

SPATIAL RELATIONSHIPS BETWEEN DOMINANT ANTS AND THE COCOA MIRID
SAHLBERGELLA SINGULARIS IN TRADITIONAL COCOA-BASED AGROFORESTRY SYSTEMS

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SUMMARY

Manipulating ant communities to control pests of cocoa has proven to be a promising strategy, especially in Asia. However, concerning African cocoa mirids, the main pests of cocoa in Africa, basic knowledge on mirid-ant relationships is still incomplete. Our study aimed to characterize the spatial relationships between dominant ant species and the mirid *Sahlbergella singularis* (Hemiptera: Miridae) in traditional cocoa-based agroforestry systems of Cameroon. Over two consecutive years, mirid and ant populations were assessed by a chemical knock-down sampling method in four plots of 100 cocoa trees, located in three different agroecological zones in the Centre region of Cameroon. Mapping procedures were used to display spatial distribution of mirid and ant populations. Also, we adapted spatial statistics methodologies of point pattern analysis to consider the regular tree position effects on insect positions. These techniques allow testing the statistical significance of Poisson null models, leading to the classification of the spatial patterns of insects into association vs. segregation. Our results clearly demonstrated spatial segregation between mirid and the dominant weaver ant *Oecophylla longinoda*, known as a key-predator in natural ecosystems. Weaver ant trumps, especially its dominant status in ant communities of cocoa ecosystems and its ecological preferences for open habitats, make it a promising candidate for conservation biocontrol against cocoa mirids in Africa.

INTRODUCTION

Manipulating ant communities to control pests of cocoa has proven to be a promising strategy, especially in Asia. For example, the black ant *Dolichoderus thoracicus* has shown real potential to protect cocoa pods from damage by *Helopeltis theivora* (Miridae) in Malaysia (Khoo & Ho, 1992). Introduction of exotic ant species for biological control of local cocoa pests has been thus considered in Asian cocoa producing countries (Majer, 1994). In West Africa, cocoa-based agroforestry systems hold the conditions for using ants in pest management: ants are particularly numerous and diversified, and communities include generalist predators, which may very well prey upon cocoa pests, such as cocoa mirids. Thus, *Oecophylla longinoda* (Latr.), *Tetramorium aculeatum* (Mayr) and some species of genera *Camponotus*, *Crematogaster* and *Polyrhachis* have been shown to be numerically dominant in cocoa plantations of Ghana and are known to be key predators of tropical ecosystems (Williams, 1954; Majer, 1972, Bigger, 1981). However, very few studies have shown the real impact of ants on cocoa mirids and their conclusions are still controversial. For example, in Ghana, Williams (1954) showed that cocoa trees with *T. aculeatum* and *O. longinoda* colonies were less damaged by mirids than neighbor trees. However, he suggested that this could be linked rather to ant colonies preference for healthy cocoa trees without mirid damage, than to predation upon mirids. In Cameroon, although ant communities of cocoa ecosystems have been described (Jackson, 1984, Tadu, 2010), basic knowledge on pest-ant relationships is lacking. Our study aimed to characterize the spatial relationships between dominant ant species and the mirid

Sahlbergella singularis (Hemiptera: Miridae) in order to better understand ecological interactions between mirids and ants for biocontrol strategy development.

MATERIALS AND METHODS

Study sites and assessment of insect populations

Over two consecutive years (2006 and 2007), mirid and ant populations were assessed in four plots of 100 cocoa trees, delimited in four traditional cocoa-based agroforestry systems. The farms were located in three different agroecological zones in the Centre region of Cameroon, two farms near Bokito (Bok1, 04°34'29''N 11°10'45''E and Bok2, 04°29'24''N 11°04'42''E), one farm near Obala (Oba, 04°06'19''N 11°28'40''E) and one farm near Ngomedzap (Ngo, 3°16'10''N 11°13'21''E). We assessed insect populations by a chemical knock-down sampling method at the population peak for mirid in the region (August-September) (see Babin *et al.*, 2010 for more details). Mirids and ants sheltered by each cocoa tree were identified and numbered. For each sample, two to four ant species were arbitrarily identified as numerically dominant according to their number compared to numbers of the other ant species.

