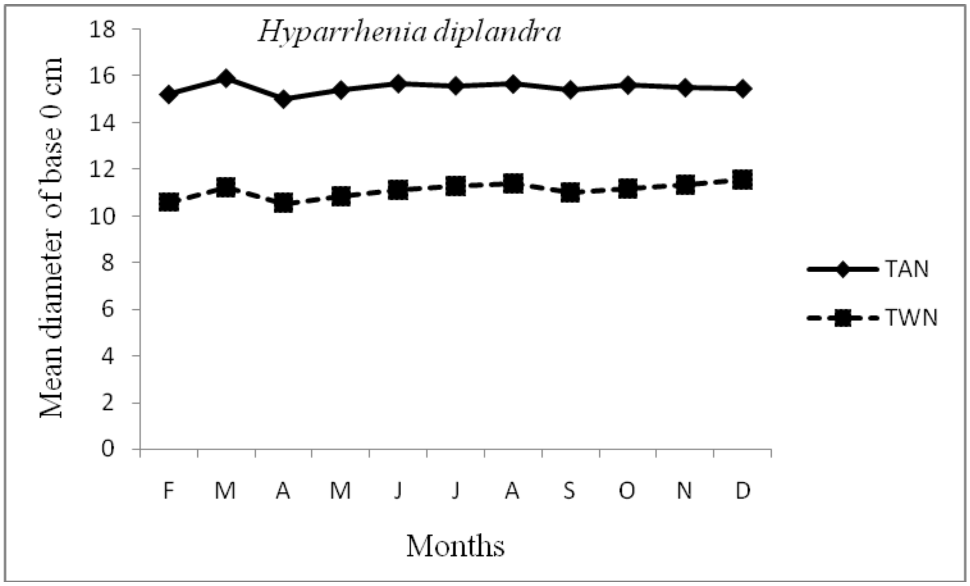

Figure 12.1b: Mean diameter growth (0cm at ground level) of *Hyparrhenia diplandra* and per recording period

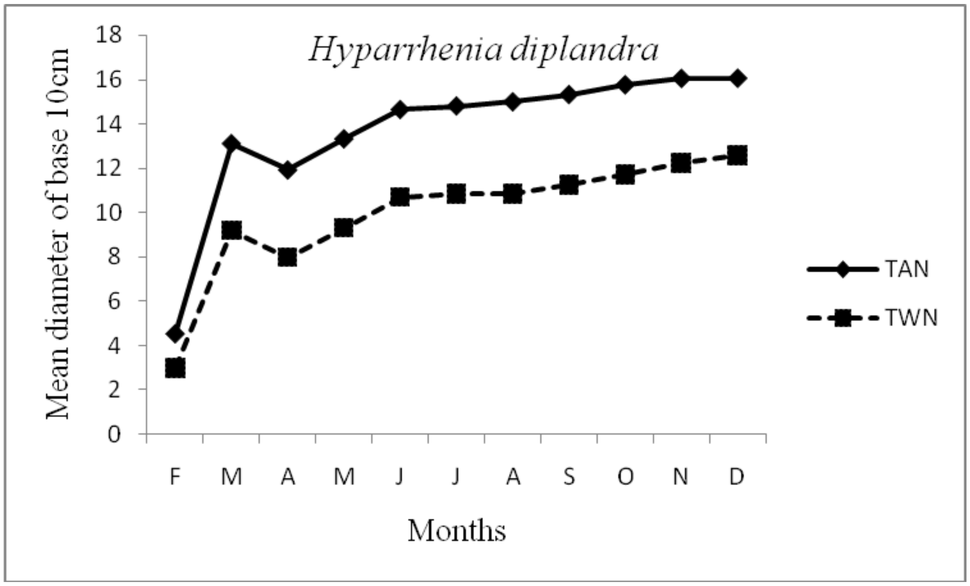

Figure 12.2b: Mean diameter growth (10 cm at ground level) of *Hyparrhenia diplandra* per recording period

