Spatial distribution of the pit builders antlion's larvae (Neuroptera: Myrmeleontidae) in the septentrional regions of Cameroon (Central Africa)

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Abstract- Antlions (Insecta: Neuroptera) are xerophilous insects adapt to arid conditions that perform some resilent behaviours to overcome some noxious effects of the global warming. This paper focuses on the determination of the diversity of the antlion in the Soudano-guinean and Soudano-sahelian area of Cameroon analyzes the distribution of antlion larvae in these regions. After 3 years of survey, 3 antlions species dominate in the North of Cameroon especially in the dry season. Pits distribution under four tropical trees species is irregular, there is higher density of pits close to the trunck at the shade. This decreases from the shade to open space. At the regional level, the antlion's pit site is influenced by the chemical composition of the soil: higher acidity, salinity, calcium and magnesium content are suppressive to larval development in one hand. In the other hand, potassium, sulfates and chloride amount are favorable to their development. *Myrmeleon quinquemaculatus* (Hagen,1853), is endemic to Guinean higher savannah of the Adamaoua region; *Myrmeleon obscurus* (Rambur, 1842) is a species widely spread in the 3 sampled regions, and *Hagenomya tristicis* (Walker, 1853) is restricted to the Soudano-sahelian zone.

Index Terms- Antlion, soil, biogeography, biodiversity, Cameroun.

I. Introduction

Adult Antlions (Insecta: Neuroptera) are characterized by their large membranous wings with a dense network of veins. They have long, slender bodies and delicate outstretched wings (ranging between 30 – 170 mm), resemble damselflies (Mansell, 1999) [1]. They are nocturnal and feeble flyers (Farji-Brenner, 2003) [2]. Antlion larvae are carnivorous and eat small terrestrial insects. Adults are generally pollinivores or predators of small insects (Cain, 1987; Stelzl and Gepp, 1990) [3; 4]. Antlion larva is sit-and-wait predators (Séméria and Berland, 1987, Badano and Pantaleoni, 2014) [5; 6]. It constructs its pit using its mandibles as shovels to flick the excavated sand (Tauber *et al.*, 2003; Mansell, 1999) [7; 1]. For overall construction, finer grain soils are preferred by antlions because these more readily dislodge prey (Farji-Brener, 2003) [2]. Pits are typically built in areas that are sheltered from rain and other elements to minimize disturbance (Youthed and Moran, 1969; Gotelli, 1993) [8; 9]. They detect approaching prey to the funnel using mechanoreceptor setae located on their bodies (Devetak, 1985) [10]. The funnels are a trapping system in fine soil causing prey to the background in the manner of quicksand. In this case, the agitations of the trapped prey contribute more to swallow it than to facilitate his escape.

The distribution of living organisms is strongly influenced by biotic and abiotic factors. Climate is the main factor responsible for the distribution of living organisms in the biosphere. Northern Cameroon is characterized by a dry climate with a long dry season and low rainfall (Suchel, 1987) [11]. This work is focused on the abiotic conditions in this region that are favorable to the installation of ant lions to investigate the influence of the chemical composition of soils over large areas and more locally the impact of the shadow of some trees to understand the spatial distribution of ant lion larvae in the dry season.

II. Material and methods

2.1. Presentation of the study area

In Africa, Cameroon is located at the bottom of the Gulf of Guinea and is in pivotal position between West and Central Africa. The country runs from south to north between 1°40 to 13 ° north of latitude to about 1250 km. From West to East, it stretches between 8°30 to 16°10 East of longitude, about 860 km. The study area started from the Adamawa plateau and plains and Mandara Mountains, this area is between 6° to 13° North of latitude and between 11° to 15° East longitude. In northern Cameroon, the climate is dominated by tropical Sahelian climate and divided in two seasons. Adamawa covers the whole of the Adamaoua Plateau; it extends in the north by a dry tropical climate. This climate is characterized by at least seven months of drought; the annual rainfall varies from 1,600 to 500 mm (Table 1). The period of plant growth (PPG) is influenced by the rains period. In high Guinea savannah, it rains up to 250 days, while in the drier Sahelian zones, it hardly reaches 100 days. The annual average temperature is 28°C±7.7°C (Djoufack Manetsa *et al.*, 2011) [12]. The Sudano-Sahelian zone of West Cameroon is characterized by the thorny steppes and grasslands periodically flooded (Lienou *et al.*, 2003) [13]. These formations have degraded due to intensive grazing bushfires (Braband, 1991) [14]. High Guinean savannah is a vast plateau essentially pastoral use, which ensures the transition between forest regions of southern and northern Sahelian formations.

