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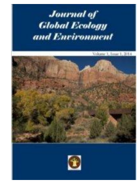

EFFECT OF INSECTICIDE TREATMENT ON ARBOREAL ANT COMMUNITY STRUCTURE IN SMALL HOLDER COCOA FARM IN THE CENTRE REGION OF CAMEROON

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AUTHORS' CONTRIBUTIONS

This work was carried out in collaboration among all authors. Authors TZ, BR and DLC gave the conception of the protocol, data collection, data analysis and wrote and corrected the manuscript.
Authors Yede, ADC and MYEB managed the data collection, manuscript writing and correction.
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ABSTRACT

To understand the effect of anthropogenic disturbances, mainly related to insecticide treatment on ant community structure, the present study was conducted on Cameroonian cocoa farms during two consecutive crop cycles. Ant sampling was based on chemical knock down in three smallholding cocoa farms selected in three different agro-ecological zones in the Centre Region of Cameroon. The C-score was used for null model analysis in order to detect deterministic factor of ant community structure and Spearman correlation test to screen relationship between pair species. Seven ant species were identified as a numerically dominant: *Crematogaster clariventris, Crematogaster gabonensis, Crematogaster striatula, Camponotus vividus, Cataulacus guineensis, Tetramorium aculeatum* and *Oecophylla longinoda.* Ant communities were structured by the competition and negative relationship were found between dominant species. Insecticide-treatments affected the ant community structure by favoring the acquisition of the dominant status by non-dominant species.

Keywords: Ant; cocoa farm; competition; dominant species.

1. INTRODUCTION

Canopies of tropical rainforest and agroforestry ecosystems are colonized by arboreal ant species whose colonies are spatially organized in a three dimensional mosaic structure [1]. Ant community structure results from the competitive interaction for nesting sites food and resources between different

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species. In ant mosaics, three hierarchical dominance status are commonly cited in the literature: dominant, sub-dominant and non-dominant. This classification rests on their behavioral and numerical dominance [1, 2]. Behavioral dominance is defined as dominance in the inter-specific encounter competition, due to superior fighting and/or recruitment abilities; and numerical dominance as predominance of particular species in numbers, biomass and/or frequency of occurrence in ant communities [3]. Ecological dominance results in the combination between behavioral and numerical dominance [3]. Dominant species tolerate non-dominant species in their territories, provided the latter are not aggressive and their ecological niches do not overlap [4]. Sub-dominance on its part, refers to non-dominant ants that can become dominant when conditions favor them, particularly in the absence of dominant ant species [5].

An ant mosaic structure may be affected by anthropogenic disturbance [6] and ant abundance [7], shade [8] as well as some other biotic factors such as the presence of invasive ant species [9]. In these communities, colonies of arboreal dominant ant species exclusively occupy large contiguous blocks of the canopy layer. Strong inter-specific competition between these dominant ant species result in non-overlapping territories that are separated by no-ants-land [10]. Despite the densely packed mosaic structure described by various authors [11,12], high proportions of trees unoccupied by dominant arboreal ants were also recorded in some of these agro-ecosystems. These trees are occupied by non-dominant arboreal ant species or ground nesting ant species that behaved as sub-dominant species [9] resulting in an ant mosaic as described [13]. Composition and structure of ant communities may have an agricultural application and several studies have revealed the beneficial effects of the dominant species on crop plantations [14, 15]. In most cases, *Oecophylla longinoda* Latreille, 1802, *Oecophylla smaragdina* Forel, 1899, *Tetramorium aculeatum* Mayr, 1923, *Wasmania aropunctata* Roger, 1863 (invasive species in Cameroon) and *Dolichoderus thoracicus* Smith, 1860 were suggested or used as biological agent for crop protection in Africa and Asia [16,17].

In the Centre region of Cameroon, cocoa is cultivated along an ecological benchmark extending from the humid forest to savanna zones. Along this ecological gradient, environmental conditions in cocoa agro-forests are highly diversified and usually cocoa trees are associated with wild and planted-fruit trees of socio-economic and ecological importance [18]. This variability in structure induces variations in pests and disease pressures and consequent variation in pesticide treatment regimes. For instance, a survey conducted in three localities in the Center Region showed that an average pesticide-use per year stood at 0 to 4, 0 to 6 and 0 to 5 times respectively at Bokito, Obala and Ngomedzap farms depending on the cocoa farmers [19].

