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Full Length Research Paper

Influence of insecticide treatment on ant diversity in tropical agroforestry system: Some aspect of the recolonization process

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In order to assess the influence of insecticides treatment on ant diversity and recolonization processes in cocoa based agroforestry systems, sampling was performed using chemical knock-down technique during two consecutive cocoa campaigns (2006 and 2007) in six smallholding cocoa farms located in tree localities of the Centre Region of Cameroon. These localities are located along the South-North agroecological benchmark ranging from Ngomedzap in the humid tropical rainforest in the south through Obala in mixed degraded forest / savannah in the transitional zone to Bokito in savannah landscape. From sampled ants, community diversity was measured using Shannon index and similarities between communities calculated using the Bray Curtis distance. After one-year recolonization following insecticide treatment, species richness increased in all the study sites, from 23 to 48 species at Ngomedzap, from 39 to 46 at Obala, and from 37 to 40 at Bokito. The diversity index increased from 2.15 to 2.29 at Obala while decreasing respectively from 2.12 to 2.04 at Ngomedzap and from 2.0 to 0.89 at Bokito. After one year recolonization following treatment, a total of 35 newly establish ant species were observed. Among them 11 were arboreal and two ground-nesting species. Comparison of the community composition and population size between the two sample periods suggested that certain arboreal nesting species such as *Oecophylla longinoda, Tetramorium aculeatum* and some species of the genus *Crematogaster* may survive insecticide treatment, thanks to their nesting behaviour. Also, recolonization process may be strongly influenced by border effects.

Key words: Ant, Bokito, cocoa farm, Cameroon, diversity, insecticides treatment, Ngomedzap, Obala, recolonization process.

INTRODUCTION

Ants and termites are two major arthropod groups in tropical humid rainforest. Both are usually cited as the numerically dominant and the most rich-species groups of artropods (Hölldobler and Wilson 1990 p.1; Watt et al., 2002; Fisher, 2005); also, they are known to play key role in various ecological processes. Despite these considerations, anthropogenic disturbances that are known to negatively affect arthropod community in these regions (Fitzherbert et al. 2008) are progressively intensifying worldwide. In the most tropical region of the world, forest loss caused by timber and fuel wood exploitations or charcoal production and continuing expansion of

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agriculture is alarming (Widodo et al., 2004; Fayle et al., 2010). These disturbances affect species richness and ant abundance in native ecosystems (Floren et al., 2001; Watt et al., 2002), as well as the dynamic of the whole ecosystem (Floren et al., 2001). Meanwhile, low diversity is not always related to anthropogenic disturbance, but may also be related either to lower species density (Schonberg et al., 2004) or to the presence of aggressive dominant ant species (Majer, 1990) or invasive species (Lebreton et al., 2003).

Even though it is well established that anthropogenic disturbances affect arthropod diversity, their impact on species richness is still under discussion. For instance, it have been demonstrated that species richness do not differ along disturbance gradient in Cordillera de Tilara'n in Costa Rica (Schonberg et al., 2004) and in the Lahn-Dill-Bergland in Germany (Dahms et al., 2005). Also, some studies have demonstrated that certain agricultural systems like agroforest give a glimmer of hope for biodiversity preservation in disturbed area. In this context, rustic cocoa farms appeared as the best systems that provide favorable condition for biodiversity preservation (Rice and Greenberg, 2000; Merijn et al., 2007) as they, support high levels of biodiversity, even approaching that of undisturbed tropical forests for some groups (Merijn et al., 2007).

In the center region of Cameroon, cocoa are grown along an agroecological benchmark that cover three vegetation types: forest in the south and savannah in the north. Between the two areas there is a forest - savannah transition zone. Along this ecological gradient, environmental conditions in cocoa agroforest are highly diversified and they usually associated cocoa trees with forest and planted fruit trees that presents and socio-economic and ecological importance (Sonwa et al., 2007). This variability induced variations in pest and disease pressures and consequently variation in pesticides treatments regime. In Cameroonian cocoa farms, the control of the main insect pest, *Shalbergella singularis* (Hemiptera, Miridae) and disease, black pod disease (mildew) caused by *Phytophtora megakarya* (Fungi) by farmers involved various insecticide and fungicides. About 60% of cocoa farmer in southern Cameroon yearly apply pesticide in their farms. These included, mainly copper based fungicides (such as Nordox, Kocide, Cacaobre and Ridomil), and various insecticides (including Azinphos methyl or Cypercal, Dursban and Aldrin). Among insecticides, some belonged to ''Class 1b'' of the World Health Organization classification, and are known to be ''highly dangerous'' (Sonwa et al., 2008) as they represent serious threat for the hole ecosystem. Consequently, they are no longer recommended in agriculture. In the center region of Cameroon, cocoa are grown along an agroecological benchmark that cover three vegetation types: forest in the south and savannah in the north. Between the two areas there is a forest - savannah transition zone. The aim of the present study was to evaluate in these areas, how arthropod communities react to the insecticides treatments. Base on ant model, the study evaluate variations in the community composition and structure after one year recolonization following an insecticide treatment in small-holding cocoa farms. Data are discussed with reference to environmental conditions and anthropogenic disturbances.

MATERIALS AND METHODS

Study sites

The study was conducted within an area situated between the latitudes 2°35' - 4°15'N and the longitudes 11°48' - 11°15'E (Figure 1). The Altitude varied between 450 and 715 m. The climate is subequatorial with a bimodal rainfall regime, and an annual rain fall of about 1900 mm. The annual mean of temperature is around 25°C with weak thermal variations (Bisseleua and Vidal, 2008). The latitudinal gradient induced progressive variation in rainfall, temperature and vegetation characteristics.

Considering this, three localities were chosen for sampling the first in the evergreen forest at Ngomedzap, the second in the semi-deciduous forest/savannah transitional zone at Obala and the third in the bushy savannah at Bokito (Letouzey, 1985).

Ngomedzap, in the southern part of the study area is covered by evergreen forest, weakly logged thanks to low human population density and low intensity of agricultural activities. Annual rainfall is around 1700 to 1800 mm (Santoir and Bopda, 1995). Cocoa agrosystems are located near the forest margin or in the dense forest environment. They presented the most diversified and dense shade trees, dominated by forest trees maintained at the garden creation mixed with some planted fruit trees.

Obala, in the centre of the area is covered by semi-deciduous forest strongly degraded because of high human population density and intense agricultural activities. Cocoa agrosystems are located in these strongly degraded forests around houses (Bisseleua and Vidal, 2008), and showed relatively less dense and less diversified shade trees communities compared to Ngomedzap, in which native forest trees have been cute and replaced by domestic trees. Annual rainfall vary between 1400 - 1700 mm/year (Santoir and Bopda, 1995).