Table 1. Presentation of the ecologiccal zones sampled in the northern Cameroon

Agro-ecological Zones	*Regions*	*Divisions*	*Localities sampled*
AREA II : *Guinean higher savannah* *- 240 to 180 days (PGP)* *- 1600 to 1200mm de pluies/an*	***Adamawa (63 701 km^2)***	*Djérem*	*Tibati*
		Faro et Déo	*Tignère*
		Mayo Banyo	*Banyo*
		Mbéré	*Meiganga*
		Vina	*Ngaoundéré*
AREA I : *Soudano-sahelian* *- 180 to 110 days (PGP)* *- 1200 to 500mm de pluies/an*	***Far North (34 263 km^2)***	*Diamaré*	*Maroua*
		Logone & Chari	*Kousseri*
		Mayo Danay	*Yagoua*
		Mayo Kani	*Kaélé*
		Mayo Sava	*Mora*
		Mayo Tsanaga	*Mokolo*
	North (68 090 km^2)	*Bénoué*	*Garoua*
		Faro	*Poli*
		Mayo Louti	*Guider*
		Mayo Rey	*Tcholiré*

** Surface of Cameroon 475 650 km2, which 466 050 km2 is the continental surface*
PGP: Plant Growth Period

The soils of the study area are red, deeper, loose, clayey, porous and favourable to the development of the forest. These soils are poor, acid and vulnerable to erosion (Onguene, 1993) [15].

2.2. Collection and rearing the larvae in the laboratory

Antlion larvae have been collected in 15 divisions of the northern regions, each year around March and April. This collection was made during three years 2011, 2012 and 2013. These larvae were extracted from their traps well with a spatula and were introduced individually in plastic cups prefilled 2/3 of fine and dry soil. Bringing back to laboratory, at first, the larvae have been reared individually in plastic cups 25cl capacity filled with fine soil sieved with a 500 micron sieve mesh, were followed until the construction of wells trap. In a second time, they were fed by termites at the rate of two preys per day, one in the morning and the other in the afternoon. The fact is noted primarily to the development of the funnel. If the funnel is not maintained, it means that the larva is feeding off and is preparing to molt, or to form the silk cocoon which marks the end of the larval life. When in three days the funnel is not maintained, the contents of the cup is made and either a more advanced stage larvae and exuviate output is present, or a silk cocoon is formed. The observation date of the change is noted. The larva of the more advanced stage is given observation in the same cup and followed until the formation of silk cocoon. The cocoons are observed in isolation until the emergence of the adult. Adults sample are stored dry, prepared and sent for identification to Dr. André Prost. They are identified at the Museum of Natural History in Paris. Thereafter, the confirmation of the identification the sample is carried out at the Royal Museum for Central Africa in Tervuren, Belgium.

2.3. Analysis of the pit distribution of *Myrmeleon obscurus* under four trees

Four species of trees with dense foliage and present in the study area were targeted in dry season: *Azadirachta indica* (Meliacae); *Khaya senegalensis* (Meliacée); *Manguifera indica* (Anacardiacae); *Acacia seyal* (Mimosaceae). *A. indica* is an evergreen tree, native to India and introduced as an ornamental plant, for its shade and firewood. It is widespread in tropical and subtropical regions. *K. senegalensis,* is a typical savannah tree, it is also planted in the streets on the roadside. It is a large tree that provides a hard red wood used in woodworking and the manufacture of charcoal. *M. indica* is a big tree that can reach 30m high. It is grown in almost all tropical countries. Its foliage is dense and rounded evergreen. Finally, *A. seyal* is a tree crown least lowered. Trees under which more than 25 funnels were present were considered. Under each tree concentric circles from the trunk were drawn at the following distances from the trunk: 100 cm; 200 cm and 300 cm. The number of funnels in defined intervals was established. Five replicates per plant species were made. At this time of the year, *M. indica* and *A. seyal* are dormant while *A. indica* and *K. senegalensis* bear flowers or fruit.

2.4. Analysis of larvae's survival of antlion in various soils

Larvae collected in the 15 divisions (Table 1) were reared on the soil of the campus of the University of Ngaoundere in one hand, and on the ground taken from their place of gathering in the other. For each case, 30 larvae were collected and monitored by location. Success of larval development is evaluated. It involves the formation of a silk cocoon at the end of larval life and the emergence of the adult insect. A parallel was drawn between the origin of the breeding ground of the larva and the success rate. The success rate is the ratio obtained by the number of adult time 100. The analysis of the chemical composition of the soil where the larvae were sampled was made. Subsequently, a relationship was made between chemical composition and survival of larvae and finally a spatial difference species is made for the entire study area.