In Cameroonian cocoa farms, the control of farmers on the main insect pest, *Shalbergella singularis* Hagl. (Hemiptera, Miridae) and disease like black pod disease (mildew) caused by *Phytophtora megakarya* Brasier & Griffin (Fungi) involves the use of various insecticides and fungicides. About 60 % of the cocoa farmers in the southern part of the country yearly applies pesticides in their farms [18]. According to some authors [18, 20], 28 different chemical products are available on the local market and sold to the cocoa farmer. These include: two herbicides, 10 mainly copper-based fungicides (such as Nordox, Kocide, Cacaobre and Ridomil) and 16 various insecticides (including Azinphos methyl or Cypercal, Dursban and Aldrin). Some of them belonged to ‘‘Class 1b’’ of the World Health Organization classification, and are known as ‘‘highly dangerous’’. So, they are no longer recommended in agriculture [18]. In Cameroon, a realistic and healthy use of pesticides and fungicides and its notice of its consequences for the farmer are lacking. It is reported that 36 % of the cocoa farmers apply chemical products with respect to the recommended dose and 64 % do not [20]. Insecticide and fungicide treatments seem to be the main anthropogenic disturbance in the cocoa agroforestry system in Cameroon. Therefore, non-respect of prescribed dose by famers represents a serious threat to both the ecosystem and human health. So far, their impact on the component of the natural ecosystems and the cocoa agroforestry system were not well investigated in spite of their high arthropod biodiversity. In a previous study conducted in the same area, it is appearing that, in the absence of insecticide treatment, ant community is structure by competition. The main dominant species found are *Camponotus acvapimensis* Mayr, 1862, *Camponotus vividus* Smith F., 1858, *Crematogaster gabonensis* Emery, 1899, *Crematogaster striatula* Emery, 1892, *Crematogaster clariventris* Mayr, 1895, *O. longina* and *T. aculeatum* [21]. Our study aims at investigating the effect of chemical insecticide treatment on ant community structure in Cameroonian cocoa farms in order to known if the insecticide treatment: (1) induce random distribution in the ant community structure; (2) affect the ecological statute of dominant ant and (3) which other ant species could be able to control trees canopy after treatment and reach dominant statute.

2. MATERIALS AND METHODS

2.1 Study Sites

The survey was conducted at Bokito, Obala and Ngomedzap, three localities in the Centre Region of Cameroon. This area is characterized by a subequatorial climate with a bimodal rainfall regime [22]. The mean annual temperature is around 25°C with slight seasonal variation. Annual rainfall varies from 1300 mm at Bokito to 1500 mm at Obala and 1800 mm at Ngomedzap. The landscape is dominated at Bokito by bushy-savannah, with patches of gallery forest [23] and human made forest mostly deeply affected by human enrichment in timber and fruit trees. At Obala, the vegetation type is a mosaic of evergreen or semi-deciduous forest and savannah [23]; while at Ngomedzap, evergreen equatorial forest with patches of semi-deciduous forest dominated the landscape [23]. Some geographical and agro-ecological characteristics of the study sites are summarized in Table 1.

2.2 Data Collection

Sampling was conducted during two consecutive cocoa campaigns, from November to December 2006 and 2007, during dry season. A total of six cocoa plots were sampled; among them, three plots were removed in the analysis due to the presence of the army ant *Dorylus nigricans* Illiger (known to induce a high perturbation on an ant community structure) in the 2007 sample. Ants were sampled using the chemical knock down technique on 100 adjacent trees in an area with the heterogeneous shade level in a plot of about 2025 m² (45m x 45 m). To achieve this, plastic sheets measuring about 4m×4m were spread at the base of each cocoa tree. Plants were subsequently sprayed with an endosulfan-based insecticide using a motorized mist-blower (Solo type 40123; Solo Kleinmotoren, Germany) at 100 ml/ha. Endosulfan was chosen because it has a broad action-spectrum and a high 'shock' effect to kill most of the insects within a few hours. Cocoa-tree canopies were sprayed around 6 A.M, when there was no wind. All arthropods that fell on the plastic sheet were collected seven hours after the spraying and preserved in hemolysis tubes containing 70% ethanol for later identification in the Laboratory of Zoology at the University of Yaoundé 1. We used the dichotomic keys of [24, 25]. Voucher specimens are preserved in the collections of the same laboratory and were compared to the ant collection of the Belgium "Institut Royal des Sciences Naturelles de Belgique".