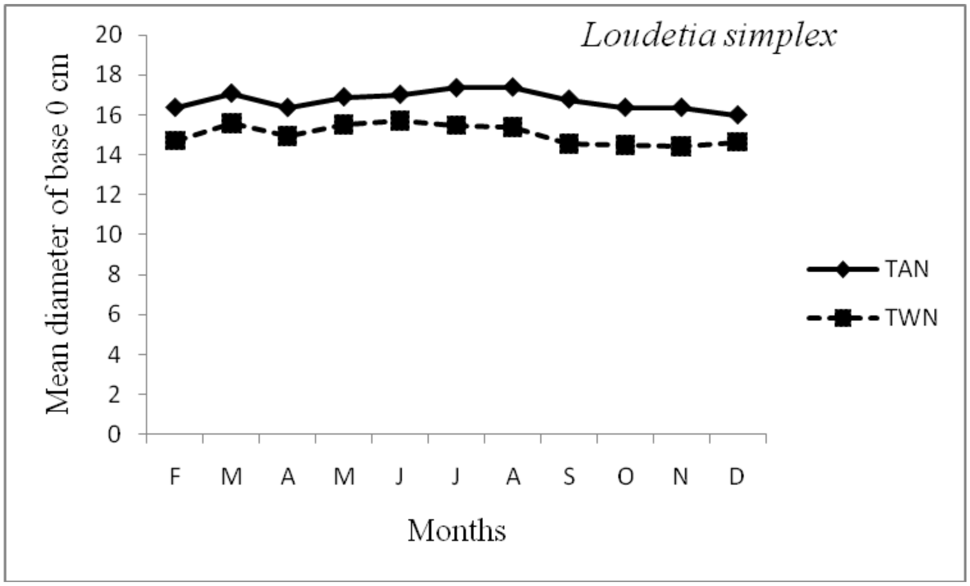

Figure 12.1c: Mean diameter growth (0 cm at ground level) of *Loudetia simplex* per recording period

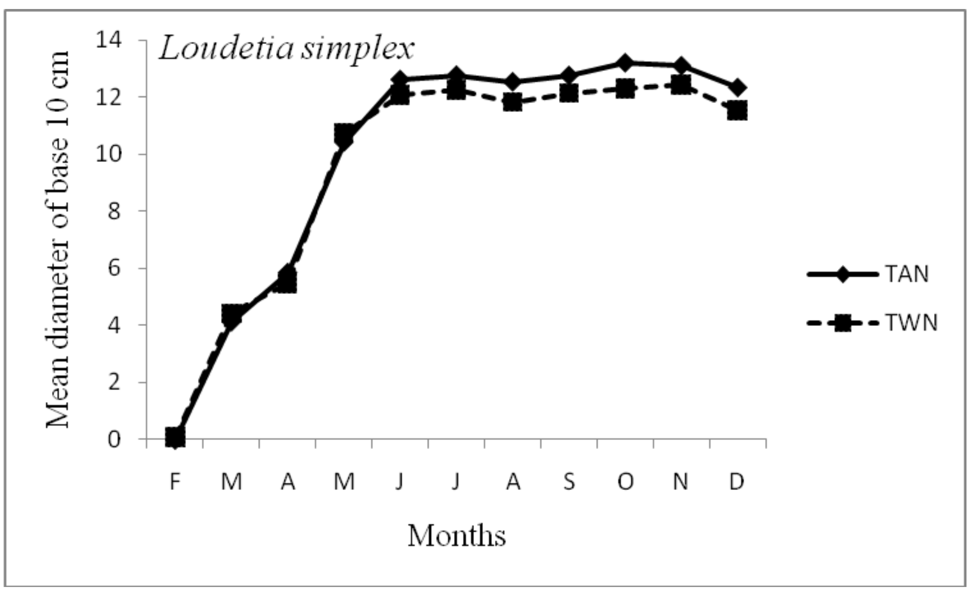

Figure 12.2c: Mean diameter growth (10cm at ground level) of *Loudetia simplex* per recording period

According to the two types of curves and the two levels of the ground (0 cm; 10 cm), the grass tufts associated with ant nest increased rapidly in diameter than those without ant nest. The different increasing and decreasing observed along the seasonal cycle were due to the effect of climatic conditions which the vegetation was submitted. The rapid growth rate observed for the grass tufts with ant nest could be due to the resources availability under these plants. During the sampling period, the rests of cocoons and many vegetal fragments were observed around some tufts associated with *Camponotus acvapinensis* ant species. Ants, through their nutritional diversity, accumulated many resources in their nest. Besides, through their nesting habits, they are agents of bioturbation, mixing soil horizons and creating avenues for water and gas exchange through the tunnels and chambers that make up their nest architecture. Their movement of materials from above and below ground concentrates nutrients and minerals in the nest and associated soil. Decaens *et al*., (2002) found that especially ants of the species Trachymyrmex sp. and Camponotus sp. contributed significantly to aggregates brought to the soil surface in Columbia, even though their nests occupied less than 1% of total soil area. These activities result in soil production and altering soil chemical, physical, and biotic profiles. Besides, at the digging period, many chambers of Camponotus eggs, cocoons and nymph were observed beneath the tufts. Lévieux (1971) showed that the nests of this ant species were constituted by many chambers, that can shelter 4 000 to 6 000 individuals. Then this ant species dig in the soil, fines galleries, which allow his moving. His used also the natural penetration voices (dead roots). The all action of *Camponotus acvapinensis* allows him to offer to grass tufts best life conditions. Hence their hardy growth.