2.5. Chemical characterization of the soils

The soils were collected from harvest sites larvae were analyzed to determine their levels of phosphore, calcium, magnesium, nitrogen, sulfate, potassium and chloride. In addition, pH and salinity were estimated. A preliminary

treatment to remove the organic matter of each floor consisted of calcination. In fact, 15 g of soil was heated in an oven at 500°C for 24 hours. After calcination, there was a mineral extraction in aqueous medium. To do this, 10 g of each calcined soil were introduced in beakers of 400 ml capacity. 100ml of distilled water was added there too. After 30 minutes of homogenization and filtration, the solution was left to stand for 1 hour. The following measurements were made in these solutions:
-The pH and salinity using a pH meter multifunction HANNA;
-Phosphorus content (Rodier, 1978) [16];
-The content of calcium and the magnesium (NF-T 90-003, AFNOR, 1986) [17];
-The total nitrogen content (Kjeldahl method: AFNOR, 1984) [18], and determination of nitrogen (Devani *et al.*, 1989) [19].
-The sulfate content Rodier (1978) [16];
-Potassium content;
-Chloride content.

2.6. Statistical analysis

At the local level, analysis of the distribution of antlions funnels under the trees was observed. The null hypothesis states that the distribution of larvae under the trees is uniform; to test this hypothesis, the Chi^2 test was used to compare the average number of funnel counted by distance interval established. This in order to determine the existence of a gradient distribution funnels function of the intensity of the shade trees. In addition, ANOVA under software Stat Graphics Plus version 5.0 was used to compare the diameters of cocoons and sizes of larvae, adults, wings and durations of cocoons.

At the regional level, the distribution of antlion larvae was made according to the chemical composition of soils. The success rate of breeding antlion larvae was analyzed in relation to the content of soils targeted seven major minerals. Discriminating analysis such as principal component analysis (PCA) and hierarchical ascending classification (HAC) were used with the XLSTAT software.

III. Results and discussions

3.1. Diversity of the antlions species sampled

During the three years of data collection, more than 500 larvae ant lions mainly stages two and three were collected and reared in laboratory. From this rearing, more than 300 adults emerged. These adults belong to two different morphological complexes of pit building antlions that occur during the dry season in the northern regions of Cameroon. Identifications of adults were carried out at the Museum of Natural History in Paris and the Royal Museum for Central Africa in Tervuren. The complex of large individuals with the largest cocoons is represented by *M. quinquemaculatus*. Their cocoons measured 14.33 ± 0.35 mm, twice as large as that of the smaller forms. The second morphotype consists of small adults with smaller cocoons observed two main representatives: *H. tristis* 6.83 ± 0.21 mm in diameter and cocoon *M. obscurus* 7.05 ± 0.16 mm.

It becomes clear that three species of ant lions dominate among the species that build funnels during the dry season in the upper Guinean savannah and Sudano-Sahelian region of Cameroon. In these regions even in the rainy season, the funnels are near houses, the biodiversity of this region is much more important and these three species can not be representative of the entire insect fauna of ant lions in this region.

3.2. Distribution of antlions funnels under the shade of some tropical trees

The antlions are subservient to both flowering trees and fruit-bearing trees. Funnels are sometimes observed at the base of the tree or even far away. Whatever the phenological stage of the tree, the funnels are present during the observation period. The densities of the funnels described in the circles were not the same for the four trees observed. There are two trends in the variation of the density of the funnels according to the distance from the trunk of the tree (Table 2). There is a positive gradient with distance from the trunk: *A. sehyala* and *K. senegalensis*, the further from the trunk, funnels are scares whereas *A. indica M. indica* are denser near the trunk of the tree.

Table 2. Distribution of the funnels of larvae of *Myrmeleon obscurus* in the dry season in four frequent tropical trees in the northern regions of Cameroon.

	Distances (concentric circles) from the trees trunk				
	0 to 1 m	**1 to 2 m**	**2 to 3 m**	**Plus de 3 m**	
Acacia	31,5	30,16	24,48	13,82	99,96
Azadirachta	12,9	21,23	27,87	37,8	79,8
Khaya	18,4	23,15	26,16	32,26	99,97
Manguifera	74,67	19,07	5,09	2,03	100,86
	137,47 (34,31%)	93,61 (23,37 %)	83,6 (20,85 %)	85,91 (21,47%)	*T=400,59*

Under *A. indica* and *M. indica,* funnels are more close to the trunk, almost 75 funnels in the first meter of the trunk for *M. indica*. *K. senegalensis* and under *A. seyal*, near the trunk, funnel density is low about 13 funnels in the first meter for *A. indica*. Further from the trunk, the density increases. At sampling period, *K. senegalensis* was in bloom. Under *A. sehyal* flowers, distribution of pits decreases from the trunk to the periphery.
Chi2 test shows that there is a very high significant difference (X2cal = 60.05> 16.2662, p <0.001) between the distribution rate funnels on different distances.