2.3 Data Analysis

2.3.1 Testing competition hypothesis

Arboreal ant use trees for nesting and for food resources. Therefore, the control of trees is essential for the survival of the colony. Thus, the distribution model of arboreal ant species on the trees when they do not fit random model may have resulted from the competition. We used C-score null model to determine if there is a random effect on the ant community structure before and after insecticide treatment. To achieve this, we constructed presence/absence data matrices with ant species in rows and the trees in columns. Analyses were done with EcoSimR (version 1.0) [26] using fixed-equiprobable model [27]. EcoSim generates 5000 random matrices, each randomized matrix generates a co-occurrence index, and after several iterations, a mean frequency distribution of indices is produced. The observed co-occurrence index (I_{obs}), calculated from the original matrice is then compared to the mean frequency distribution for the randomized matrice (I_{sim}). The C-Score index was calculated using:

$$CU = (r_i - S)(r_j - S)$$

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

Table 1. Description of the studied cocoa plots where ants were sampled between in 2006 and 2007 survey

Parameter	Site		
	Bokito	**Obala**	**Ngomedzap**
Latitude	04°34'29''	04°06'19''	03°16'10''
Longitude	11°10'45''	11°28'40''	11°13'21''
Altitude (m)	450	600	700
Ages in years	60	20	60
Density per ha	1300	1400	1500
Prunning /year	0	0	1
Weeding/year	1	0	2
Number of fruits trees	6	6	2
Number of timbers trees	5	2	5

In a competitively structured community, the C-Score should be significantly higher than that expected by chance. The Standardized Effect Size (SES) which converts a p-value into a standardized deviate is used as a response variable in meta-analyses and comparisons between sets of results. Large positive values of the SES indicate increasingly small upper-tail probabilities, and large negative values of SES indicate increasingly small lower-tail probabilities. Non-significant tail probabilities usually fall between -2.0 and +2.0 [27]. We considered as: numerical dominant species, ant species that were found on at least 30 % of the sampled cocoa and whose population densities reached a minimum of five individuals per occupied tree; Subdominant species, those that were found on less than 30 % of the sampled cocoa and characterized by population densities inferior to 5 individuals per tree; and non-dominant species, those found on less than 10 % of the cocoa per site. Analyses were done with dominant species, based on the hypothesis that rare species may have contributed to mask competition between dominant species.

2.3.2 Association model between dominant species

The relationship between ant species were achieved based on Spearman rank correlation test and correlogram was built using a corrplot package (version 0.77, 2016) [28] for R software (version 3.2.2. 2015). The Spearman rank correlation test is given by the following formula:

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

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 species of the pair.

3. RESULTS AND DISCUSSION

3.1 Results

3.1.1 Ant fauna in cocoa farm before treatment

In studied plots, ant faunas were numerically dominated at Bokito by *Cataulacus guineensis* (28.15 %), *Oecophylla longinoda* (25.77 %), *Tetramorium aculeatum* (16.35 %) and *Polyrarchis decemdentata* (15.33 %) during the 2006 sampling. Each of these species was encountered on more than 50 % of the sampled trees (Table 2). Also, with a relative abundance of 71.38 % and occurrence on trees of 45%, *O. longinoda* was the single numerical dominant species during the 2006 survey at Obala (Table 2). Again, the Ngomedzap ant community was dominated by two *Crematogaster* species: *Crematogaster clariventris* (33.83 %) and *Crematogaster striatula* (23.88 %) in the 2006 campaign. Both species occurred respectively on 28 % and 22 % of the trees in this plot (Table 2).

3.1.2 Ant fauna in cocoa farm after treatment

One year after treatment at Bokito, during the 2007 sampling, among the four dominant species recorded in 2006, only *O. longinoda* remained dominant with 78.34 % of workers collected (Table 3) and occurred on 82 % of the sampled trees (Table 3). At Obala, *O. longinoda* abundance decreased in the farm (44.84 % of the ant fauna) while *Crematogaster gabonensis* abundance increased from 10.40 % in 2006 to 36.84 % in 2007. The number of trees occupied by *C. gabonensis* workers also increased from 65 % in 2006 to 85 % in 2007 (Tables 2&3). In Ngomedzap ant community *C. clariventris* remained the main numerical dominant species (41.07 %) followed by *Camponotus vividus* (13.11 %) and *T. aculeatum* (11.99 %) (Table 3).

