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Ant assemblage structure on cocoa trees in smallholder farms in the Centre Region of Cameroon

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Abstract

We investigated the ant community structure in cocoa farms in the Centre Region of Cameroon. Ants were collected on the cocoa trees during the years 2006 and 2007 using chemical knock-down. We tested the hypothesis of the existence of deterministic factor in the structuration of ant mosaic using C-Score; we assessed the relationship between the numerical dominant and subdominant ant species using Spearman correlation test and discussed on the influence of vegetation structure and farm management on the ant community structure. A total of 53 ant species belonging to 20 genera and five subfamilies were identified from a set of 51,525 workers collected. C-score analysis supported the hypothesis that ant community were structured by competition. Negative relationships were found between dominant ant species. Farming practices which were mainly pruning, chemical treatment and habitat structure appeared to influence the ecological status and distribution of dominant ant species.

Résumé

Nous avons étudié la structure de la communauté de fourmis dans les exploitations cacaoyères de la région du centre du Cameroun. Des fourmis ont été collectées sur les cacaoyers au cours des années 2006 et 2007 au moyen d'un abattage chimique. Nous avons testé l'hypothèse de l'existence d'un facteur déterministe dans la structuration de la mosaïque de fourmis à l'aide de C-Score ; nous avons évalué en nombre la relation entre les espèces de fourmis dominantes et sous-dominantes à l'aide du test de corrélation de Spearman et avons examiné l'influence de la structure de la végétation et de la gestion de l'exploitation agricole sur la structure de la communauté de fourmis. Au total, 53 espèces de fourmis appartenant à 20 genres et 5 sous-familles ont été identifiées parmi un ensemble de 51525 ouvrières recueillies. L'analyse par modèle nul a corroboré l'hypothèse selon laquelle les communautés de fourmis étaient structurées par concurrence. Des relations négatives ont été trouvées entre les espèces de fourmis dominantes. Les pratiques agricoles consistant principalement en la taille, le traitement chimique et la structure de l'habitat semblaient avoir une influence sur l'état écologique et la répartition des espèces de fourmis dominantes.

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KEYWORDS
ant, Cameroon, cocoa, C-score, dominant species

1 | INTRODUCTION

Agroforestry systems consist of land-use systems and technologies where woody perennials plants are grown on the same land as agricultural crops and/or animals (Schroth et al., 2004; Sperber, Azevedo, Muscardi, Szinwelski, & Almeida, 2012). The domestication of indigenous fruit and nut trees is becoming recognised as an important component of agroforestry in some African countries, which is sprouting meaningful impacts on rural development (Asaah et al., 2011). In Cameroon, land use was dominated by cocoa and coffee plantations, which together make up nearly 85% of the inventoried land area used in some regions (Degrande et al., 2006).

In rainforest canopies and crop plantations, ants are among the major component of arthropod fauna (Dejean et al., 2016; Dejean, McKey, Gibernau, & Belin, 2000; Majer, 1990). Ants have been reported to range from 5% to 72% (Majer, 1972) and 10% to 31% (Majer, Delabie, & Smith, 1994) of arthropod biomass in cocoa farms in Ghana and Brazil, respectively.

In cocoa farm, arboreal ant communities were organised in a three-dimensional mosaic pattern, known as "arboreal ant mosaic" (Dejean et al., 2016; Leston, 1972). Based on their behaviour and colony structure, ants were classified into three hierarchical ecological groups known as dominant, subdominant and nondominant (Leston, 1971; Majer, 1972). In the dominance concept, some authors distinguish numerical and behavioural dominance. The numerical dominance is a predominance of particular species in numbers, biomass and/or frequency of occurrence in ant communities (Davidson, 1997) while behavioural dominance is defined as the dominance in interspecific encounter competition due to the superior fighting and/or recruitment abilities (Schoener, 1983). The combined effect of both numerical and behavioural dominance leads to the notion of ecological dominant species characterised by populated colonies, with generalised diets, high rate activity and high inter- and intraspecific aggressiveness (Andersen & Patel, 1994; Dejean, Corbara, Orivel, & Leponce, 2007). Dominant species tolerate nondominant species in their territories, provided the latter are not aggressive and their ecological niches do not overlap (Room, 1971). As for subdominant, these comprise nondominant ants that can become dominant when conditions favour them, particularly in the absence of dominant ant species (Majer et al., 1994).

The structure of ant mosaic in cocoa agroforestry systems is often related to the (a) interspecific competition (Jackson, 1984), (b) constraints that are bounded by the choice of the nesting site by founding queens (Djieto-Lordon & Dejean, 1999), (c) canopy structure (Dejean, Corbara, & Orivel, 1999), (d) anthropogenic disturbances (Floren, Freking, Bielil, & Linsenmair, 2001), (e) preference for different stage of trees development (Schulz & Wagner, 2002), (f) aggressive behaviour (Dejean et al., 2007), (g) stochastic processes (Sanders, Crutsinger, Dunn, Majer, & Delabie, 2007), (h) lighting intensity in the cocoa farm (Tadu, Djieto-Lordon, Yede, Messop Youbi, Aléne, et al., 2014) and (i) ontogenic succession of territorial dominant arboreal ant species from sapling to mature trees (Dejean et al., 2016).