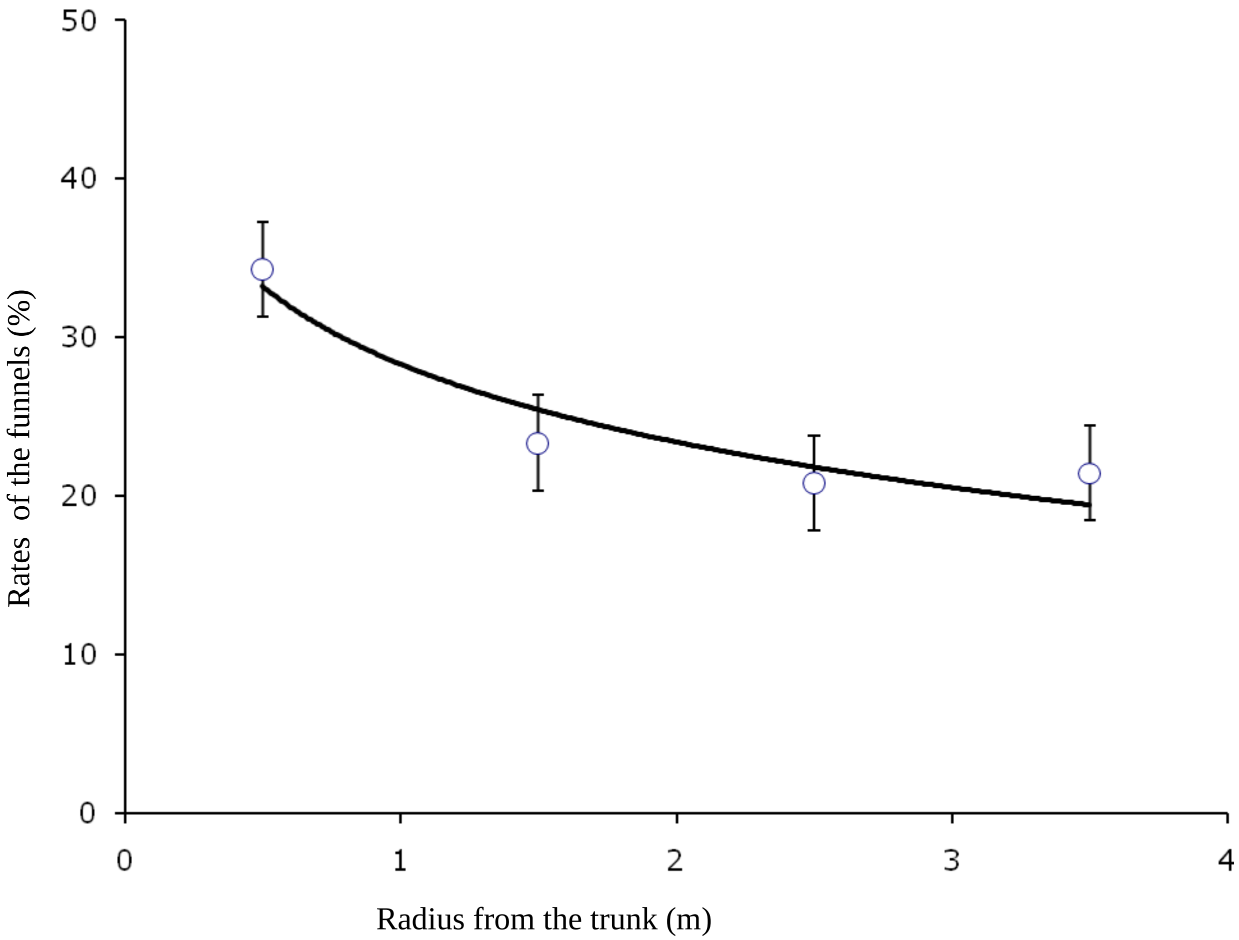

Figure 1. Variation of the density antlion larvae funnels from the trunk on the outskirts of four frequent tropical trees in the northern regions of Cameroon.

A comprehensive analysis of the density of funnels in the shade of trees shows a trend towards a negative gradient with distance from the trunk of the tree (Figure 1). The funnels are built near the trunk. As a result, antlions settle more in the shade of trees in open areas. These hunters also settle where their chance of catching prey is high. Settle near the trunk of a tree is dormant maximizes the chances of prey capture. Indeed, ants and other antlions prey pass by the trunk to look for resources in the foliage. (McClure, 1976; Gatti and Farji-Brener, 2002) [20; 21] . When the tree is flowering or fruiting, funnels would be constructed fart from the trunk. It may maximize to catch prey.