Bokito, located in the northeast part of the area, is covered by bushy-savannah vegetation with patches of gallery-forest and man-made agroforest (Letouzey 1985). The annual rainfall is the lowest (1300 to 1500 mm/year) (Santoir and Bopda, 1995). Cocoa plantations showed less dense and less diversified shade tree communities, composed of man-made mixture of planted forest and domestic trees (Table 1).

The study farms at Ngomendzap were the older (60 years) compared to Obala (20 years) and Bokito (20 to 60 years) (Table 1). From different points of view (geographical, environmental and agronomical), Obala site appeared to be intermediate between Bokito and Ngomedzap. The choice of plantations was guide on one hand by its geographical location with a view to covering contrasting agroecological conditions and on the other by the absence of any insecticide treatment for at least three years. Table 1 gives the main geographical and agroecological characteristics of the chosen plantations.

Sampling method

During 2006 and 2007 respectively, ants were sampled in selected plots by chemical knock down. For each plantation, ants were sampled on 100 adjacent trees in an area with heterogeneous

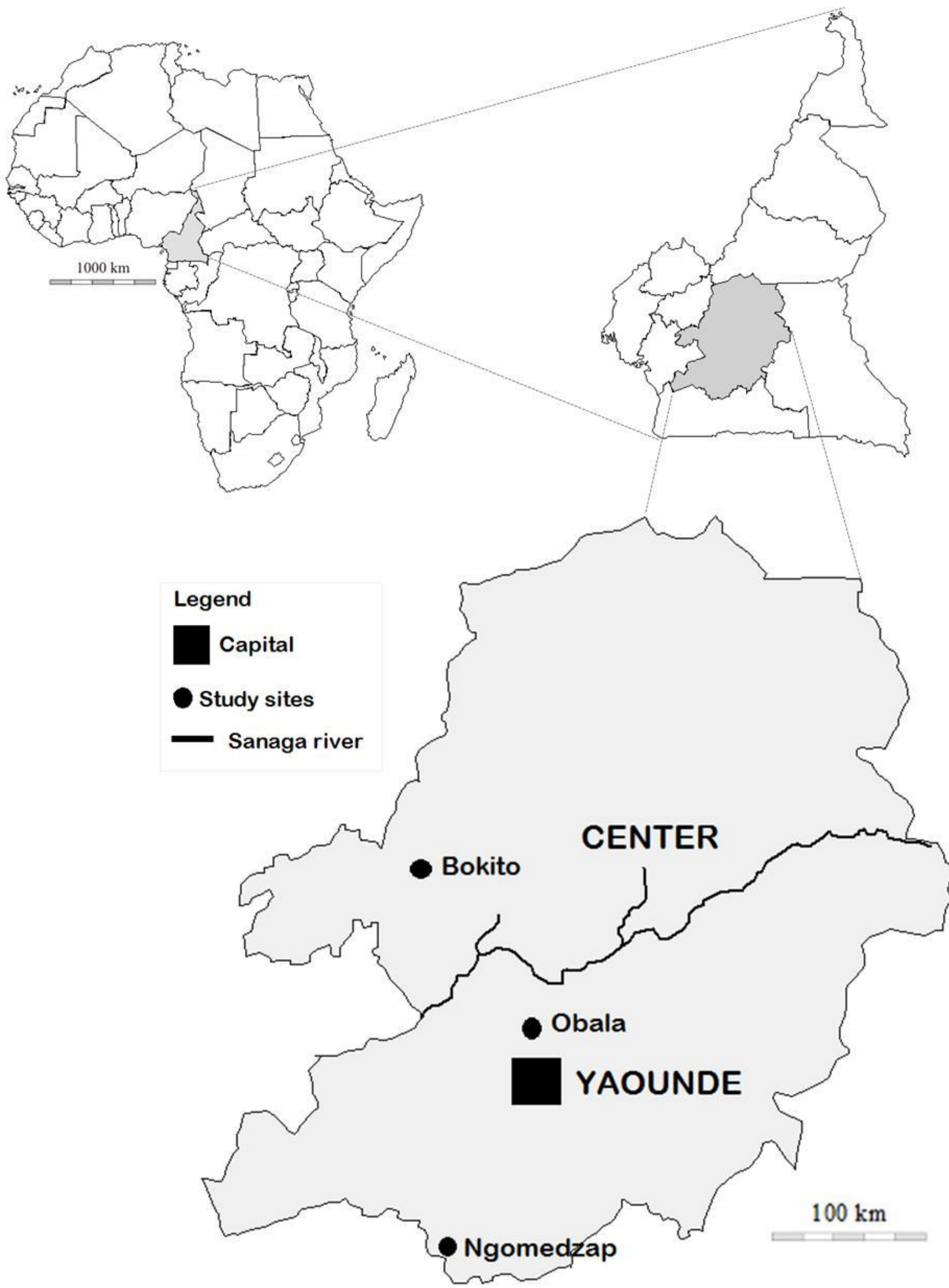

Figure 1. Map indicating the location of the study sites.

shade level. Plots measured about 2025 m² (45 × 45 m). To achieve this, Plastic sheets measuring 4 × 4 m were spread at the foot of each cocoa tree. Plants were subsequently sprayed with an endosulfan-based insecticide using a motorized mistblower (Solo type 40123; Solo Kleinmotoren, Germany) at 100 mL/ha.

Endosulfan was chosen because it has a broad action-spectrum and a sufficient 'shock' effect, to kill most of the insects within few hours. Cocoa trees canopies were sprayed around 6 A.M, when there was no wind. Ten hours after the spraying, all the arthropods felt on the plastic sheet were collected and preserved in hemolysis

Table 1. Geographic point and maintenance activity of the six plots sprayed in southern Cameroon cocoa farms during 2006 - 2007 campaign.

Parameter	Site					
	Bokito		Obala			Ngomedzap
Farms	BO.PI	BO.PII	OB.PI	OB.PII	OB.PIII	NG.PI
Latitude	04°29'24''	04°34'29''	04°06'19''	04°06'14''	04°08'58''	03°16'10''
Longitude	11°04'42''	11°10'45''	11°28'40''	11°28'52''	11°23'02''	11°13'21''
Altitude (m)	450	450	600	650	550	700
Ages/year	20	60	20	60	60	60
Density/ha	1000	1300	1400	1300	1300	1500
Prunning/year	0	0	0	0	0	1
Weeding/year	2	1	0	0	1	2

tubes containing 70% ethanol. Ants were later sorted in the laboratory and kept apart for identifications. These were conducted in the Laboratory of Zoology at the University of Yaounde 1, based on the dichotomic keys (Hölldobler and Wilson, 1990; Bolton, 1994; Taylor, 2002). Samples were later compared to the collection of the Belgium “Musée Royal d'Afrique Centrale” at Tervuren. Voucher specimens are preserved in the Laboratory of Zoology at the University of Yaounde 1 (Cameroon).