3.1.3 Ant mosaic structure

3.1.3.1 Testing competition hypothesis for space monopolization

A strong evidence for competition-based structuration of the ant mosaic was noted during the 2006 in Bokito and Ngomedzap. In fact, in these communities, the observed C-score value was higher than the simulated C-score value; and the obtained SES value was out of bornes of non-significant difference comprised between -2 and 2 interval (Fig. 1). At Obala however, evidence for competition-based ant community structure was not obvious. One year after insecticide-treatment (2007) both at Obala and Bokito, inter-specific competition remained the deterministic factor of ant communities structure. Nevertheless, at Ngomedzap analyses failed to confirm that ant community structure resulted from competition (Fig. 1).

The black continuous vertical line represents the observed index value (Iobs), the arrow indicates the mean of the Simulate Index (Isim) and the pairs of black vertical thin-dashed and thick-dashed lines represent respectively one- and two-tailed 95% confidence intervals. Large positive values of Standardized Effect Size (SES) indicate increasingly small upper-tail probabilities, and large negative values of SES indicate increasingly small lower-tail probabilities. Non-significant tail probabilities fall between -2.0 and +2.0.

Table 2. Variation of ant abundance and ant occurrence before treatment (2006) in the three studied Cameroonian cocoa farms

Species	Site					
	Bokito		Obala		Ngomedzap	
	Ab	Oc	Ab	Oc	Ab	Oc
Atopomyrmex mocquerysi E. Andre, 1889	349(5.89)	27(27.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
Camponotus acvapimensis Mayr, 1862	111(1.87)	30(30.0)	25(0.64)	13(13.0)	18(4.48)	13(13.0)
Camponotus vividus F. Smith, 1858	116(1.96)	40(40.0)	98(2.52)	29(29.0)	18(4.48)	11(11.0)
Cataulacus guineensis F. Smith, 1853	1667(28.15)	60(60.0)	24(0.62)	14(14.0)	3(0.75)	3(3.0)
Crematogaster clariventris Mayr, 1895	38(0.64)	3(3.0)	4(0.10)	3(3.0)	136(33.83)	28(28.0)
Crematogaster gabonensis Emery, 1899	14(0.24)	6(6.0)	405(10.40)	65(65.0)	1(0.25)	1(1.0)
Crematogaster striatula Emery, 1892	2(0.03)	2(2.0)	0(0.0)	0(0.0)	96(23.88)	22(22.0)
Oecophylla longinoda Latreille, 1802	1526(25.77)	59(59.0)	2779(71.38)	45(45.0)	0(0.0)	0(0.00)
Pheidole megacephala Fabricius, 1793	0(0.00)	0(0.0)	5(0.13)	4(4.0)	29(7.21)	2(2.0)
Polyrachis decemdentata Andre, 1889	908(15.33)	81(81.0)	203(5.21)	32(32.0)	1(0.25)	1(1.0)
Tetramorium aculeatum Mayr, 1866	968(16.35)	54(54.0)	10(0.26)	1 (1.0)	12(2.99)	6(6.0)
Other species	223(3.77)	-	340(8.73)	-	88(21.89)	-
Total	5922	100	3893	100	402	100

Ab and Oc representing ant abundance an ant occurrence on the trees respectively, relative abundance and occurrence are given into brackets

Table 3. Variation of ant abundance and ant occurrence after insecticide treatment (2007) in the three studied Cameroonian cocoa farms