3.3. Larval survival on the original ground and in Ngaoundere's ground.

Larvae might survive efficiently once they are reared on their native soil. When reared in the soil of the university campus, a variation related to soil is observed. Soils have a beneficial or negative effect on the efficient larval survival. The lonely exception comes from Tibati where 100% of larvae survive on a soil which is not their native one (Table 3). Soil of Ngaoundere has nagative effect on the survival of larvae from nine sites. Larvae collected in Tignère (-70.83%), Kaélé (-75%), Guider (-42.85%) are the most sensitive to soil quality in Ngaoundere. Conversely, larvae collected in five localities survived better on the Ngaoundere's ground (Table 3). The soil of the campus has a beneficial effect on the development of larvae collected in Poli (57.14%), Mokolo (+ 66.67%) and Mora (50%).

Table 3. Survival of antlions' larva collected in different regions.

	Survival rates (%)		
Localities	**Soil of sampling area**	**soil of Ngaoundéré**	**Effect of soil**
Banyo	100	70	- 30 %
Meiganga	60	80	+ 25 %
Ngaoundéré*	90	90	0
Tibati	100	100	0
Tignère	60	17,5	- 70,83 %

Garoua	90	75	- 16,7 %
Guider	70	40	- 42,85 %
Poli	30	70	+ 57,14 %
Tcholiré	80	85	+ 5,88 %
Kaélé	60	15	- 75%
Kousséri	50	40	- 20 %
Maroua	80	70	- 12,5 %
Mokolo	10	30	+ 66,67 %
Mora	30	60	+ 50 %
Yagoua	80	55	- 31,25 %
Moyenne	66	59,83	

*** =** control

3.4. Analysis of the chemical composition of soil of sampling localities

The different analysis of the chemical composition of soil show large variability. Major trends analyzes show that the soil of Guider is more acidic with a PH = 5.19. In general, the soils of the study area vary from neutral to weakly basic. Soils with high salinity are those of Mokolo, Kaélé and Guider. Compared to ammonia nitrogen, the soil of Tignère is one that has the highest content and a significant amount of magnesium and calcium. Mineral is present in the soil of Kousséri. The richest soil potassium and phosphorus is the one of Mokolo (Table 4). As to the content of calcium, it is almost zero in the ground of Tignère, high in the soil Kousséri and low in soils of Mokolo and Kaélé.

Table 4. Chemical composition of soil in some division of Cameroon where larvae's of antlions were sampled in 2011, 2012 and 2013.

Localité	PH	salinité	Azote	P	K	Sulfates	Mg	Ca	Cl
Ngaoundéré	7,15de	**8,09d**	0,83ef	2,31c	0,41b	15,19c	0,17ef	0,23d	0,40e
Meiganga	**8,30h**	<u>0a</u>	0,52bc	1,37b	**13,95l**	**61,36k**	0,11c	0,38h	0,53g
Banyo	6,60bc	6,09c	0,65cde	**198,85l**	4,27f	15,33cd	0,34i	0,26e	0,28c
Tignère	7,22de	0,30b	**51,96h**	26,58j	3,62e	17,87fg	<u>0a</u>	<u>0a</u>	<u>0,23ab</u>
Tibati	6,19b	0,06a	<u>0,25a</u>	<u>0a</u>	6,57h	17,35f	0,2ghe	0,22d	0,24b
Maroua	6,52b	0,25b	0,69cde	13,25g	0,69b	16,34e	0,25h	0,30f	0,46f
Mokolo	7,66efg	0,01a	0,44ab	1,19b	<u>0a</u>	18,31g	0,22g	0,13c	0,21a
Kaélé	7,31de	0,00a	0,43ab	5,27f	1,20c	15,17c	0,19f	0,13c	0,25b
Yagoua	7,63ef	0,01a	0,31a	2,77d	2,11d	16,15de	0,02a	0,02b	0,25b
Kousséri	7,29de	0,30b	0,63bcde	17,45h	8,14i	13,65b	0,15d	0,33g	0,37d
Mora	7,09cd	0,41b	0,81def	23,28i	8,52j	23,66i	0,08b	0,74i	**0,77h**
Guider	<u>5,19a</u>	0,06a	0,61bcd	3,99e	9,12k	15,18c	0,17def	0,26e	0,30c
Garoua	8,17gh	0,03a	0,81def	1,14b	0,61b	12,09a	0,16de	**1,46h**	0,24b
Poli	8,16gh	0,05a	4,31g	4,00e	5,26g	39,55j	**0,63j**	0,93j	0,38d
Tcholiré	8,14fgh	0,0a	0,90f	0,13a	0,52b	<u>2,63h</u>	0,62j	<u>0a</u>	0,28c

For each parameter the maximal values are in bold type and the minimal values are underline.

Communities which larva survival was lower can be considered suppressive soils are characterized by high levels of nitrogen, absence of calcium and magnesium. Soil of Ngaoundere has high salinity and the one of Guider is acidic. These criteria explain rates above 40%. Soils that are more favorable for larva development are rich in potassium, magnesium and sulfates. In addition, the soils of the Sudano-Sahelian zone have salinity almost zero compared to Adamawa.
The discriminant analysis of the data obtained (table 4) was used to determine the elements that are strongly correlated with hatchability. Chemical elements that are positively correlated with the outbreak are potassium (0.329), sulfates (0.228) and magnesium (0.297). The element that adversely affects the development of antlions is nitrogen (N = -0.234). The other elements are negligible because their very small values show that they have no significant effect on the survival of antlions.