Data analysis

Ant diversity

Prior to analyzes data from each locality were pooled. In order to characterize ant community, Shannon diversity index was compute using Estimate 8.2 software (Colwell, 2006) and the Equitability index (E) calculated using the following formulae:

$$H' = -\sum_{i=1}^{N} P_i \mathrm{Log}_2 P_i$$

$$E = \frac{H'}{\log_2 S}$$

Where P_i (= n_i/N) is proportion of i species in the population.

The effect of insecticide on species richness and ant diversity was evaluated by comparing the community of 2006 to that of 2007 using Friedman chi squared test (Q) and associated Wilcoxon test corrected with sequential Bonferroni procedure for pairwise comparison. The analyses were conducted with R software (R 2.13.1, 2011).

To evaluate the impact of insecticide treatment on ant community composition, Bray Curtis index also known as Sorensen quantitative index was used to determine similarities between the community of the first year to that of the second and the cluster was performed using Ward aggregation method. Bray Curtis index is given by the following formula:

$$C_n = \frac{2jN}{N_a + N_b}$$

Where N_a: is the total number of individual in site A; N_b: the total number of individual in site B and 2jN: is the sum of the lower of the abundance for species found in both sites.

Variation of the ant community composition

Between the 2006 and the 2007 campaigns, ant species collected were separated into pre-establish (present in the 2006 sample) and newly establish ant species (new species that appeared in 2007). The effect of treatment on each pre-establishes ant population was assessed by comparing the abundance between the two samples using Friedman chi squared test (Q) and associated Wilcoxon test corrected with sequential Bonferroni procedure for pairwise comparisons. The analysis was done using R software (R 2.13.1, 2011).

Also to assess geographic variation of the re-colonizing community in relation to locality and nesting behavior, newly established ant species were organized in presence/absence matrices data according on one hand, to locality and on the other hand to nesting habits and clusters were performed using Euclidian distance base on Ward aggregation method using XLSAT software (version 2010.4.02; Addinsoft, 2010).

RESULT

Effect of insecticide treatment on ant richness and diversity

A total of 60 ant species belonged to 7 subfamilies, 24 genera were identified from a sample of 52911 workers (Appendix 1) during the two collection campaigns on the three sites. After one year recolonization, data obtained indicated a significant increase of species richness and ant abundance in each study site. Contrarily, the diversity decreased in both Bokito and Ngomedzap, while increasing at Obala (Table 2).

In 2006, the community parameter varied between the sites, with Ngomedzap showing the highest diversity, but the lowest abundance and species richness. It was followed by Obala that also showed the highest species richness but not the highest abundance, while the lowest diversity and the highest abundance were observed at Bokito (Table 2).

One year after insecticide treatment, were observed significant variations of the three community parameters on each site (Table 2). According to the site, there are significant variation of mean number of workers per tree

Table 2 Variation of Shannon diversity index under treatment effect in center region of Cameroon (2006-2007).

Parameter	Site						Q test
	Bokito		Obala		Ngomedzap		
	2006	2007	2006	2007	2006	2007	
Sample size (N)	13239	17788	7253	8924	402	5305	
Mean number of workers/tree	66.20±8.71[a]	88.94±24.41[b]	23.63±10.32[a]	29.07±10.84[a]	4.02±2.82[a]	53.05±10.44[b]	Q= 198.99; df= 5; P<0.0001***
Specific richness (S)	37[a]	40[a]	39[a]	46[b]	23[a]	48[b]	Q= 199.17; df= 5; P<0.0001***
Shannon index (H')	2.0[a]	0.89[b]	2.15[a]	2.29[b]	2.12[a]	2.04[a]	Q= 199.17; df= 5; P<0.0001***
Equitability (E)	0.55[a]	0.24[b]	0.59[a]	0.60[a]	0.68[a]	0.53[b]	Q= 199,17 ; df= 5; P<0.0001***

Q test: Friedman Chis-square test; ***significant difference with P< 0.001; the different letter in each site translate a significant difference at 5% interval confidence level between 2006 and 2007 samples base on Wilcoxon pairwise test corrected with sequential Bonferonni procedure.

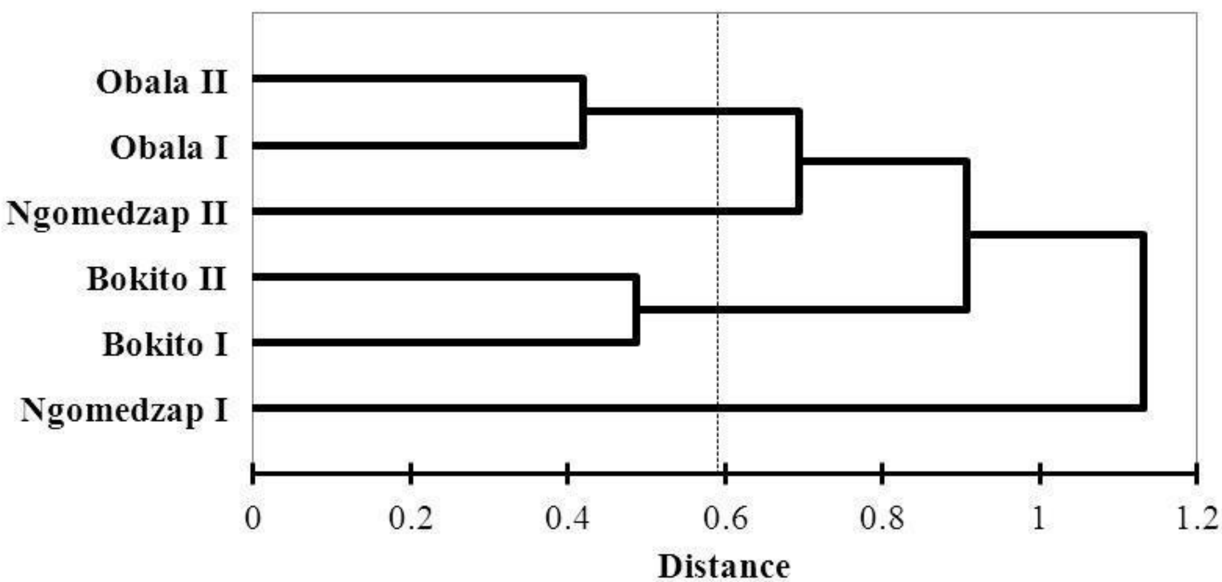

Figure 2. Similarity between site after treatment and recolonization (Cluster analysis was performing with XLSTAT 2010.4.02 base on Bray Curtis distance use Ward aggregation method). I and II represent respectively 2006 and 2007 sampling.