Spatial analyses

Mapping procedures were used to display spatial distribution of mirid and ant populations. Then, we used bivariate point pattern analysis to study the results of potential ecological interactions among mirids and ants. We adapted the K-function from Ripley (1977) to consider the regular tree position effects on insect positions by discretizing the space (see O'Driscoll, 1998 or Tentelier & Piou, 2011 for examples of discrete space K-function). We tested two types of null hypotheses for each couple of mirid-ant species: 1) there was no spatial interaction, 2) given the spatial distributions of the two, which follow specific ecological processes, there was no interaction. For these, we used two tests of respectively: 1) the spatial randomization of all point positions, 2) the randomization of the species label of these points. These techniques allowed testing the statistical significance of deviation of our data from the null models, leading to the classification of the spatial relationships of insects into association, segregation or no spatial relationships. Ant-mirid ecological interactions were hypothesized according to these results and existing knowledge.

RESULTS

Among the 60 ant species collected, 10 were considered as numerically dominant in at least one of the 8 samples (4 plots x 2 years) (Table 1). *Oecophylla longinoda* was numerically dominant in the four samples of the Bokito plots. By contrast, *Crematogaster striatula* was dominant in the four samples of Ngomedzap and Obala sites. *Crematogaster gabonensis* and *Camponotus vividus* were dominant in three samples, *Tetramorium aculeatum*, *Polyrhachis decemdentata* and *Dorylus nigricans* in two samples, and finally *Crematogaster clariventris*, *Cataulocus guineensis* and *Camponotus acvapimensis* were numerically dominant in one sample.

Figures 1 and 2 show distribution maps for *S. singularis* and dominant ants of two representative samples, Bak1 and Bak2 for year 2006. *S. singularis* and the different ant species were clearly showing spatial aggregation when considered separately. Distribution maps also revealed that *S. singularis* and *O. longinoda* tended to segregate in the two plots where this species was dominant.

Table 1 gathers the results of interpretation of K-functions constructed through point pattern analysis. The K-functions clearly confirmed spatial segregation between *S. singularis* and *O. longinoda* in the three samples where this species was dominant. Spatial segregation was also shown for *P. decemdentata* for two samples. *Crematogaster* spp., *Camponotus* spp. and *T. aculeatum* showed segregation, association and even no spatial relationships with mirids, depending on the plot, year of sampling and analysis method.

DISCUSSION & CONCLUSION

First, our results show that the weaver ant *O. longinoda* was always highly dominant in cocoa plots located near Bokito, a site characterized by bush-savanna type vegetation. This suggests that this arboreal species (for nesting and foraging) prefers open cocoa plantations, with low shade level. On the other hand, other species like *C. striatula* were dominant in plots of Obala and Ngomedzap sites, where cocoa is usually grown in more diversified agroforestry systems, with high level of shade. Manipulating ant

communities for pest control implies an in-depth knowledge of ant ecological preferences. Research work is currently dealing with this topic in Cameroonian cocoa ecosystems and preliminary data shows that ant communities vary between localities, depending on natural environment of cocoa plantations (Tadu *et al.*, 2010)

Table 1: Numerically dominant ant species, numbers, and spatial tests for the different plots and years of observation leading to the hypothesized ecological relationships towards *Sahlbergella singularis*.

Ant species	Plot	Year	n	Spatial tests (K-function)		Ecological relationships
				Spatial randomization	Random labeling	
<i>Oecophylla longinoda</i> *	Bok1	2006	1526	Segregation	Segregation	Predation
	Bok1	2007	3222	-	-	
	Bok2	2006	4149	Segregation	Segregation	
	Bok2	2007	10414	Segregation	Segregation	
<i>Crematogaster gabonensis</i>	Bok2	2006	944	Association	Segregation	Neutralism
	Bok2	2007	1023	Association	Segregation	
	Oba	2007	1137	No relation	Segregation	
<i>Crematogaster striatula</i>	Oba	2006	695	No relation	Segregation	Neutralism
	Oba	2007	1201	No relation	Segregation	
	Ngo	2006	96	No relation	Segregation	
	Ngo	2007	1391	Segregation	Segregation	
<i>Crematogaster clariventris</i>	Ngo	2006	136	Segregation	Segregation	Uncertain
<i>Tetramorium aculeatum</i>	Bok1	2006	968	Association	Segregation	Neutralism
	Ngo	2007	406	No relation	Segregation	
<i>Polyrhachis decemdentata</i>	Bok1	2006	908	Segregation	Segregation	Predation
	Bok2	2006	646	Segregation	Segregation	
<i>Cataulacus guineensis</i>	Bok1	2006	1627	Segregation	Segregation	Uncertain
<i>Camponotus vividus</i>	Bok2	2006	570	Association	Segregation	Neutralism
	Oba	2006	537	Association	Segregation	
	Ngo	2007	444	Association	Segregation	
<i>Camponotus acvapimensis</i>	Bok2	2007	849	Association	Segregation	Uncertain
<i>Dorylus nigricans</i>	Oba	2007	984	Association	Segregation	Neutralism
	Ngo	2007	1919	Association	Segregation	

* *Oecophylla longinoda* was numerically dominant in plot Bok1, year 2007, but mirids were not numerous enough to conduct spatial analysis.