2.2. Effect of ants on seeds productivity and biomass of perennial grass tufts

The seeds quantity collected on grass tufts (with and those without ant nest) in the three study sites, deferred one by the other. An analysis of variance showed a significant different between the weight of seeds for a same grass species within habitats. *Andropogon schirensis* (F= 45.08; p= 0.00), *Hyparrhenia diplandra* (F= 6.37; p= 0.00) and *Loudetia simplex* (F= 22.3; p= 0.00). Study site 1 recorded the height test values of the weight of grass tufts seeds associated with ant nest. According to the grass species, *Hyparrhenia diplandra* recorded the height values of the weight of seeds (Table 4). The t test was used to assess the conformity test of the seeds weight of grass tufts which associated and without ant nest within the study sites. It showed a significant differences between the seed of the two types of grass tufts (with and without ant nest) only for *Hyparrhenia diplandra* (t = 6.75; p associated value = 0.00). There are no differences for *Andropogon schirensis* (t =1.69; p = 0.09); and *Loudetia simplex* (t =0.85; p = 0.40). The biomass which quantified at the end of seasonal cycle recorded equally the same tendency of the productivity. Study site 1 recorded the height values of the weight and *Hyparrhenia diplandra* gave the best values of the tufts associated with ant nest(table 5).The Student t conformity test showed the significant different between the grass tufts associated with and without ant nest. *Andropogon schirensis* (As = t = 2.86; p associated value = 0.01 < 0.05); *Hyparrhenia diplandra* (Student t value =5.59; p associated value = 0.00 < 0.05); *Loudetia simplex* (Student t value =0.81; p associated value = 0.42> 0.05).

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At savanna stratum level, there are significant difference between the grass tufts associated with and those without ant nest ($t = 5.62$; $p = 0.00 < 0.05$). A summary of the amount of harvest make in Lamto herbaceous stratum and that, according to the grass species associated with and without ant nest (table 6).

Table 4: Seeds weight (g/m²) according to the study sites

TAN: Tufts with Ant Nest; TWN: Tufts without ant nest

			Seeds production (g/m²) per grasses species			
	A. schirensis		*H. diplandra*		*L. simplex*	
	TAN	**TWN**	**TAN**	**TWN**	**TAN**	**TWN**
Study site 1	0.06	0.05	0.13	0.05	0.06	0.06
Study site 2	0.02	0.01	0.08	0.03	0.03	0.03
Study site 3	0.02	0.01	0.08	0.04	0.04	0.04

Table 5: Biomass dry weight according to the study site

	Biomass production (g/m²) per grasses species					
	Andropogon schirensis		*Hyparrhenia diplandra*		*Loudetia simplex*	
	TAN	**TWN**	**TAN**	**TWN**	**TAN**	**TWN**
Study site 1	1.00	0.93	3.16	1.38	0.75	0.78
Study site 2	0.51	0.24	0.91	0.58	0.41	0.30
Study site 3	0.54	0.34	1.29	1.15	0.45	0.42

Table 6: Summary of seeds and biomass weight collected according to the grasses species

	Andropogon schirensis		*Hyparrhenia diplandra*		*Loudetia simplex*		Savanna stratum	
	TAN	**TWN**	**TAN**	**TWN**	**TAN**	**TWN**	**TAN**	**TWN**
Biomass (g/m²)	0.68	0.50	1.79	1.04	0.54	0.50	1.00	0.68
% Biomass	57.59	42.41	63.31	36.69	51.76	48.24	59.6	40.4
Productivity (g/m²)	0.03	0.023	0.08	0.03	0.07	0.05	0.07	0.04
% Productivity	55.29	44.71	70.89	29.11	55.28	44.72	65.28	34.72

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The best data of productivity and biomass recorded on study site 1 could be due: firstly by soil structure and the vegetation composition, secondly by the effect of ant activities on the soil. Ant activities could be explained by the process of bioturbation, which involve the mixing and accumulation of soils from different sources and horizons (Nkem *et al.*, 2000; Frouz *et al.*, 2008). That mechanism can substantially change the environment for plant growth. The dominant ant sub family recorded in study site 1, are composed of large species such as *Camponotus acvapimensis*; *Mesoponera ambigua*; *Mesoponera caffraria*. These large ant species, throught the belowgrown activity due to their numerical dominant, created many galleries. That allowed them to rummage in the soil. That could create very well microclimatic conditions for plants roots. However, the plant development is depending of the roots health. *Hyparrhenia diplandra* has a very dense rooting, which concentrated in the 15 or 20 first centimeters, but can extend "antennal" until 100 cm in the soil (Monnier, 1968). That could explain the best results of the association of this grass with ants. The results support those of Edoukou (2015), where *Hyparrhenia diplandra* produced a great biomass amount.

CONCLUSION

This study allowed showing that Lamto savanna in the whole, is colonized by *Camponotus acvapimensis*. Specifically; it is dominated by ponerinae sub family in study site 1, by myrmicinae in study site 2 and by formicinae sub family in study site 3. The species richness was high beneath *Andropogon schirensis* grass species in study site 2. There are no correlations between the ant nest and grass tufts size. *Hyparrhenia diplandra* has the highest association rate of perennial grasses in Lamto savanna. The tufts associated with ants, recorded the best growth in higher and diameter than those without ant nest. They also recorded the best productivity (seeds) and best quantity of biomass product. This study allowed verifying that the growth and productivity (seeds and biomass quantity) of Lamto savanna perennial grasses depend not only of savannas' heterogeneity (see study site 1, 2 and 3) but above all by their association with ant nest. That allowed concluding that the association with ants nest is benefit for the growth and the productivity of Lamto perennial grasses.

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