(P < 0.001), species richness (P < 0.001) and diversity index (P < 0.001) between the two sampling period (Table 2). For instance, at Ngomedzap, despite a highly significant increase of species richness and mean number of workers per tree, there was non-significant decrease of the diversity index. The same trend was observed at Bokito where the increased of the mean number of workers per tree and species richness were followed by a significant decreased of the diversity index. Contrarily, at Obala, the increase of mean number of workers par tree and diversity were subsequent to a significant increase of the diversity index (Table 2).

Cluster analysis based on species composition perform on the base of Bray Curtis distance revealed no significant variation between the ant communities of the two samples both at Bokito and Obala. Contrarily, ant community at Ngomedzap was highly disturbed and new establishes community tends to be more similar to that of Obala (Figure 2).

Influence of treatment on community structure

Bokito ant community

Before the first treatment the community was composed of 37 ant species, numerically dominated by, *Oecophylla longinoda* (42.87%), *Cataulacus guineensis* (13.14%), *Polyrachis decemdentata* (11.74%), *Crematogaster gabonensis* (7.83%) and *Tetramorium aculeatum* (7.37%). After one year of re-colonization process, there were an increase of the number of species to 40, with 11 newly established species (*Axinidris bidens, Tapinoma* sp.2, *Camponotus* sp.3, *Phasmomyrmex aberrans, Polyrachis* monista, *Polyrachis* sp.1, *Polyrachis* sp.3, *Crematogaster pulchella, Myrmicaria opaciventris, Pheidole* sp.1, and *Pachycondyla* sp.1) and seven *(Cataulacus* sp.2, *Tetramorium* sp.3, *Anochetus* sp.1, *Plathytyrea modesta*, *Tapinoma melanocephalum*, *Technomyrmex* sp.1, and *Dorylus nigricans)* that disappeared were disappear.

In terms of abundance, there was significant increase of the abundance of *O. longinoda* that remained the dominant ant species in the community. The same trend was encountered with *Camponotus acvapimensi* whose relative abundance increased from (0.86 to 5.95%). Contrarily, there was a drop in the abundance of some dominant species such as *T. aculeatum* (from 7.37 to 1.78 %) and *P. decemdentata* (from 11.74 to 1.25 %), *Cataulacus guineensis* from 13.14 to 0.07), while those of *Crematogaster gabonensis* remained relatively stable (from 7.37 to 5.379%) (Appendix 1).

Obala ant community

At Obala, the first community was made of 39 ant species, numerically dominated by *Oecophylla longinoda* (38.80%) and *Crematogaster gabonensis* (13.33%). After one year of recolonisation process, six ant species desapeared (*Crematogaster* sp1., *Pachycondyla sorror*, *Pa. tarsata*, *Ta. melanocephalum*, *Technomyrmex* sp1., and *Technomyrmex* sp2), while 13 new species (*Anoplolepis tenella*, *Camponotus* sp.2, *Polyrachis monista, Polyrachis* sp.1, *Polyrachis* sp.3, *Polyrachis* sp.5, *Atopomyrmex mocquerysi, Cataulacus* sp.1, *Pheidole* sp.1, *Tetramorium* sp.2, *Anochetus* sp.2, *Platythyrea* sp. and *Tetraponera ophthalmica* were observed.

Concerning the community structure, there was a decrease in the abundance of *O. longinoda* (from 38.80 to 18.13%), *Camponotus vividus* (from 13.10 to 4.90%) and polyrrhachis decemdentata (from 6.31 to 2.38%) while there was increase in abundance of *Crematoagster gabonensis* (from 13.33 to 29.98%), Crematogaster striatula (from 0.04 to 13.58%), *Cr. gabonensis* (from 5.79 to 29.98. and *P. laboriosa* (from 0.15 to 2.29%) (Appendix 1).

Ngomedzap ant community

For the first treatment a community composed of 23 ant species, numerically dominated respectively *Crematogaster striatula (*23.88 %) and *Cr. clariventris (*33.83 % workers) was sampled one year after the treatment, three of these ant species were no longer found (*Pheidole* sp.2, *Anochetus* sp.1 and *Pa. tarsata*), while 28 newly esta-blished species were obtained.

Concerning the relative abundance, with exception of few species that showed significant increase of the abundance: *Cr. striatula* from 23.88 to 26.22% *Tetramorium aculeatum* from 2.99 to 7.65 and *Camponotus vividus* from 4.48 to 8.37%) many species showed reduction of their relative abundance (Appendix 1).

Globally, one year after insecticide treatment the population of *C. acvapimensis* (P< 0.0001), *C. vividus* (P< 0.0001), *Cr. clariventris* (P< 0.0001), *Cr. gabonensis* (P< 0.0001), *Cr. striatula* (P< 0.0001), *O. longinoda* (P< 0.0001), *P. decemdentata* (P< 0.0001) and *T. aculeatum* (P< 0.0001) were significantly affected (Table 3).

For instance *C. acvapimensis* population increased at Bokito and Obala and felt at Ngomedzap. *Oecophylla longinoda* population increased at Bokito and decreased at Obala. *Crematogaster* population decreased at Bokito same as *T. aculeatum* (Table 3). Differences obtain with pairwise comparison were consigned in Table 3.

Ant recolonization and distribution

After treatment and recolonization 35 ant species were new established in prospected farms. Among them, 11, 13 and 29 ant species were collected respectively at Bokito, Obala and Ngomedzap. Among the 35 species identified, 21 are site-specific (15 at Ngomedzap, four at Bokito and two at Obala), and only three species are common to the three localities (Figure 3).

In relation to their nesting behavior, new establish species are grouping inside specialize arboreal ant species, ground dwelling ant species with arboreal habit, ground nesting species and finally undetermined nesting behavior (grouping ants species that may indifferently be encountered in various opportunistic structure on the ground or in trees) (Figure 4).

DISCUSSION

Influence of insecticide treatment on ant richness and diversity

Influence of treatment on ant species richness with a total of 60 ant species were collected between 2006 and 2007 in small-holding cocoa farms located along the South-North agro ecological gradient in southern Cameroon, the diversity appeared relatively diversifies. Highest species richness was observed respectively the forest (Ngomedzap) and the transitional (Obala) landscapes compared to savannah (Bokito). This may related to either the natural heterogeneity in relation with availability of various habitat (Schonberg et al., 2004; Ramesh et al., 2010), phytophy-siognomies (Cardoso et al., 2010) or to the variations in the level of anthropogenic disturbance (Folgarait, 1998; Floren et al., 2001; Savitha et al., 2008; Ramesh et al., 2010).