Thanks to their predatory and territorial behaviours, dominant arboreal ants may efficiently protect their host plants from herbivorous insects (Dejean et al., 2000; Majer, 1976, 1994). The use of ants as biological control agents in plant protection may involve either the periodic introduction of predatory species or the manipulation of the ant mosaic in order to favour the expansion of beneficial species (Majer, 1986; Way & Khoo, 1992). Examples of such ecological dominant ants in Cameroonian cocoa farm are *Oecophylla longinoda* Latreille, 1802 and *Tetramorium aculeatum* Mayr, 1866 (Tadu, Djieto-Lordon, Yede, Messop Youbi, Aléne, et al., 2014; Tadu, Djieto-Lordon, Yede, Messop Youbi, Fomena, et al., 2014) cited as potential biological control agents against pest in cocoa farms across Africa (Leston, 1973). The colonies of these two species and those of various species of *Crematogaster* genus exhibit high resistance to insecticide treatment in the cocoa farm (Tadu et al., 2013).

In Cameroon, several studies have described ant mosaic in rainforest (Dejean, Djieto-Lordon, & Lenoir, 1994), palm oil plantations (Dejean, Fawty, Djob Bikoi, & Djieto-Lordon, 1993) and cocoa farms (Jackson, 1984). Nevertheless, none of these studies had considered the north–south latitudinal gradient in the Centre Region which induces variation in vegetation structure, pressure of insect pest and fungi in cocoa farms. Our study is aimed at investigating the existence of ant mosaic in smallholder cocoa farms, determining the relationship between numerical dominant and subdominant species and the influence of vegetation and farm management on ant community structure.

2 | MATERIALS AND METHODS

2.1 | Study sites

The Centre Region of Cameroon is characterised by a subequatorial climate with a bimodal rainfall regime (Suchel, 1988). The mean annual temperature is around 25°C with slight seasonal variation (Bisseleua & Vidal, 2008). The study was conducted at Bokito, Obala and Ngomedzap, three cocoa production localities in the Centre Region of Cameroon. At Bokito, vegetation is bushy-savannah with patches of gallery forest. The landscape at Obala is a mosaic of evergreen or semi-deciduous forest and savannah, while at Ngomedzap,

TABLE 1 Main geographical and agro-ecological characteristics of the study sites and selected cocoa farms

Parameter	Site: Bokito	Obala	Ngomedzap
Latitude	04°34′N	04°10′N	03°16′N
Longitude	11°07′E	11°31′E	11°12′E
Altitude (m)	450–500	550–650	700–750
Annual rainfall (mm)[a]	1,300–1,500	1,400–1,500	1,700–1,800
Main farm characteristics[b]			
Age (years)	30–60	30–60	>60
Cocoa trees ha^{-1}	1,000–1,700	1,000–2,000	900–2,600
Weedings $year^{-1}$	0–2	0–2	0–1
Prunings $year^{-1}$	1–4	1–3	0–3
Insecticide sprayings $year^{-1}$	0–4	0–6	0–5
Fungicide sprayings $year^{-1}$	0–6	1–8	4–7

[a]According to Santoir and Bopda (1995),
[b]from Babin (2009), minimal and maximal values for each parameter are represented in the table.

landscape is dominated by evergreen equatorial forest with patches of semi-deciduous forest (Letouzey, 1985). Some geographical and agro-ecological characteristics of the study sites are summarised in Table 1.

2.2 | Sampling method

Sampling was conducted on 21 cocoa plots, from November to December 2006 and 2007 during dry season. Twelve plots were removed in the analysis due to the presence of army ant *Dorylus nigricans* Illiger (induce high perturbation in ant community structure) and pseudo replication plots in the sample. Each plot measured 45 × 45 m and harboured 100 cocoa trees distant of 3 m approximately from each other. Ants were sampled in every one of the 100 cocoa trees per plot in a farm using a chemical knockdown (Armbrecht, Jiménez, Alvarez, Ulloa-Chacon, & Armbrecht, 2001). To achieve this, plastic sheets with dimensions 4 × 4 m were spread at the base of each cocoa tree. Tree canopies were sprayed around 06:00 a.m. with an endosulfan-based insecticide, using a motorised mist blower at 100 ml/ha, and ants were collected on the plastic sheets 7 hr later and preserved in haemolysis tubes containing 70% ethanol. Ants were later sorted and identified in the zoology laboratory of the University of Yaoundé 1, using dichotomous keys of Hölldobler and Wilson (1990) and Bolton (1994) for subfamily and genera levels, respectively, and Taylor (2010) for species level when possible. Samples were later compared to the ant collection of "Institut Royal des Sciences Naturelles de Belgique" in Belgium for identification confirmation. Voucher specimens are kept at the zoology laboratory of the University of Yaoundé 1 in Cameroon.