Species	Site					
	Bokito		Obala		Ngomedzap	
	Ab	Oc	Ab	Oc	Ab	Oc
Atopomyrmex mocquerysi E. Andre, 1889	81 (1.97)	13 (13.0)	1 (0.03)	1 (1.0)	1 (0.03)	1 (1.0)
Camponotus acvapimensis Mayr, 1862	206 (5.01)	40 (40.0)	22 (0.62)	9 (9.0)	94 (2.78)	32 (32.0)
Camponotus vividus Smith, 1858	3 (0.07)	3 (3.0)	73 (2.05)	33 (33.0)	444 (13.11)	43 (43.0)
Cataulacus guineensis Smith, 1853	5 (0.12)	5 (5.0)	24 (0.67)	11 (11.0)	22 (0.65)	13 (13.0)
Crematogaster clariventris Mayr, 1895	0 (0.00)	0 (0.0)	28 (0.79)	8 (8.0)	273 (8.06)	35 (35.0)
Crematogaster gabonensis Emery, 1899	1 (0.02)	1 (1.0)	1313 (36.84)	85 (85.0)	111 (3.28)	15 (15.0)
Crematogaster striatula Emery, 1892	2 (0.05)	1 (1.0)	9 (0.25)	2 (2.0)	1391 (41.07)	67 (67.0)
Oecophylla longinoda Latreille, 1802	3222(78.34)	82(82.0)	1598(44.84)	26(26.0)	12 (0.35)	1 (1.0)
Pheidole megacephala Fabricius, 1793	39 (0.95)	6 (6.0)	13 (0.36)	2 (2.0)	189 (5.58)	11 (11.0)
Polyrachis decemdentata Andre, 1889	140 (3.40)	45(45.0)	93 (2.61)	18(18.0)	2 (0.06)	2 (2.0)
Tetramorium aculeatum Mayr, 1866	314 (7.63)	38(38.0)	58 (1.63)	26(26.0)	406 (11.99)	65 (65)
Other species	100 (2.43)	-	332 (9.32)	-	442 (13.05)	-
Total	4113	100	3564	100	3387	100

Ab and Oc representing ant abundance an ant occurrence on the trees respectively, relative abundance and occurrence are given into bracket

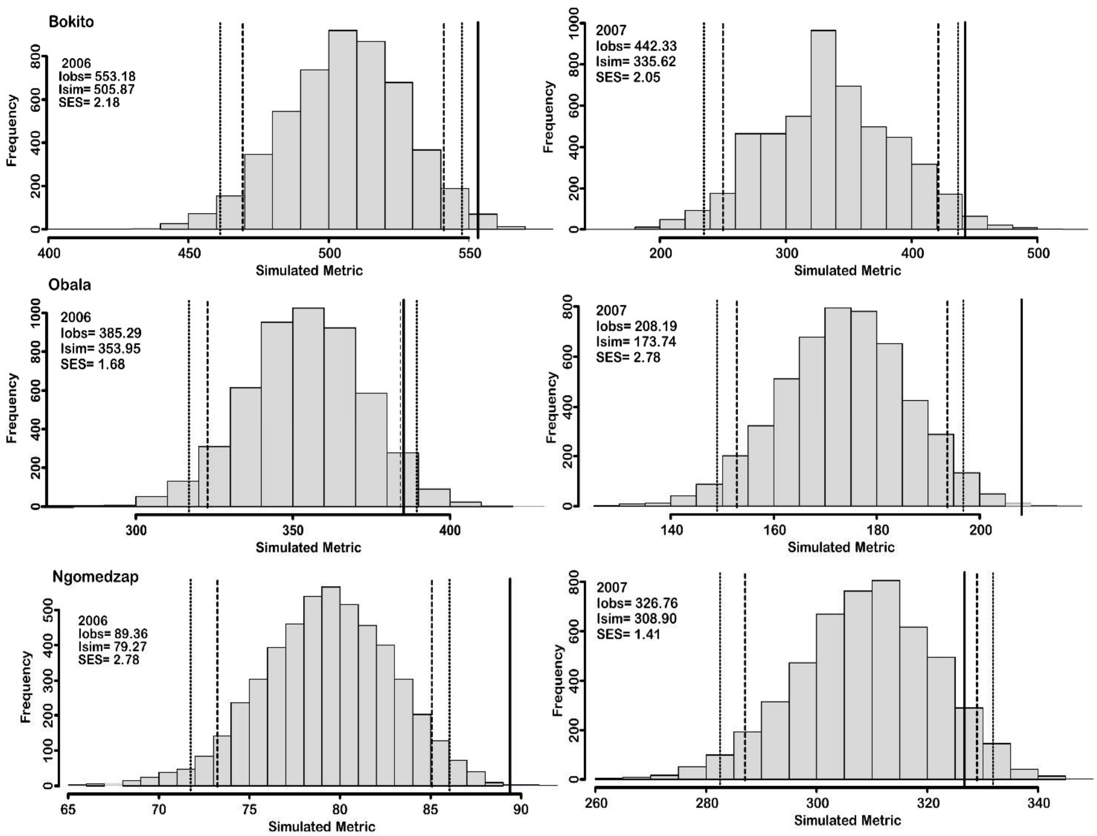
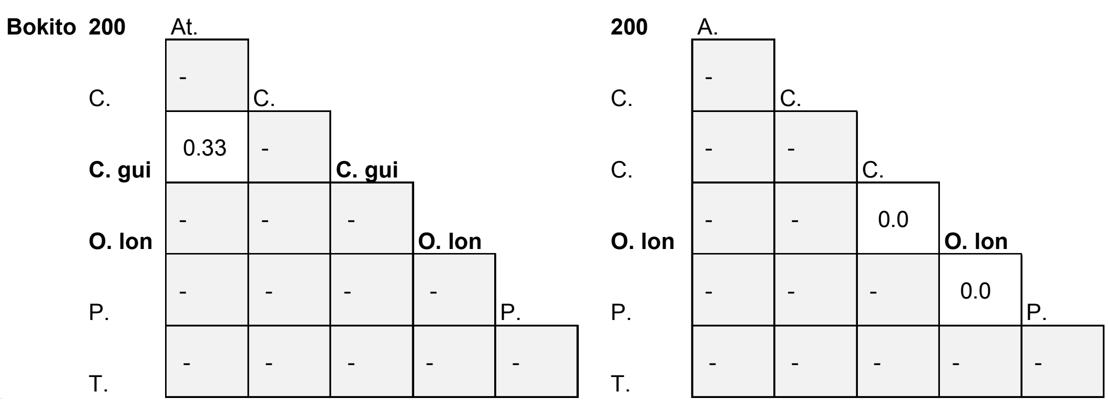