Most of dominant ants show variable spatial relationships with mirids, suggesting that mirid distribution was apparently not affected by these species. For example, results for *Tetramorium aculeatum*, which is sometimes considered as a potential biocontrol agent for cocoa mirids in West Africa (Entwistle, 1972), suggest that ecological relationship between *T. aculeatum* and *S. singularis* is rather neutralism than predation. The army ant *D. nigricans* also displayed variable spatial association with mirids suggesting they do not interact. Contrary to all of the other dominant ants in our study, the army ant is a tramp species, without delimited territory, from which it could expel other insects. Moreover, *D. nigricans* is a ground nesting and foraging ant and our results confirm the shared assumption that it does not forage on cocoa trees (Room, 1971).

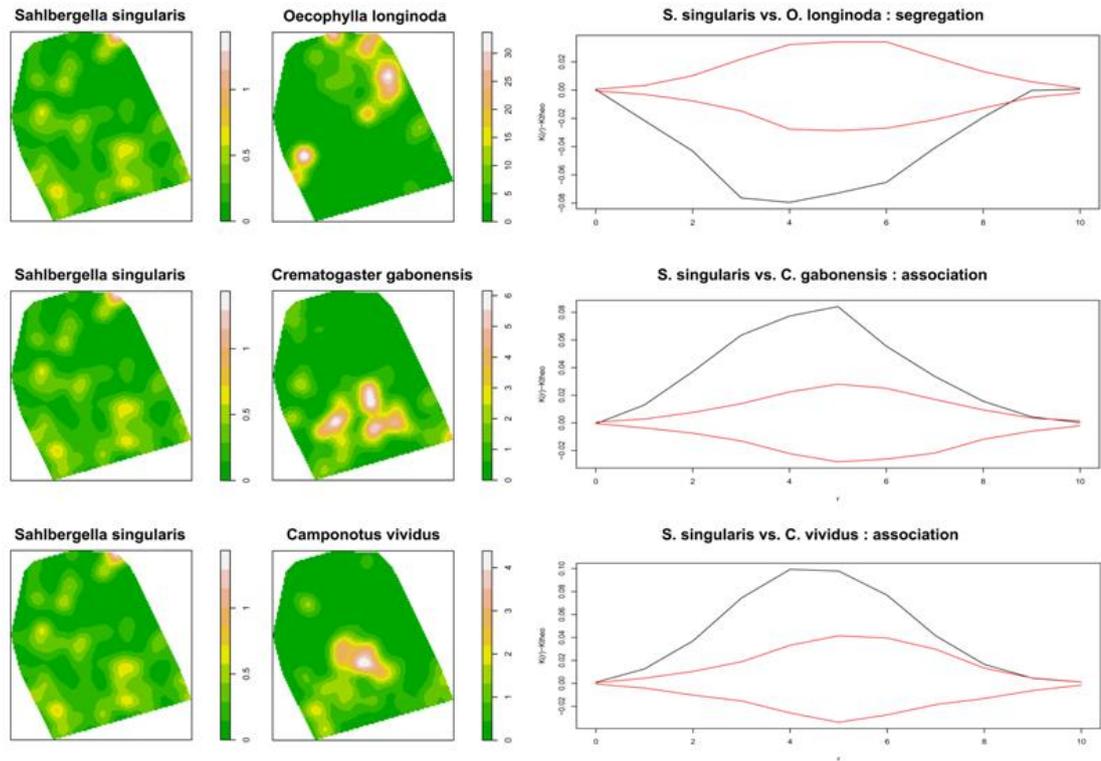


Figure 1: Distribution maps for *Sahlbergella singularis* and 3 dominant ant species for plot Bok1, year 2006, and relevant K-function curves (black curves) showing the spatial relationship between mirid and ants. Red curves show the Poisson null model interval. Black curve between red curves = no spatial relationship, black curve below red curves = segregation, black curve above red curves = association.