2.3 | Ant community structure

2.3.1 | Test of the hypothesis of competition on ant community structure

Arboreal ants use trees for nesting and for food resources (nectar, honeydew and various arthropods species as preys). Consequently, the control of occupied trees is a gage of long-term availability of vital resources for the colony. Therefore, when there is nonrandom distribution in species co-occurrence on the trees, the evidence of competition as structuring factor may be admitted.

To clarify, if there is nonrandomness on ant distribution using null model (Wilson, 1987), we constructed presence/absence matrices data with ant species in rows and trees in columns. We submitted these matrices to the C-Score null model analyses using the package EcoSimR (version 1.0) (Gotelli & Entsminger, 2001) with fixed-equiprobable model and swap algorithm (Gotelli, 2000). The observed co-occurrence index (I_{obs}), calculated from the original matrices, is compared to the mean frequency distribution for the randomised matrices (I_{sim}) using standardised effect size (SES). C-Score was calculated by the following formulae:

$$\mathrm{CU} = (r_i - S)\,(r_j - S)$$

where S is the number of shared sites, r_i and r_j are the row totals for species i and j.

In a competitively structured community, the C-Score should be significantly higher than that expected by chance. Large positive values of the SES indicate increasingly small upper-tail probabilities, and large negative values of SES indicate increasingly small lower-tail probabilities. Nonsignificant tail probabilities usually fall between −2.0 and +2.0 (Gotelli & Entsminger, 2001).

We considered numerical dominant ant species that were found on at least 30% of the sampled cocoa trees and whose population densities reached a minimum of five individuals per occupied trees. Subdominant species were found on <30% of the sample cocoa trees and whose population densities are inferior to 5 individuals per trees, and nondominant or rare species were found on <10% of the cocoa trees per site.

Analyses were done firstly on the whole ant community, and secondly, we removed all nondominant species based on the hypothesis that these species may contribute to mask interspecific competition between numerical dominant species.

2.3.2 | Interaction between ant species

The relationship between ant species was achieved based on Spearman rank correlation test (Blüthgen & Stork, 2007), and a correlogram was built using corrplot package (version 0.77, 2016) (Wei & Simko, 2016). Spearman rank correlation coefficient is given by the following formula:

$$r = 1 - 6 \sum_{i=1}^{n} \frac{d_i^2}{n\,(n^2 - 1)}$$

TABLE 2 Diversity of numerical dominant ant species collected in the Bokito, Obala and Ngomedzap cocoa farms between 2006 and 2007

Species	Site							
	Bokito		Obala		Ngomedzap		Total	
	A	B	A	B	A	B	A	B
Camponotus acvapimensis Mayr, 1862	1,528 (3.43)	135 (33.75)	424 (7.29)	98 (32.67)	170 (14.06)	59 (29.50)	2,122 (4.12)	292 (32.44)
Camponotus vividus Smith F., 1858	166 (0.37)	60 (15.0)	950 (16.34)	144 (48.00)	35 (2.89)	21 (10.50)	1,151 (2.23)	225 (25.00)
Cataulacus guineensis Smith F., 1853	1,777 (3.99)	99 (24.75)	100 (1.72)	37 (12.33)	30 (2.48)	14 (7.00)	1,907 (3.70)	150 (16.67)
Crematogaster clariventris Mayr, 1895	63 (0.14)	10 (2.50)	205 (3.53)	30 (10.00)	425 (35.15)	71 (35.50)	693 (1.34)	111 (12.33)
Crematogaster gabonensis Emery, 1899	259 (0.58)	34 (8.50)	1,695 (29.16)	144 (48.00)	11 (0.91)	5 (2.50)	1,965 (3.81)	183 (20.33)
Crematogaster striatula Emery, 1892	11,474 (25.78)	105 (26.25)	701 (12.06)	41 (13.67)	97 (8.02)	23 (11.50)	12,272 (23.82)	169 (18.78)
Oecophylla longinoda Latreille, 1802	24,100 (54.15)	229 (57.25)	49 (0.84)	14 (4.67)	0 (0.00)	0 (0.00)	24,149 (46.87)	243 (27.00)
Polyrhachis decemdentata Andre, 1889	1,587 (3.57)	183 (45.75)	409 (7.04)	94 (31.33)	103 (8.52)	27 (13.50)	2,099 (4.07)	304 (33.78)
Tetramorium aculeatum Mayr, 1866	2,048 (4.60)	106 (26.50)	26 (0.45)	8 (2.67)	21 (1.74)	11 (5.50)	2,095 (4.07)	125 (13.89)
Other species	1,501 (3.37)	–	1,254 (21.57)	–	892 (26.22)	–	3,072 (5.96)	–
Total	44,503	**400**	5,813	**300**	1,209	**200**	51,525	**900**