Fig. 1. Interspecific competition hypothesis testing before and after insecticide treatment on numerical dominant species in ant communities in Cameroon cocoa farms based on null model

3.1.3.2 Association model between numerical dominant species before treatment

Before treatment, on the basis of Spearman correlated test, *O. longinoda* appeared negatively associated with *C. guineensis* (r= -0.18; p= .05; n= 67) at Bokito (Fig. 2, Bokito 2006); while at Obala, *O. longinoda* was negatively associated with *C. gabonensis* (r= -0.43; p= .05; n= 78) (Fig. 2). At Ngomedzap, a negative relationship was found between *C. clariventris* and *C. striatula* (r= -0.82; p= .05; n= 47) (Fig. 2, Ngomedzap 2006).



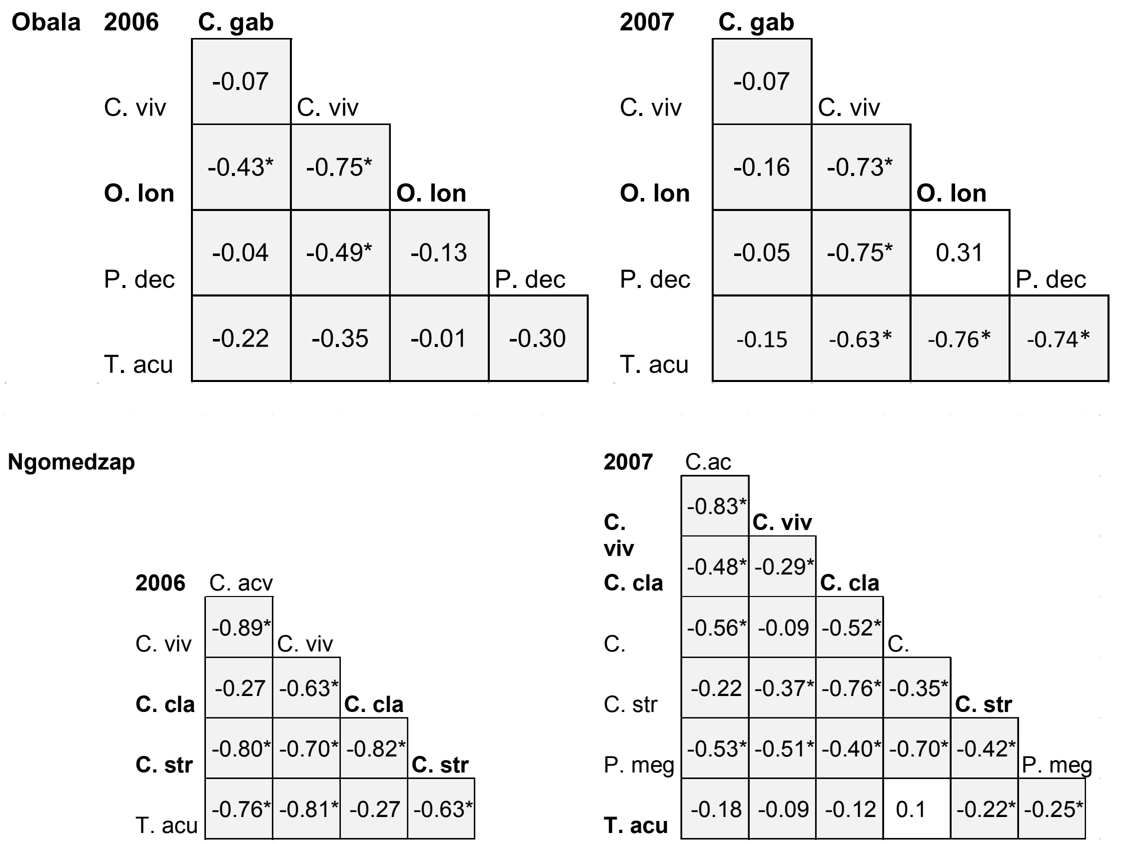


Fig. 2. Association model between numerical dominant and subdominant ant species before (2006) and after (2007) insecticide treatment at Bokito, Obala and Ngomedzap cocoa farms

One year after the treatment, *O. longinoda* appeared as the unique dominant species in Bokito farm (Fig. 2, Bokito 2007). *Oecophylla longinoda* and *C. gabonensis* remain dominant at Obala and negative relationship was found between them (r= -0.16; p= .05; n= 78) (Fig. 2, Obala 2007). Following insecticide treatment, *C. vividus* and *T. aculeatum* acquired dominant statute at Ngomedzap and established negative relationships with both *C. striatula* and *C. clariventris* (Fig. 2, Ngomedzap 2007).

3.1.3.3 Association model between numerical dominant and subdominant species

Before treatment we found a negative relationship between *O. longinoda* and *P. decemdentata* (r= -0.01; p= .05; n=71) at Bokito farms (Fig. 2, Bokito 2006). At Obala, *C. gabonensis* was negatively associated with *C. vividus* (r= -0.07; p= .05; n= 68) and *P. decemdentata* (r= -0.04; p= .05; n=73) (Fig. 2, Obala 2006) while at Ngomedzap, negative relationships were found between *C. clariventris* and *C. acvapimensis* (r= -0.27; p= .05; n= 33) and between *C. clariventris* and *T. aculeatum* (r= -0.27; p= .05; n= 30) (Fig. 2, Ngomedzap 2006).