The complexity of the structure in natural forest at Ngomedzap and the intermediate character of vegetation structure of Obala offered a great diversity of habitat,

Table 3. Variation of ant abundance between numerical dominant species under treatment effect in center region of Cameroon (2006-2007).

Species	Site						Q test
	Bokito		Obala		Ngomedzap		
	2006	2007	2006	2007	2006	2007	
Camponotus acvapimensis	114 (0.86)a	1058 (5.95)b	204 (2.81) a	290 (3.25) a	18 (4.48) a	94 (1.77) b	Q= 63.61; df= 5 ; P< 0.001***
Camponotus vividus	694 (5.24) a	223 (1.25) b	950 (13.10) a	437 (4.90) a	18 (4.48) a	444 (8.37) b	Q= 211.88; df= 5 ; P< 0.001***
Oecophylla longinoda	5676 (42.87) a	14336 (80.59) b	2814 (38.80) a	1618 (18.13) a	0 (0.00)	12 (0.23)	Q= 184.54; df= 3 ; P< 0.001***
Polyrachis decemdentata	1554 (11.74) a	222 (1.25) b	458 (6.31) a	212 (2.38) b	1 (0.25) a	2 (0.04) b	Q= 248.41; df=5 ; P< 0.001***
Crematogaster clariventris	39 (0.29) a	18 (0.10) a	199 (2.74) a	31 (0.35) a	136 (33.83) a	273 (5.15) a	Q= 53.96; df=5 ; P< 0.0001***
Crematogaster gabonensis	977 (7.38) a	1030 (5.79) a	967 (13.33) a	2675 (29.98) b	1 (0.25) a	111 (2.09) b	Q= 305.81; df=5 ; P< 0.0001***
Crematogaster striatula	250 (1.89) a	7 (0.04) b	696 (9.60) a	1212 (13.58) b	96 (23.88)a	1391 (26.22)b	Q= 81.18; df=5 ; P< 0.0001***
Tetramorium aculeatum	976 (7.37)a	316 (1.78)b	14 (0.19)a	86 (0.96)b	12 (2.99) a	406 (7.65) b	Q= 93.94; df= 5 ; P< 0.0001***

Q test: Friedman Chi-square test ; ***significant difference with P< 0.001; the different letter in each site translate a significant difference at 5% interval confidence level between 2006 and 2007 samples base on Wilcoxon pairwise test corrected with sequential Bonferonni procedure.

favorable to the establishment of various species. This may explain the high species richness recorded in both sites. The vegetation structure also relies on the variation of anthropogenic disturbances level based on farm management strategies. Thanks to climatic variations, there were site variation in pest and diseases pressure, induction variation in pesticide application model, weeding frequencies and mechanical destruction of arboreal ant-nests during pruning activities.

Specific richness increase under treatment effect increased gradually from savannah to forest. In fact, at climax stage, ant mosaic is known as very compact structure with a few gaps or no ant's lands between colonies (Hölldobler and Lumsden, 1980; Majer et al., 1994 b). Under treatment effect, ant mosaic was broken; population size on dominant ant colonies reduced and thus, marginal space was created, along with declining of intensity of interspecific competition between numerical dominant ant species (Sensus Davidson, 1997). This contributed to the establishment of submissive species that arise from neighboring vegetation.

Similarity between sites

Forest (Ngomedzap) and transitional (Bokito) areas are separated from savannah (Bokito) by Sanaga River. Both sites were more homogenous on a point of view of their vegetation structure and other factor like proximity. Therefore, ant communities remain more similar between Ngomedzap and Obala farms compared to Bokito cocoa farms.

The proximity between sites has been also suggested by Cardoso et al. (2010) to explain variation of similarity in ant communities in a Brazilian Restinga. Despite anthropogenic disturbance mainly insecticide use, both communities (Obala and Ngomedzap) can evolve differently but may not change drastically.

Influence of treatment on ant diversity

Insecticides treatment significantly affected diversity at Ngomedzap and Bokito but not at Obala. According to his intermediate characters, Obala ant community is liable to combined effect of natural environmental pressure and anthropogenic disturbance encounter in forest and savannah areas. In response of permanently high disturbance link to insecticide and fungicide used more than another sites, various ant species are developing mechanism to resist stressing and restoring rapidly their population. Evidence of negative influence of anthropogenic disturbance on ant diversity was also demonstrated by Floren et al. (2001) along disturbance gradient at Kinabalu National Park in Malaysia.

Insecticide treatment and pre-establish ant communities

Evidence of harmful formerly established ant communities are well demonstrating according to achieve result. If some species' colonies are able to survive to insecticide treatment, others could not and their population significantly decreased. It was the case of *O. longinoda*, *T. aculeatum* and some species of the genus *Crematogaster*. The pesticide treatment may negatively or positively affect each species population depending of various intrinsic as well as extrinsic factors.

In the last cases, the ability of a species to rapidly colonized liberated spaces from adjacent areas or to escape insecticide treatment thanks to nest-structure. *Oecophylla longinoda* colonies live in multiple nest nests are made of host plant leaves pull together and stitch with silk produced by a larva (Leston, 1973; Dejean et al., 1997; Djieto-Lordon and Dejean, 1999). *Tetramorium aculeatum* colonies live in carton nest build under host plant leaves (Dejean, 2000 a) this structure may provide