Note: A: ant abundance; B: ant occurrence on the trees; relative abundance (A) and relative occurrence (B) are given into bracket; the number in bold represent number of cocoa trees sample per site and in all site combine.

where $d_i = (r_{xi} - r_{yi})$ is the difference between x and y ranks for each sampled tree shared by species a_i and a_j, and n is the total number of sampling units in which each species was recorded. r varies from −1 to 1 for a perfect discordance and perfect concordance, respectively. If $r = 0$, there is no association between the paired species.

3 | RESULTS

3.1 | Species abundance

From 900 cocoa trees sample, 53 ant species belonging to six subfamilies and 23 genera were identified from a total of 51,525 workers collected (Appendix A). At Bokito, *O. longinoda* and *Crematogaster striatula* were the most abundant with 54.15% and 25.78% of the total number of collected ants, respectively; they were followed by *T. aculeatum* (4.60%) and the formicine *Polyrhachis decemdentata* (3.57%). At Obala, *Crematogaster gabonensis*, *Camponotus vividus* and *Cr. striatula* were the most abundant species, with 29.16%, 16.34% and 12.06% of the total number of ants collected, respectively. The two formicine ant species *Camponotus acvapimensis* and *P. decemdentata* were also sampled in Obala, at 7.29% and 7.04%, respectively. At Ngomedzap, *Crematogaster clariventris* and *C. acvapimensis* were the most abundant species with 35.15% and 14.06%, respectively, and to a lesser extent by *P. decemdentata* (8.52%), *Cr. striatula* (8.02%) and *C. vividus* (2.89%; Table 2).

3.2 | Species frequency on the trees

At Bokito, the most frequently sample ants were *O. longinoda* which were found on the 57.25% of the total number of sampled trees, followed by *P. decemdentata* (45.75%), *C. acvapimensis* (33.75%), *T. aculeatum* (26.50%) and *Cr. striatula* (26.25%). At Obala, the most frequently occurring species were *Cr. gabonensis* and *C. vividus* found on 48.0%, of the total number of sampled trees for each, followed by *C. acvapimensis* (32.67%), *P. decemdentata* (31.33%) and *C. striatula* (13.67%). At Ngomedzap, the most frequent species were *Cr. clariventris* (35.50%) and *C. acvapimensis* (29.50%) followed by *P. decemdentata* (13.50%), *C. striatula* (11.50%) and *C. vividus* (10.50%; Table 2).

3.3 | Test of the hypothesis of competition on ant community structure

When all species of the community were considered, there was no strong evidence that interspecific competition affected structure of the ant mosaic in cocoa farms in Bokito, Obala and Ngomedzap farms. In fact, the observed C-score index (I_{obs}) was significantly lower than the simulated C-score index (I_{sim}) in Bokito and Ngomedzap and not significant for Obala farms. In contrast, when we considered only the numerical dominant and subdominant species, I_{obs} was significantly higher than I_{sim} at Bokito and Obala, but not significant for Ngomedzap. Therefore, there was strong evidence that competition structured the distribution of numerically dominant species in Bokito and Obala (Figure 1).

3.4 | Relationship between numerical dominant species

At Bokito farms, negative and significant relationship was found between *Cr. striatula* and *O. longinoda* ($r = -0.60$; $p < 0.05$; $n = 289$; Figure 2a). *Crematogaster striatula* was negatively correlated with *Cr. gabonensis* ($r = -0.66$; $p > 0.05$; $n = 177$) and with *C. vividus* ($r = -0.38$; $p < 0.05$; $n = 157$) at Obala farms (Figure 2b). Negative association was found between *Cr. clariventris* and *C. acvapimensis* ($r = -0.45$; $p < 0.05$; $n = 104$) at Ngomedzap farm (Figure 2c).

3.5 | Relationship between numerical dominant and subdominant species

At Bokito, negative relationships were found between *O. longinoda* and *P. decemdentata* ($r = -0.39$; $p < 0.05$; $n = 299$), *Cr. striatula* and *O. longinoda* ($r = -0.60$; $p < 0.05$; $n = 289$), *Cr. striatula* and *P. decemdentata* ($r = -0.52$; $p < 0.05$; $n = 242$), *O. longinoda* and *Cataulacus guineensis* ($r = -0.45$; $p < 0.05$; $n = 271$), and *O. longinoda* and *T. aculeatum* ($r = -0.57$; $p < 0.05$; $n = 273$; Figure 2a).