After treatment and plot recolonization, positive non-significant relationships were found between *O. longinoda* and *P. decemdentata* and between *O. longinoda* and *Ca. guineensis* at Bokito farm (Fig. 2, Bokito 2007); whereas a negative non-significant association was found between *C. gabonensis* and *T. aculeatum* at Obala (r= -0.15; p= .05; n= 79) (Fig. 2, Obala 2007). At Ngomedzap, negative significant association was found between *Cr. striatula* and *P. Megacephala* (r= -0.42; p= .05; n= 72) and positive between *C. clariventris* and *T. aculeatum* (r= -0.12; p= .05; n= 72) during the first sampling (Fig. 2, Ngomedzap 2007).

Numerically dominant species are in bold. Negatives relationships were in grey and positives in black. The star in superscript corresponds to the significant relationship at 5 % confidence interval. C.gui: *Cataulacus guineensis*; C.acv: *Camponotus acvapimensis*; C. Cla: *Crematogaster clariventris*, C. str: *Crematogaster striatula*; O.lon: *Oecophylla longinoda;* T.acu: *Tetramorium aculeatum*.

3.2 Discussion

Before and after treatment, seven numerical dominant species were identified census [29]: *C. guineensis, C. vividus, C. gabonensis, C. striatula, C. clariventris, O. longinoda,* and *T. aculeatum.* These species, with a few exceptions have been recorded and regularly cited as numerical dominant and most frequently found in various African agroforestry systems by various authors. For instance, in Ghanaian's cocoa farms, *C. clariventris, C. striatula, T. aculeatum, O. longinoda* and *C. acvapimensis* have been found and recorded as dominant [1, 11]. In Cameroon, *T. aculeatum, C. gabonensis, O. longinoda* and *Pheidole megacephala* was recorded as dominant at Nkoevome cocoa farms [30] and in the secondary forest [31,32].