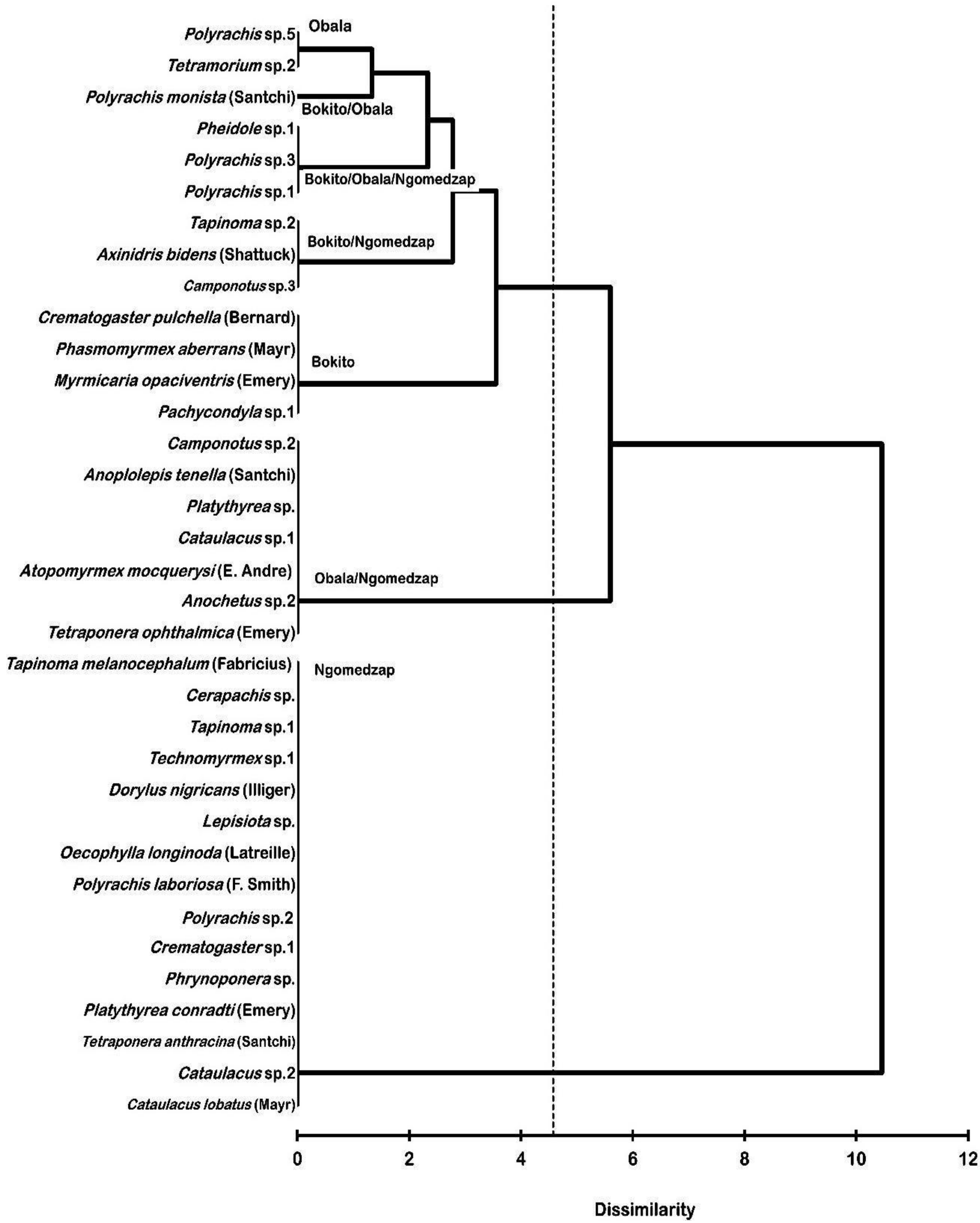

Figure 3. Common and proper distribution of new ant species according to site (Cluster analysis was performing using Euclidian distance with Ward aggregation method, XLSTAT 2010.4.02).

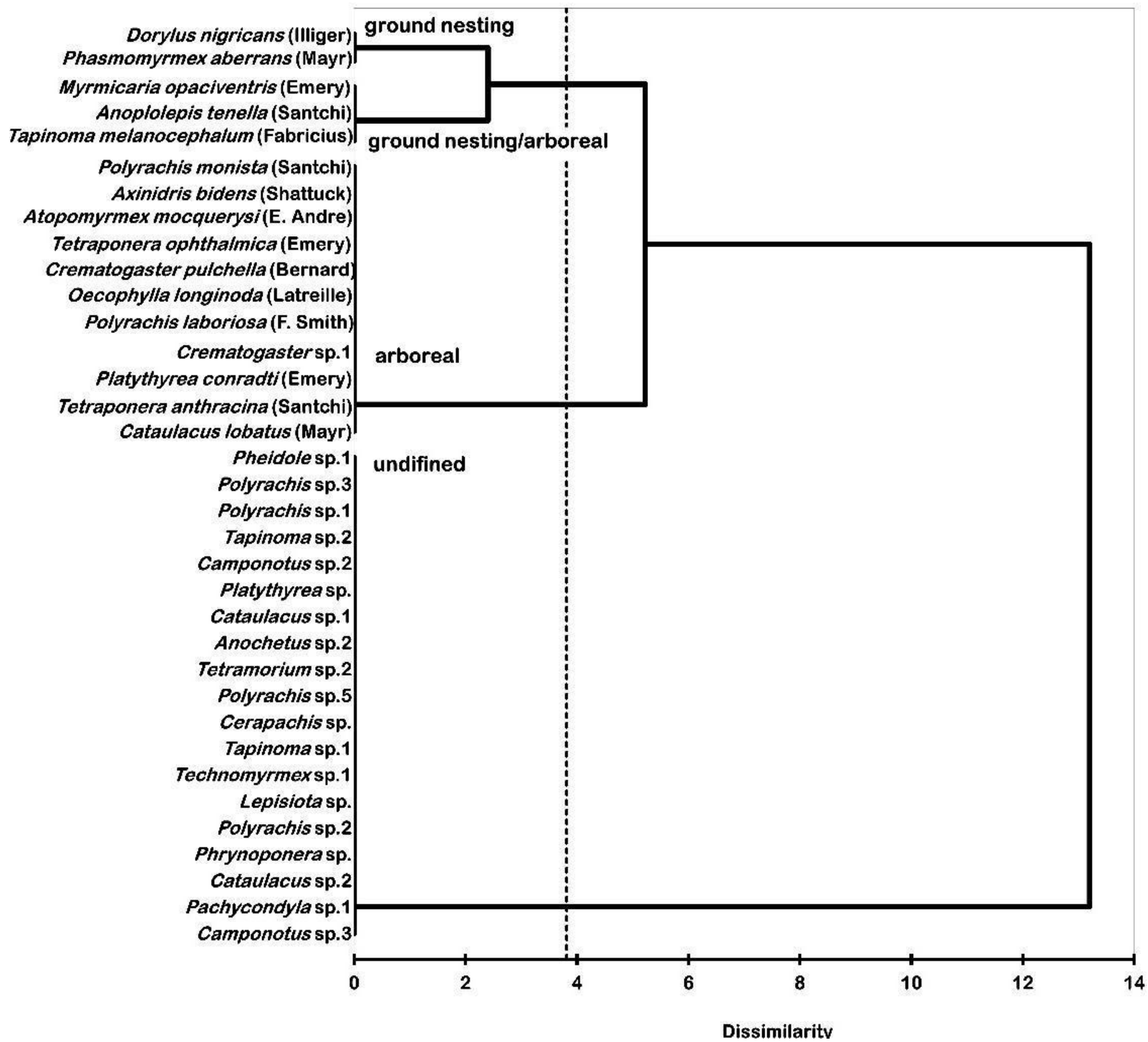

Figure 4. Distribution of new establish species according to their nesting behavior (Cluster analysis was performing using Euclidian distance with Ward aggregation method, XLSTAT 2010. 4.02)

waterproof to a nest. For some *Crematogaster* spp. nesting behavior habitually include carton nest located on shade tree, hollow twigs or branches, crevices and old pods (Leston, 1973). Species such as *Cr. striatula* nest opportunistically in the twigs, crevices and old pods, this nesting behavior may provide a best protection to the colony and just the workers that forage outside the nest may be affected. Similar was the situation of *Cr. clariventris* (carton nest) who built their nest habitually on shade tree (Leston, 1973). These structures may keep the center of colony safe during insecticide treatment (Leston, 1973; Majer, 1978).