At Obala, negative relationships were found between *Cr. striatula* and *C. vividus* ($r = -0.28$; $p < 0.05$; $n = 157$), *Cr. striatula* and *Ca. guineensis* ($r = -0.79$; $p < 0.05$; $n = 70$), and *Cr. clariventris* and *Cr. gabonensis* ($r = -0.43$; $p < 0.05$; $n = 177$). Positive relation was

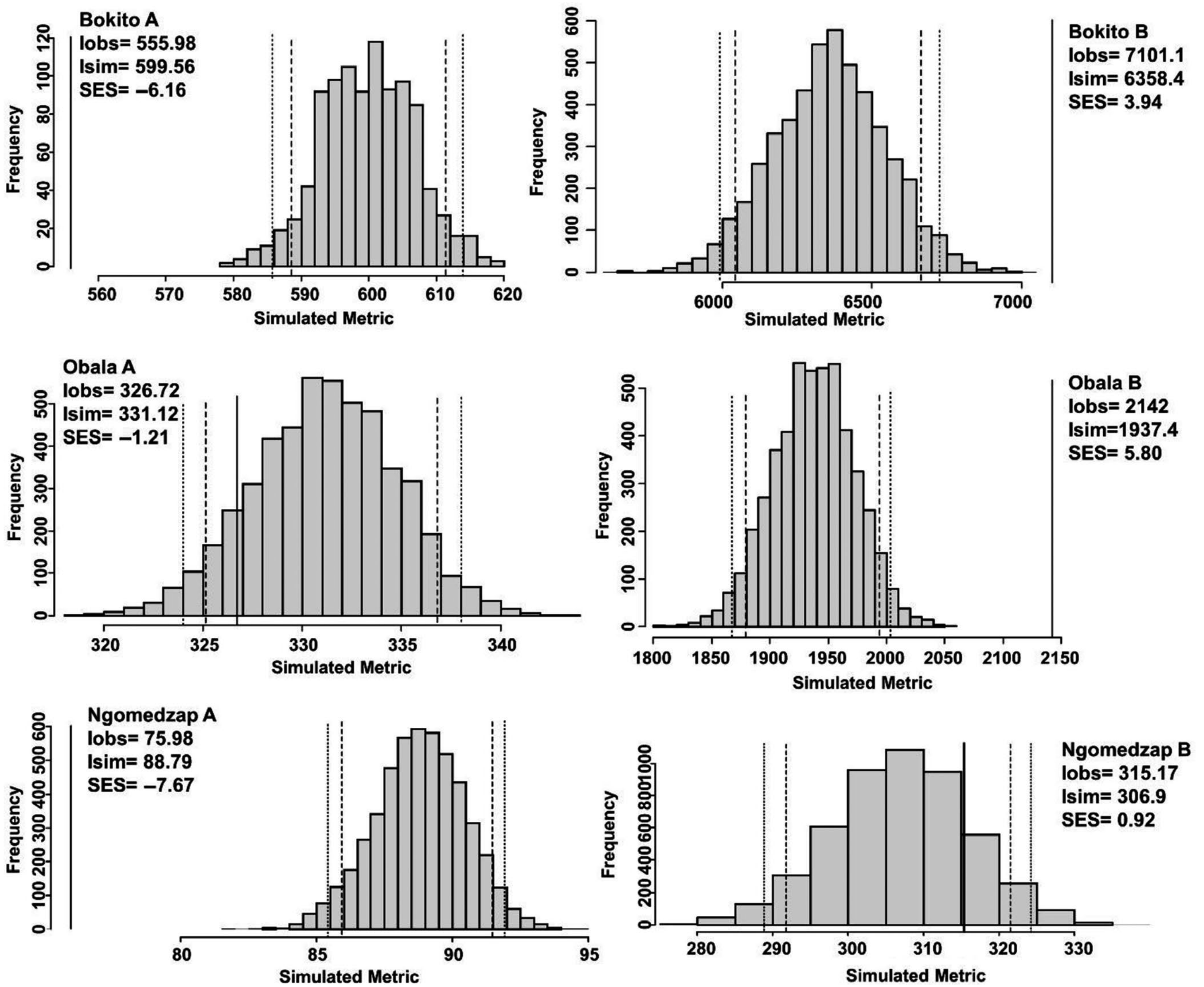

FIGURE 1 Interspecific competition hypothesis testing on whole ant community (A) and between numerical dominant (B) species based on null model. The black continuous vertical line represents the observed C-score index value; the pairs of black vertical thin-dashed and thick-dashed lines represent one- and two-tailed 95% confidence intervals, respectively. Large positive values of standardised effect size (SES) indicate increasingly small upper-tail probabilities, and large negative values of SES indicate increasingly small lower-tail probabilities. Nonsignificant tail probabilities usually fall between −2.0 and +2.0

found between *C. vividus* and *Cr. clariventris* ($r = 0.38$; $p < 0.05$; $n = 61$) (Figure 2b).