3.5. Biogeography of antlion's larvae

The map on the distribution of different species of larvae of antlions in the northern regions of Cameroon shows that *M. quinquemaculatus* is confined in the Adamawa. This specie is found only in this agro-ecological zone and is found in Mbéré and vina division. Adults were observed in Djérem and Mayo-Banyo division. *M. quinquemaculatus* could be an indicator of a specific agro-ecological zone. This shows that Adamawa region has almost the same climate with a long rainy season which starts in March and a short dry season which begins in December. The vegetation is a shrub savannah with tall grass (Griffiths, 1985) [22]. Larvae of *H. tristis* are present in the two agro-ecological zones, but in a single division in the Adamawa region. Figure 5 shows that this species is distributed along the western part of the study area. It extends from Faro and Deo division of Mayo-Sava through the Benoue, Mayo-Louti, Mayo-Kani and Mayo-Tsanaga.

According to larvae of *M. obscurus*, it is present in all localities (Figure 2). This species can be considered as generalist as it is adapt to all weather conditions. This confirms the work of Mansell (2002) [23] and Michel and Letourmy (2007) [24] which showed that *M. obscurus* is the most widespread species in Africa.

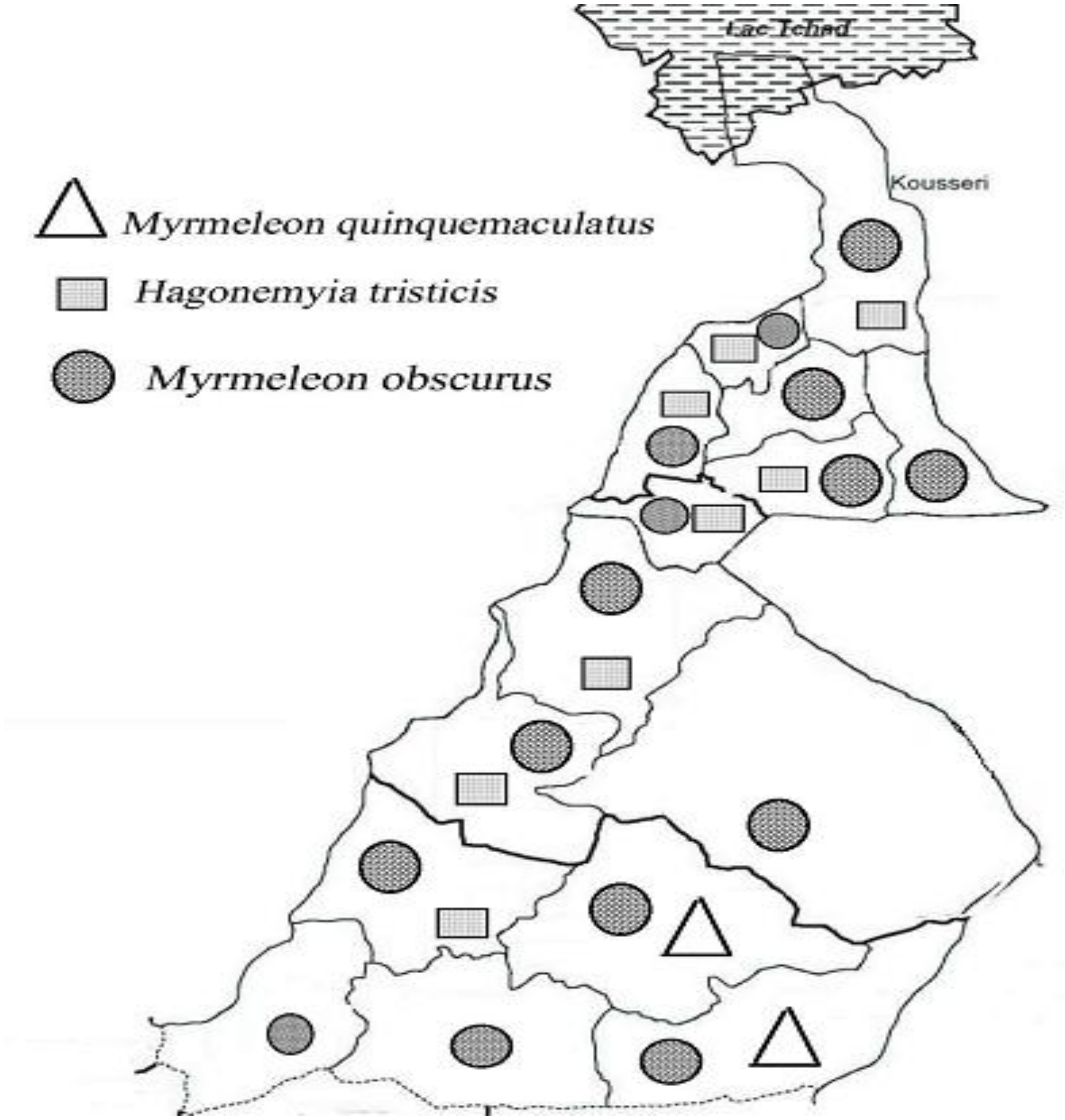