The success of ecological *Crematogaster* species in agrosystems was also explained by pruning activities during which nests of *Tetramorium aculeatum* and *Oecophylla longinoda* were destroyed, favoring the expansion of the formers whose nest were located out of the sprayed areas. Impact of pruning is more evident in Ngomedzap farm where one year after our first treatment, both an increase of *T. aculeatum* abundance and arrival of *O. longinoda* occurred. According to the fact that during the one-year recolonization period, there were no management activity conducted by farmers on the pots, the environment were favorable to the establishment an expansion of *T. aculeatum* and *O. longinoda* colonies.

Recolonization process

With respect to nesting behavior, three categories of ant were distinguished among the species that were appeared in the community only during the second sampling: (1) arboreal ant species, (2) Ground-dwelling ant species with arboreal foraging, who exploit homopterans for honeydew and (3) ground-nesting species. Despite the widespread on insecticide applications in agrosystems in Cameroon, very few studies have been conducted on their impact on the arthropods communities. Kenne et al. (2003) in an experimental orchard at Minkoa Meyos demonstrated that regular and persistent application of insecticide treatments favored proliferation of ground-nesting arboreal-foraging ant species that may monopolised the tree crowns. Dominant arboreal nesting species such as *Oecophylla longinoda* that newly colonized studied plots at Ngomedzap exhibit a slow recolonization rate small size colony indicating the establishment phase. This is in conformity with Kenne et al. (2003) who cited this species among the pioner arboreal ant species that colonied tree crown afetr insecticide treatment.

In the studied communities, potential beneficial ant species represented by *O. longinoda* and *T. aculeatum* may be affected by the treatment; the same trend was observed by Leston (1973) and Majer (1978) in Ghana cocoa farms. These authors hypothesized that even a single spray may cause considerable damages to the population of *O. longinoda* and *T. aculeatum,* two potential biological agents. Their abundance decrease in favor of increase of abundance of species belonged to *Crematogaster* genus (Majer, 1978) and other dominant ground-dwelling arboreal foraging and ground-nesting species. These species usually are positively associated with Hemipterans and scale insect that pose problem in agricultural areas (Blüthgen and Fiedler, 2002; Kenne et al., 2003). Nevertheless, another aspect to look at is the phytopathological implication or recolonization process of tree by ground nesting species after treatment. In fact, several ground species to protect their trophobionts transport soil particles that contains fungus spore. Passively, these species may contribute to vertical propagation of fungus disease agents in cocoa farm.

Conclusion

In favor of the disturbance due to insecticide effect, ant species richness increased in all the study sites, while diversity decrease both at Bokito and Ngomedzap, contrarily to Obala where it increased. High turnover observed at Obala may be explained by the high level of anthropogenic disturbance observed in the locality. At Ngomedzap and Bokito, area with less anthropogenic disturbance, turnover may probably take a longer times-period. On the three sites, treatment favored the proliferation of newly established arboreal ant species, ground-dwelling species and ground species. Nesting behavior of various dominant ant species procures protection to colony against chemical treatment and other mechanical factors of disturbance. Border effect due to the proximity with adjacent farms, fallows or native vegetation is an important factor that may affect recolonization process of farm. Though, anthropogenic disturbance may alter the distribution and abundance of certain ant species, they contributed to the ecological success of other ant species. Agronomical importance of tree crowns recolonization by ground-dwelling ant species was investigated, in order to understand their implication in the propagation of fungus diseases in cocoa farms. In fact, protections of trophobionts by these species are required for transportation of soil particles that contain fungus spores on the tree to build a habit.

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Appendix 1. Diversity, distribution and variation of ant abundance in camerounian cocoa farms before (2006) and after treatment (2007) and plot recolonization.