The ant community found at Ngomedzap showed negative and significant association between *Cr. striatula* and *C. acvapimensis* ($r = -0.75$; $p < 0.05$; $n = 83$), *Cr. striatula* and *Cr. clariventris* ($r = -0.70$; $p < 0.05$; $n = 90$), and *C. acvapimensis* and *T. aculeatum* ($r = -0.51$; $p < 0.05$; $n = 73$). Negative and significant association was also found between *Cr. clariventris* and *T. aculeatum* ($r = -0.26$; $p < 0.05$; $n = 78$; Figure 2c).

4 | DISCUSSION

4.1 | Species abundance and frequency distribution

Regarding species abundance and occurrence, ant communities were dominated by *Cr. striatula* and *O. longinoda* at Bokito, and *Cr. gabonensis*, *Cr. striatula* and *C. vividus* at Obala. Ngomedzap ant community was dominated by *Cr. clariventris* and *C. acvapimensis*. These species were reported among the most abundant ant species in Ghana (Majer, 1972) and Cameroon (Jackson, 1984) cocoa farms and in palm oil plantations and secondary forest in Cameroon (Dejean et al., 1999, 1994). Their simultaneous presence in great number in Bokito and Obala farms may have led to a high interspecific competition for food and space or anthropogenic disturbances which has affected the size of the colony of some dominant ant species in cocoa agroforestry system and favours the expansion of other ant colonies (Tadu et al., 2013). In cocoa farms, several Crematogaster species usually nest on the shade trees and their workers forage on surrounding cocoa trees; sometimes, these cocoa trees harbour satellite nests (Hölldobler & Lumsden, 1980). We suggest that the workers will exert a lower control on forage trees than on those

(a)

	C.viv	C.acv	Ca. gui	Cr. cla	Cr. gab	**Cr. str**	**O. lon**	P. dec
C.acv	−0.77*							
Ca. gui	−0.41*	−0.52*						
Cr. cla	−0.53*	−0.38*	−0.51*					
Cr. gab	−0.71*	−0.60*	−0.59*	−0.63*				
Cr. str	−0.74*	0.10	−0.67*	−0.44*	−0.71*			
O. lon	−0.49*	−0.61*	−0.45*	−0.20*	−0.38*	−0.60*		
P. dec	−0.05	−0.47*	−0.04	−0.05	−0.08	−0.52*	−0.39*	
T. acu	−0.24*	−0.64*	−0.30*	−0.20*	−0.46*	−0.73*	−0.57*	−0.15*

(b)

	C. viv	C. acv	Ca. gui	Cr. cla	**Cr. gab**	**Cr. str**	O. lon	P. dec
C. acv	−0.79*							
Ca. gui	−0.50*	−0.29*						
Cr. cla	0.38*	−0.56*	−0.78*					
Cr. gab	−0.54*	−0.25*	−0.19*	−0.43*				
Cr. str	−0.28*	−0.46*	−0.79*	−0.85*	−0.66*			
O. lon	−026*	−0.42*	−0.70*	−0.64*	−0.14	−0.74*		
P. dec	−0.55*	−0.63*	−0.51*	−0.30*	−0.27*	−0.77*	−0.14	
T. acu	−0.24*	−0.27*	−0.65*	−0.72*	−0.08	−0.64*	−0.79*	−0.15

(c)

	C. viv	**C. acv**	Ca. gui	**Cr. cla**	Cr. str	P. dec
C. acv	−0.34*					
Ca. gui	−0.73*	−0.40*				
Cr. cla	−0.43*	−0.45*	−0.31*			
Cr. str	−0.81*	−0.75*	−0.87*	−0.70*		
P. dec	−0.61*	−0.51*	−0.73*	−0.20	−0.84*	
T. acu	−0.82*	−0.51*	−0.52*	−0.26*	−0.78*	−0.74*

FIGURE 2 Associations between numerical dominant ant species during 2006 and 2007 samplings at Bokito (A), Obala (B) and Ngomedzap (C) cocoa farms. Numerically dominant species are in bold. Negative relationships are in grey, and positive relationships in white. The stars in superscript correspond to the significant relationship at 5% confidence interval. O.lon: *Oecophylla longinoda*; Cr.cla: *Crematoagster clariventris*; C.viv: *Camponotus vividus*; Cr.gab: *Crematogaster gabonensis*; P.dec: *Polyrhachis decemdentata*; T.acu: *Tetramorium aculeatum*; Ca.gui: *Cataulacus guineensis*; C.acv: *Camponotus acvapimensis*

supporting the nest, and they increase the control on cocoa trees when these ones harbour satellite nests. Both factors may increase the occurrence of other ants' species on cocoa trees, principally, opportunistic species like *C. acvapimensis*, for example Ngomedzap farm. Consequently, the ant community structure may appear to be at the first stage of the colonisation process.