Based on the null model, the community structure of numerical dominant species described in the three studied cocoa plots was globally structured by competition with a slight variation among sites. Between 2006 and 2007, two antagonistic situations were founded: (1) at Obala, before treatment, the role of competition as a structuring factor of dominant ant species was not evident but it appeared evident after treatment; (2) at Ngomedzap it was the contrary. To explain these observations we suggest that: (1) habitat heterogeneity, that involves the diversification of nesting sites and other resources may contribute to limiting the risk of competition between dominant species; (2) anthropogenic disturbances (mainly insecticide and fungicide treatments) may induce the creation of empty space in the ant mosaic by damaging the colony of dominant ant species and the struggle for the colonization of these free spaces favor the establishment of competition; (3) some dominant arboreal ant species like *C. striatula* and *C. clariventris* are weakly affected by the treatments as they nest in a twig or build their nest with a carton on a shade tree. As such, they have the ability to rapidly recolonize free space to prevent the establishment of other competitive ant species. Moreover, each dominant species struggles to control subdominant species that constitute another potential competitor. So we suggest that maintenance of the dominant status depends not only on the ability of a dominant species to control other dominant species, but also on their ability to exert a control on subdominant species in their territory.

Ant species were classified into tree ecological groups: (i) dominant (numerical dominant census) [3, 29], (ii) subdominant and (iii) non-dominant species [1, 5, 33]. Among the numerically dominant species recorded in this study, *C. clariventris, C. striatula, T. aculeatum* and *O. longinoda* have been reported as ecologically dominant in Ghanaian's cocoa farms and various ecosystems in Cameroon including cocoa farm [21]. Dominant status of opportunistic ant species like *C. guineensis* and *C. vividus* was not reported in the literature and may be explained by the habitat structure and farm management practices such as pruning, fungicide and insecticide treatments that frequently affect the populations of dominant species.

It seems also that the surrounding environment dominated by savannah and the poor shade canopy may influence the ant community composition more than human made forests where the cocoa is cultivated as is the case at Bokito. Also, shade density might be an important factor as stated [11]. The previous author, hypothesized that *C. acvapimensis* and *O. longinoda* dominate in young cocoa farms with a poor shade canopy density or in poor shade canopy inside cocoa farm and as such have a strong impact on ant structure as well. Also, [7] found a strong spatial relationship between poor shade and the high occurrence of O. longinoda at Bokito and Obala farms; and a clear relationship with shaded farms at Ngomedzap for *Crematogaster* species. The associated trees in the farm were dominated by fruit trees at Bokito and Obala whereas timber trees were weakly represented in both sites. However, at Ngomedzap farms, high density of timber trees compared to fruit trees may favor the colonization of farms by *Crematogaster* species. *Crematogaster clariventris* usually build their nests on the shade trees; whereas, *C. striatula* are opportunistically nesting in trees excavations [34]. This particular nesting behavior can keep colonies free from insecticide treatment and other farmer practices that contribute to destabilize arboreal ant communities.

Before and after treatment, interaction between numerical dominant and subdominant species were negative, suggesting mutual exclusion. Sometimes, positive relationships were reported among dominant species; it's the case between *C. clariventris* and *T. aculeatum* found in Ghana in a cocoa farm [12]. This relationship is only possible because of a temporal separation of their activity [35], by imitation of colonial odor [12] or sometimes by a specific architecture of the trees. The most association we found were negative, probably impacted mainly by frequencies of insecticide and fungicide treatments. In fact, there is a great difference in frequency of insecticide and fungicide treatments within the three studied sites.

4. CONCLUSION

Based on the null model, ant communities in the three study plots were structured by competition with a little variation induced by site effect and insecticide treatment effect. Seven numerical dominant species were recorded: *Cataulacus guineensis, Camponotus vividus, Crematogaster gabonensis, Crematogaster striatula, Crematogaster clariventris, Oecophylla longinoda,* and *Tetramorium aculeatum*. Most relationships found between dominant and subdominant species were negative before and after treatments, suggesting that ant mosaic is basically leaned on mutual exclusion between species. Habitat structure and farm management practices in relation to fungicide and insecticide treatments favor the acquisition of the dominant status by non-territorial species.

DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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