Figure 1. Distribution map of the pits of larvae of *M. quinquemaculatus, M. obscurus* and *H. tristis* collected in the northern regions of Cameroon (2011, 2012 and 2013)

3.6. Correlation between localities and different variables

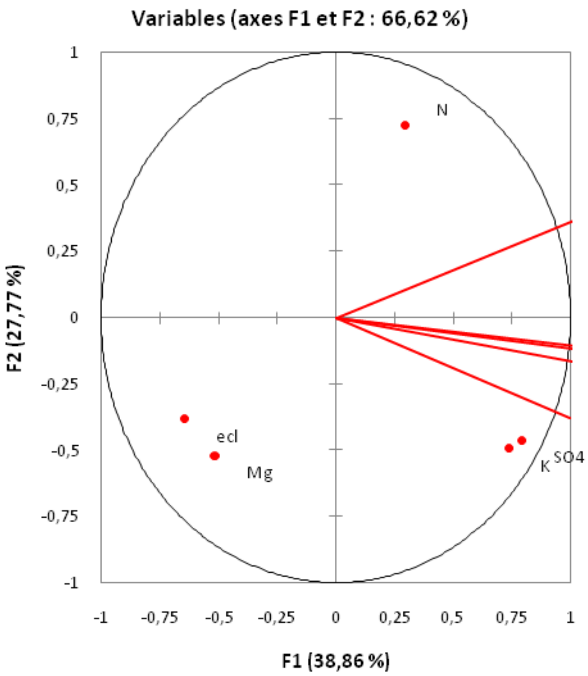

Figure 3. Variables correlation in circle on the axis system F1xF2

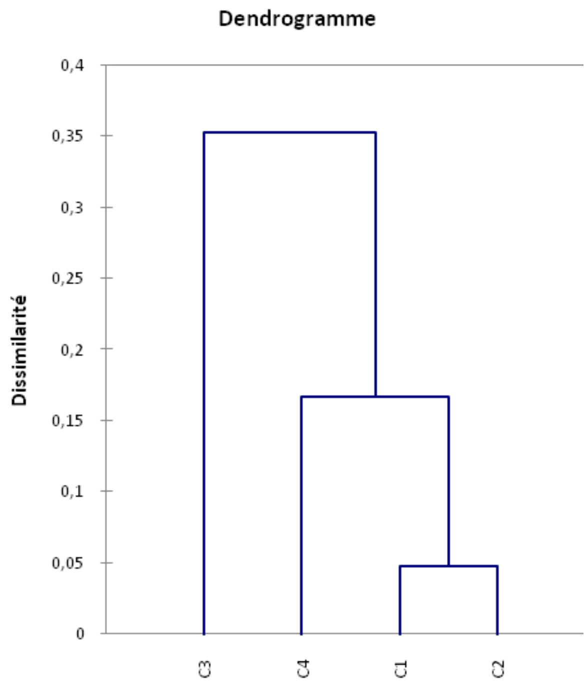

Figure 4. Correlation between differents localities and soils chemical composition.

The result obtained from the ACP shows that four variables used to assess the survival of larvae of antlions can be organized into two main components (F1 and F2) that express approximately 66.62% of the variation. The first principal component (F1) explains 38.86% of the variations and the second principal component (F2) 27.77%. F1 is represented by the potassium (K), sulphate (SO4), magnesium (Mg) and then hatching that F2 is represented by the nitrogen (N). It can be seen, according to this circle, a correlation between the emergence and magnesium variables ($r = 0.32$, $P < 0.05$) on the one hand and between the potassium and the sulfates ($r = 0.67$; $P < 0.05$) on the other. For the principal component F1, the most correlated variables are hatching (64.5%), magnesium (51.7%), sulfate (79.3%) and potassium (73.8%). The reconciliation between the different parameters shows a relationship between survival and soil chemical compounds. As to the component F2, the most correlated variables are: nitrogen (72.6%) and magnesium (51.7%).