4.2 | Null model

Few studies have been carried out on ant community structure in Cameroon. All have described a tri-dimensional mosaic structure (Dejean et al., 1994; Jackson, 1984). By using null model, we establish that ant community of cocoa farm were structured in mosaics by competition. Nevertheless, the competition hypothesis is more evident between numerical dominant and subdominant species, while the presence of nondominant species masked the competition effect in ant mosaic. This may be explained by the spatial distribution model of rare species which were generally randomly distributed and showed no spatial dependence between the adjacent trees in the farm (Tadu, Djieto-Lordon, Yede, Messop Youbi, Aléne, et al., 2014) and the permanent disturbances of ant communities by human activities as stated by Kenne et al. (2003) and Tadu et al. (2013).

4.3 | Ant community structure

Ant species that usually structured mosaics were classified into three ecological status: dominant (Davidson, 1997, 1998), subdominant and nondominant species (Armbrecht et al., 2001; Majer et al., 1994). Six numerical dominant ant species were found during this survey: *C. vividus*, *C. acvapimensis*, *Cr. gabonensis*, *Cr. striatula*, *Cr. clariventris* and *O. longinoda*. The same species were also reported as dominant in cocoa farms in Ghana (Leston, 1972) and in Nigeria (Taylor, 1977; Taylor & Adedoyin, 1978). In Cameroon, the study conducted by Jackson (1984) at Nkoemvon identified the following dominant species: *O. longinoda*, *T. aculeatum*, *Cr. gabonensis* and *Pheidole* sp.2. Dejean et al. (1999) identified three dominant ant species including *O. longinoda* and two *Crematogaster* species, in Cameroonian rainforest. In an oil palm plantation in Southern Cameroon, *Cr. gabonensis*, *T. aculeatum*, *O. longinoda*, *Monomorium* sp. and *Pheidole megacephala* were found as dominant (Dejean, Djieto-Lordon, & Durand, 1997). In the most studied cases, negative interactions were predominant between dominant ants whatever the habitat. This result supports the hypothesis that mosaic structure is basically rested on the mutual intolerance between dominant ant species (Jackson, 1984; Leston, 1972) and the ability of dominant species to control the populations of subdominant and rare ant species in their territories. Sometime, two dominant species can co-exploit trees and then be reported as co-dominant (Majer, 1972). For example, positive association between *T. aculeatum* and *Cr. clariventris* is possible thanks to the different activity patterns (Leston, 1972; Majer, 1982) or tree architecture. Likewise, food availability (Armbrecht et al., 2001) and tree architecture may favour the cohabitation by lessening of interspecific competition between dominant ants.

4.4 | Influence of environmental factors on ant communities' structure

In the Centre Region of Cameroon, ant communities' structure may be influenced at macro-ecological level by vegetation structure which affects diversity and nesting site availability. In fact, at Bokito and Obala, domesticated forest and semi-deciduous forest, less complex in composition and structure than natural forests at Ngomedzap, may have limited the diversity and the availability of potential nesting sites for some arboreal ants. Under these conditions, competitive arboreal-nesting dominant species may control available habitats and restrict nesting site for other species.

A spatial variation of the numerically dominant ant species suggests that there might be dominance status of ant species which is not fixed related to the environmental conditions and the anthropogenic disturbances. For some ant species commonly recorded as dominant like *O. longinoda*, *T. aculeatum*, *Cr. clariventris* and *Cr. gabonensis*, their status varies from subdominant to nondominant according to the site. This translates the fact that any ant species could reach dominant status favoured by the vegetation structure and farm management practices. Looking at the farming practices, pruning is more frequent at Ngomedzap compared to Bokito and Obala. This may explain the absence of dominant ant species like *O. longinoda* and *T. aculeatum* which built their nest with cocoa leaves, whereas insecticide treatments were more frequent at Obala farms than Ngomedzap and Bokito. The fungicide treatments were more accentuated at Ngomedzap than Obala and Bokito. Insecticide and fungicide treatments increase habitat disturbances by nest destruction; therefore, the ant communities' structure may have affected. The related situation may be explained, for example, by the dominance of *C. acvapimensis* at Ngomedzap cocoa farm.

5 | CONCLUSION

The arboreal ant community in Cameroonian cocoa farm is dominated by *C. acvapimensis*, *C. vividus*, *Cr. gabonensis*, *Cr. striatula*, *Cr. clariventris* and *O. longinoda*. The studied ant communities were structured by competition. Negative relationships were found between numerical dominant species. Environmental conditions and anthropogenic pressure influence on distribution and ecological status of various ant species. Insecticide and fungicide treatments were the most frequent farming practices for crop protection suggesting a possible harmfulness on ant mosaic structure.

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DATA ACCESSIBILITY

Data of some agro-ecological parameter in the study site were provided by (a) Santoir and Bopda (1995) and from (b) Babin (2009).