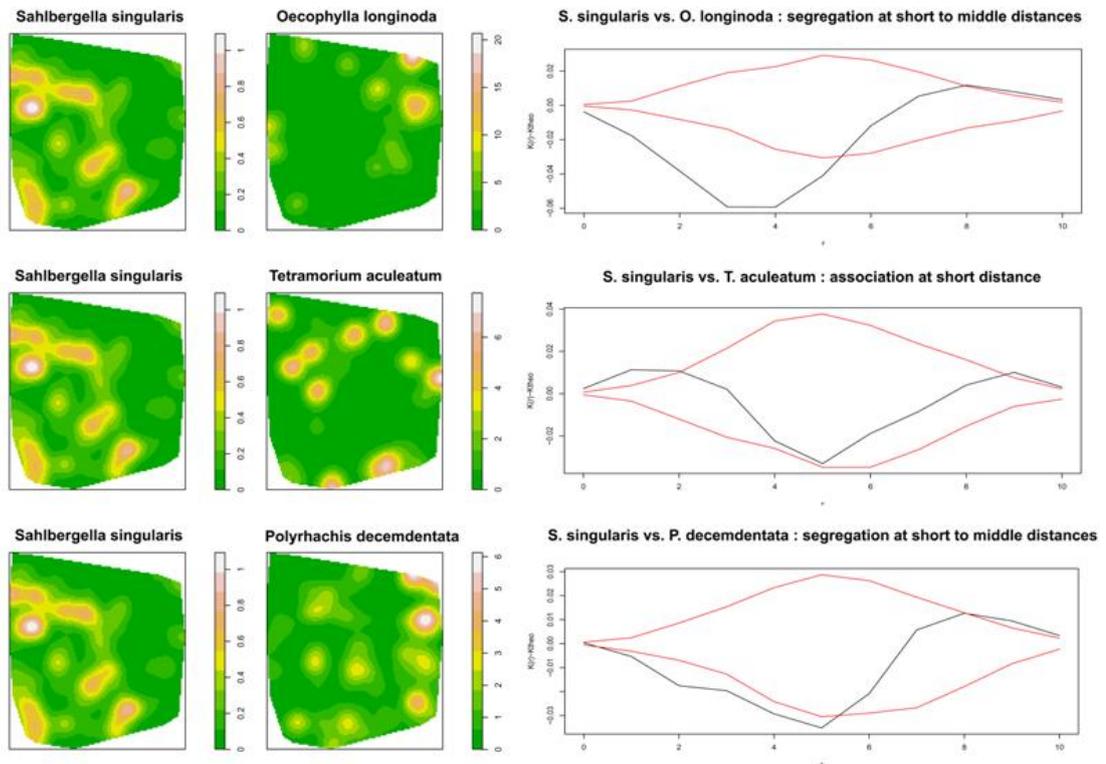


Figure 2: Distribution maps for *Sahlbergella singularis* and 3 dominant ant species for plot Bok2, year 2006, and relevant K-function curves (black curves) showing the spatial relationship between mirid and ants. Red curves show the Poisson null model interval. Black curve between red curves = no spatial relationship, black curve below red curves = segregation, black curve above red curves = association.

Only two species showed constant spatial segregation relationships with mirids: *Oecophylla longinoda* and *Polyrhachis decemdentata*. The second species is a ground nesting and arboreal foraging ant (Room, 1971). Our results show that *P. decemdentata* seem to forage on cocoa trees sheltering *O. longinoda*, for the most part. Ecological relationships between *P. decemdentata* and *S. singularis* may be influenced by the presence of the highly dominant *O. longinoda* on the same trees. In any case, these results show that it is important to consider the ant community as a whole and to characterize relationships between ants in order to develop IPM strategies based on ant predation. An example of competition between dominant ants and its implication in biological control is given by Seguni *et al.* (2011).

According to the results of spatial analysis, the weaver ant *Oecophylla longinoda* showed undeniable predation relationship toward *S. singularis*. This is consistent with previous works in Africa, which showed predation of weaver ants on other crop pests, such as fruit flies (Van Mele *et al.*, 2007). Our study also showed that *O. longinoda* may be highly dominant when habitat suits to its colonies. In this case, competition with other dominant ant species may be limited. Finally, *O. longinoda* preference for open habitats, such as unshaded or slightly shaded cacao plantations may lead to the presence of the ant in those plantations or areas of plantations where mirids are more frequently found (Babin *et al.*, 2010).

To conclude, as the close Asian species *O. smaragdina* which has been used by Chinese farmers for centuries to clean their fruit trees (Way & Khoo, 1992), *O. longinoda* should be considered as an efficient candidate for conservation biocontrol in African cocoa plantations.

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