The HPC has brought together the various localities in 4 classes (Figure: 4) based on hatchability and chemicals that affect the survival of antlions. Class I consists of Guider, Maroua and Ngaoundere with a hatching rate of 80%; Class II consists of Garoua, Kousséri Meiganga and bound by a survival rate that varies between 60 and 70%. Class III consists of Banyo, Tibati and Tcholiré whose emergence rate of ant lions is 100%; low nitrogen content of soils in these areas warrant the survival of antlions. Furthermore, these soils have high levels of magnesium. This element would be the main responsible for the survival of antlions as it is highly correlated with the outbreak (Figure 3). Class IV is formed by Kaélé, Mora, Poli and Tignère, with a survival rate which varies between 30 and 50%. This low hatching rate is justified by the high content of these soils in nitrogen. This confirms the results obtained with the ACP (Figure 3) where the two axes form a right angle of correlation.

3.7. Commons factors to different localities

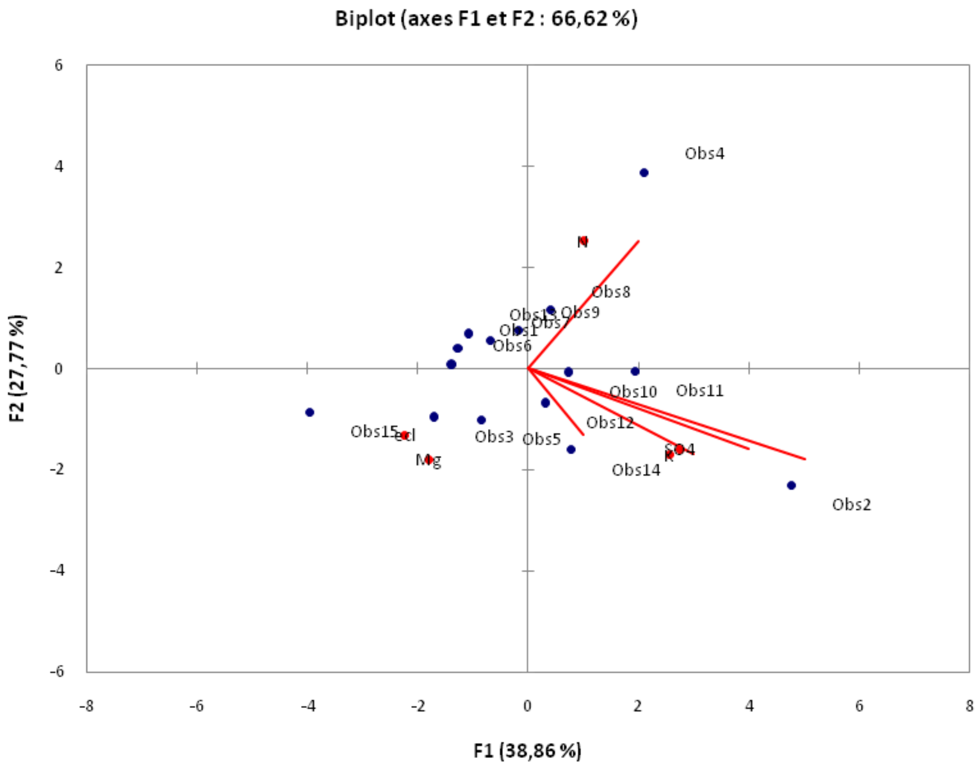

Figure 5. Locality and variables distribution on the axis system F1xF2

Different locations shown in F1xF2 axis system (Figure 5), explain that the component 1 corresponds to those with the same content and potassium sulphate on the one hand and those of the same magnesium content and the rate of survival, while the component 2 corresponds to those having the high content of nitrogen in their floors. We also observe the correlation circles illustrate between the analyzed variables and localities. These results confirm those of CAH (Figure: 4) where different classes are formed, based on hatching rate and the chemical composition of soils of different localities. Soils very close to the center of the marker locations will possess very low concentrations of the different variables.

The climatic reheating entails the ground acidification which is not convenient to the survival of insects. The antlion larvae concentrate their pitfall traps under trees shielded from this phenomenon. The leaves which fall of these trees would reduce this sourness and would serve as food for their preys. This would explain the adaptation of these insects in these dry circles and explained the rough climatic conditions.

IV. Conclusion

At the end of this study, three species of antlions were identified. It is respectively *H. tristicis*, *M. obscurus* and *M. quinquemaculatus*. Their distribution was studied at local and regional level. Under the trees, the gradient distribution funnels respect the tree trunk to the periphery, while under the trees without flowers, this density decreases from the trunk center to the periphery. At the regional level, *H. tristis* is a species present in the two agro-ecological zones; *H. tristicis* is more concentrated in the Sudano-Sahelian zone while *M. quinquemaculatus* is confined to the area of high Guinean savannah. The parameters that influence the survival rate of larvae collected in different localities were identified. These are: magnesium, potassium, sulfate, nitrogens, low temperature and rainfall.

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