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APPENDIX A

DIVERSITY OF ANT FAUNA COLLECTED ON THE TREES IN COCOA AGROFORESTRY SYSTEM IN THE CENTER REGION OF CAMEROON

	Sites			
Family/Genera/Species	Bokito	Ngomedzap	Obala	Total
Dolichoderinae	4	1	60	65
Tapinoma	4	1	40	45
Tapinoma melanocephalum (Fabricius)	0	0	22	22
Tapinoma sp.1	4	1	18	23
Technomyrmex	0	0	20	20
Technomyrmex sp.1	0	0	19	19
Technomyrmex sp.2	0	0	1	1
Formicinae	28,058	426	2,122	30,606
Anoplolepis	13	0	2	15
Anoplolepis tenella (Santchi)	13	0	2	15
Camponotus	1,922	290	1,491	3,703
Camponotus acvapimensis (Mayr)	1,528	170	424	2,122
Camponotus brutus (Forel)	188	28	66	282
Camponotus maculatus (Forel)	12	3	3	18

(Continues)

APPENDIX A (Continued)

Family/Genera/Species	Sites: Bokito	Ngomedzap	Obala	Total
Camponotus pompeius (Forel)	3	1	11	15
Camponotus vividus (F. Smith)	166	35	950	1,151
Camponotus sp.1	25	51	32	108
Camponotus sp.3	0	2	5	7
Lepisiota	2	1	11	14
Lepisiota sp.	2	1	11	14
Oecophylla	24,100	0	49	24,149
Oecophylla longinoda (Latreille)	24,100	0	49	24,149
Phasmomyrmex	22	0	2	24
Phasmomyrmex aberrans (Mayr)	21	0	2	23
Phasmomyrmex sp.	1	0	0	1
Polyrhachis	1,999	135	567	2,701
Polyrhachis decemdentata (Andre)	1,587	103	409	2,099
Polyrhachis laboriosa (F. Smith)	5	0	10	15
Polyrhachis militaris (Fabricius)	15	22	27	64
Polyrhachis monista (Santchi)	1	0	0	1
Polyrhachis weissi (Santchi)	100	10	93	203
Polyrhachis sp.2	287	0	28	315
Polyrhachis sp.4	4	0	0	4
Myrmicinae	16,154	751	3,525	20,430
Atopomyrmex	387	5	10	402
Atopomyrmex mocquerysi (E. Andre)	387	5	10	402
Cataulacus	1,829	36	505	2,370
Cataulacus erinaceus (Stitz)	1	0	13	14
Cataulacus guineensis (F. Smith)	1,777	30	100	1,907
Cataulacus lobatus (Mayr)	51	6	57	114
Cataulacus sp.1	0	0	20	20
Cataulacus sp.2	0	0	315	315
Crematogaster	11,797	533	2,742	15,072
Crematogaster clariventris (Mayr)	63	425	205	693
Crematogaster gabonensis (Emery)	259	11	1,695	1,965
Crematogaster pulchella (Bernard)	1	0	0	1
Crematogaster striatula (Emery)	11,474	97	701	12,272
Crematogaster sp.1	0	0	141	141
Monomorium	0	0	1	1
Monomorium sp.	0	0	1	1
Myrmicaria	1	42	191	234
Myrmicaria opaciventris (Emery)	1	42	191	234
Pheidole	88	86	34	208
Pheidole megacephala (Fabricius)	80	83	31	194
Pheidole sp.1	1	0	0	1
Pheidole sp.2	7	3	3	13
Tetramorium	2,052	49	42	2,143

(Continues)

APPENDIX A (Continued)

Family/Genera/Species	Sites: Bokito	Ngomedzap	Obala	Total
Tetramorium aculeatum (Mayr)	2,048	21	26	2,095
Tetramorium sp.1	4	25	8	37
Tetramorium sp.2	0	1	0	1
Tetramorium sp.3	0	2	8	10
Ponerinae	209	30	105	344
Anochetus	4	10	86	100
Anochetus sp.1	4	10	85	99
Anochetus sp.2	0	0	1	1
Odontomachus	202	0	8	210
Odontomachus troglodytes (Santchi)	202	0	8	210
Pachycondyla	2	9	3	14
Botroponera soror (Emery)	1	0	1	2
Paltothyreus tarsatus (Fabricius)	1	2	2	5
Pachycondyla sp.1	0	6	0	6
Pachycondyla sp.2	0	1	0	1
Platythyrea	1	11	8	20
Platythyrea conradti (Emery)	0	4	0	4
Platythyrea modesta (Emery)	1	7	8	16
Pseudomyrmecinae	78	1	1	80
Tetraponera	78	1	1	80
Tetraponera anthracina (Santchi)	78	1	1	80
Total	44,503	1,209	5,813	51,525