Site	Bokito		Obala		Ngomedzap	
Sample	**2006**	**2007**	**2006**	**2007**	**2006**	**2007**
Cerapachiynae						
Cerapachis sp. *	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	4 (0.08)
Dolichoderinae						
Axinidris bidens (Shattuck)*	0 (0.00)	2 (0.001)	0 (0.00)	0 (0.00)	0 (0.00)	2 (0.04)
Tapinoma melanocephalum (Fabricius)*	2 (0.02)	0 (0.00)	21 (0.29)	0 (0.00)	0 (0.00)	52 (0.98)
Tapinoma sp1. *	10 (0.08)	15 (0.08)	20 (0.28)	90 (1.01)	0 (0.00)	55 (1.04)
Tapinoma sp2. *	0 (0.00)	1 (0.01)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.02)
Technomyrmex sp1.	1 (0.01)	0 (0.00)	19 (0.26)	0 (0.00)	0 (0.00)	1 (0.02)
Technomyrmex sp2.	0 (0.00)	0 (0.00)	1 (0.01)	0 (0.00)	0 (0.00)	0 (0.00)
Dorylinae						
Dorylus nigricans (Illiger)*	30 (0.23)	0 (0.00)	1 (0.01)	1048 (11.74)	0 (0.00)	1919 (36.17)
Formicinae						
Anoplolepis tenella (Santchi)*	0 (0.00)	0 (0.00)	0 (0.00)	4 (0.04)	0 (0.00)	1 (0.02)
Camponotus acvapimensis (Mayr)	114 (0.86)	1058 (5.95)	204 (2.81)	290 (3.25)	18 (4.48)	94 (1.77)
Camponotus brutus (Forel)	126 (0.95)	88 (0.49)	61 (0.84)	105 (1.18)	25 (6.22)	28 (0.53)
Camponotus maculatus (Forel)	10 (0.08)	2 (0.01)	3 (0.04)	27 (0.30)	1 (0.25)	6 (0.11)
Camponotus pompeius (Forel)	1 (0.01)	1 (0.01)	11 (0.15)	3 (0.03)	1 (0.25)	1 (0.02)
Camponotus sp1.*	17 (0.13)	3 (0.02)	34 (0.47)	18 (0.20)	24 (5.97)	21 (0.40)
Camponotus sp2. *	0 (0.00)	0 (0.00)	0 (0.00)	8 (0.09)	0 (0.00)	3 (0.06)
Camponotus sp3.*	0 (0.00)	9 (0.05)	5 (0.07)	23 (0.26)	0 (0.00)	33 (0.62)
Camponotus vividus (F. Smith)	694 (5.24)	223 (1.25)	950 (13.10)	437 (4.90)	18 (4.48)	444 (8.37)
Lepisiota sp. *	1 (0.01)	2 (0.01)	0 (0.00)	0 (0.00)	0 (0.00)	35 (0.66)
Oecophylla longinoda (Latreille)*	5676 (42.87)	14336 (80.59)	2814 (38.80)	1618 (18.13)	0 (0.00)	12 (0.23)
Phasmomyrmex aberrans (Mayr)*	0 (0.00)	23 (0.13)	4 (0.06)	6 (0.07)	0 (0.00)	0 (0.00)
Polyrachis decemdentata (Andre)	1554 (11.74)	222 (1.25)	458 (6.31)	212 (2.38)	1 (0.25)	2 (0.04)
Polyrachis laboriosa (F. Smith)*	19 (0.14)	9 (0.05)	11 (0.15)	204 (2.29)	0 (0.00)	2 (0.04)
Polyrachis militaris (Fabricius)	12 (0.09)	1 (0.01)	46 (0.63)	31 (0.35)	1 (0.25)	11 (0.21)
Polyrachis monista (Santchi)*	0 (0.00)	1 (0.01)	0 (0.00)	9 (0.10)	0 (0.00)	0 (0.00)
Polyrachis sp1. *	0 (0.00)	4 (0.02)	0 (0.00)	48 (0.54)	0 (0.00)	20 (0.38)
Polyrachis sp2. *	62 (0.47)	52 (0.29)	53 (0.73)	38 (0.43)	0 (0.00)	8 (0.15)
Polyrachis sp3. *	0 (0.00)	5 (0.03)	0 (0.00)	1 (0.01)	0 (0.00)	1 (0.02)
Polyrachis sp5. *	0 (0.00)	0 (0.00)	0 (0.00)	2 (0.02)	0 (0.00)	0 (0.00)
Polyrachis weissi (Santchi)	53 (0.40)	40 (0.22)	138 (1.90)	221 (2.48)	8 (1.99)	8 (0.15)
Myrmicinae						
Atopomyrmex mocquerysi (E. Andre)*	349 (2.64)	81 (0.46)	0 (0.00)	215 (2.41)	0 (0.00)	1 (0.02)
Cataulacus erinaceus (Stitz)	43 (0.32)	1 (0.01)	9 (0.12)	18 (0.20)	0 (0.00)	0 (0.00)
Cataulacus guineensis (F. Smith)	1739 (13.14)	12 (0.07)	65 (0.90)	42 (0.47)	3 (0.75)	21 (0.40)
Cataulacus lobatus (Mayr)*	174 (1.31)	1 (0.01)	69 (0.95)	2 (0.02)	0 (0.00)	2 (0.04)
Cataulacus sp1. *	1 (0.01)	56 (0.31)	0 (0.00)	23 (0.26)	0 (0.00)	5 (0.09)
Cataulacus sp2. *	3 (0.02)	0 (0.00)	21 (0.29)	1 (0.01)	0 (0.00)	9 (0.17)
Crematogaster clariventris (Mayr)	39 (0.29)	18 (0.10)	199 (2.74)	31 (0.35)	136 (33.83)	273 (5.15)
Crematogaster gabonensis (Emery)	977 (7.38)	1030 (5.79)	967 (13.33)	2675 (29.98)	1 (0.25)	111 (2.09)
Crematogaster pulchella (Bernard)*	0 (0.00)	7 (0.04)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)
Crematogaster sp1.	89 (0.67)	10 (0.06)	143 (1.97)	0 (0.00)	0 (0.00)	2 (0.04)
Crematogaster striatula (Emery)	250 (1.89)	7 (0.04)	696 (9.60)	1212 (13.58)	96 (23.88)	1391 (26.22)
Myrmicaria opaciventris (Emery)*	0 (0.00)	2 (0.01)	66 (0.91)	11 (0.12)	3 (0.75)	12 (0.23)
Pheidole megacephala (Fabricius)	59 (0.45)	108 (0.61)	9 (0.12)	16 (0.18)	29 (7.21)	189 (3.56)

Appendix 1. Contd.

Pheidole sp1.*	0 (0.00)	2 (0.01)	0 (0.00)	2 (0.02)	0 (0.00)	23 (0.43)
Pheidole sp2.	4 (0.03)	9 (0.05)	0 (0.00)	0 (0.00)	1 (0.25)	0 (0.00)
Tetramorium aculeatum (Mayr)	976 (7.37)	316 (1.78)	14 (0.19)	86 (0.96)	12 (2.99)	406 (7.65)
Tetramorium sp1.	1 (0.01)	3 (0.02)	7 (0.10)	1 (0.01)	5 (1.24)	11 (0.21)
Tetramorium sp2.	0 (0.00)	0 (0.00)	0 (0.00)	10 (0.11)	1 (0.25)	3 (0.06)
Tetramorium sp3.	2 (0.02)	0 (0.00)	8 (0.11)	10 (0.11)	2 (0.50)	24 (0.45)
Ponerinae						
Anochetus sp1.	1 (0.01)	0 (0.00)	80 (1.10)	72 (0.81)	10 (2.49)	0 (0.00)
Anochetus sp2. *	0 (0.00)	0 (0.00)	0 (0.00)	14 (0.16)	0 (0.00)	43 (0.81)
Odontomachus troglodytes (Santchi)	47 (0.37)	19 (0.11)	36 (0.50)	19 (0.21)	0 (0.00)	0 (0.00)
Pachycondyla soror (Emery)	0 (0.00)	0 (0.00)	1 (0.01)	0 (0.00)	0 (0.00)	0 (0.00)
Pachycondyla sp1.	0 (0.00)	1 (0.01)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)
Pachycondyla tarsata (Fabricius)	5 (0.04)	0 (0.00)	1 (0.01)	0 (0.00)	2 (0.50)	0 (0.00)
Phrynoponera sp.*	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.02)
Platythyrea conradti (Emery)*	0 (0.00)	0 (0.00)	4 (0.06)	1 (0.01)	0 (0.00)	3 (0.06)
Platythyrea modesta (Emery)	11 (0.08)	0 (0.00)	3 (0.04)	12 (0.13)	4 (1.00)	4 (0.08)
Platythyrea sp. *	0 (0.00)	0 (0.00)	0 (0.00)	2 (0.02)	0 (0.00)	2 (0.04)
Pseudomyrmecinae						
Tetraponera anthracina (Santchi)*	87 (0.66)	8 (0.04)	1 (0.01)	5 (0.06)	0 (0.00)	4 (0.08)
Tetraponera ophthalmica (Emery)*	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.01)	0 (0.00)	1 (0.02)
Total	13239	17788	7253	8924	402	5305

*New establish ant species.