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RESEARCH ARTICLE

GEOGRAPHICAL DISTRIBUTION OF MIRIDSIN THE COCOA ORCHARD OF CÔTE D'IVOIRE

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ABSTRACT

Cocoa orchard is the target pests as mirids that cause loss of very important to farmers production. To reduce the populations of these insects, leaches were conducted in seven districts of cocoa production in Ivory Coast. Sheeted cocoa underwent treatments with the insecticide super Callifan 40 EC. Insecticide treatments helped raise and identify different species of mirids. The results revealed the presence of four species of mirids: *Sahlbergellasingularis, Distantiellatheobromae, Bryocoropsislaticollis* and *Helopeltis sp*. The species *S. singularis*, listed in all areas of production, represented 77.93% of the harvested mirids. *B. laticollis* with an attendance rate of 16.50% was limited to the coastal area and mountains district. D. theobromae and Helopeltis sp., Represented respectively 3.76 and 1.8% of harvested mirids.

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INTRODUCTION

Miridsbelongto the order of Arthropods. They are the most damaging insects of the cacao tree. These insects bite stems, branches and pods and causing particularly serious damage. These bites jeopardize the survival of the cocoa and decreases production from 30 to 40% each year. This factsignificantly reduces the yield and therefore the farmer's income (N'Guessan, 2005; Babin et al., 2008; Anikwe and Okelana, 2009). Two miridstribesmeet on the cocoa tree. Mirids Tribe Monaloniini feed by biting almost exclusively young bodies cocoa. Mirids of this tribe preferably bite cherelles and pods (Braudeau, 1969). Mirids Tribe Odoniellini bite pods, the greedy, the twigs and stems. Species like *Bryocoropsislaticollis* not only bite the pods. *S. singularis*and *D. theobromae* feed on cocoa spicy fruit in all stages of development (cherelles and pods), the aoûtées shoots or semi-aoûtées at the ends of branches and orthotropic shoots, called greedy (Babin, 2009). Mirids sting and suck the sap different bodies of the cocoa tree. Two types of damage are caused by mirids: primary damage and secondary damage. The primary damage resulting from the direct action of the bite of these insects.

Bites of Monaloniniitype'smirids produce stigmonoses type lesions (Carayon, 1977). These lesions are more important than those due to most of the other mirids. Lesions caused by these pins are darker than the rest of the organs. Saliva injected by insect poisons and destroys these plant cells on a more or less important area. Immediately after the bite, it occurs around the point of insertion of the rostrum of the bug, a dark green stain. This task is slightly depressed quickly turns brown and becomes black later (**Figure 1**).

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Figure 1. Mirid pitting on pods

Generally pods stitched continue their maturation. A cocoa plot,severely attacked by mirids has defoliated branches. It showed dry leaves carried by the dead branches. A gradual disappearance of the canopy occurs. Cocoa trees are reduced to trunks and often death follows. On mature pods, lesions do not prevent the maturation of the fruit. In contrast, lesions on young pods cause necrosis and fall. On ripened shoots, the bite causes the formation of very characteristic crevices (N'Guessan, 2005).

Secondary damage is due to the invasion of lesions by a fungus: *Calonectriarigidiuscula* Benk (1878). Lesions infected by this fungus are deeper than uninfected. Infected lesions often reach the xylem and phloem. The fungus grows inside the xylem and cambium of the plant. What will cause disruption of the flow of sap. Faced with damage from mirids it is necessary to search for their presence or absence in the different producing areas to establish cocoa mapping and effective fight against these pests schedule.

MATERIALS AND METHODS

Study site

The study was conducted in the southern half, which represents almost all of the production of cocoa in Ivory Coast. It located below the 8th parallel. The Ivorian forest south has a humid tropical climate. It has four seasons of unequal length. These are two rainy seasons and two dry seasons. The long rainy season begins in mid-March and take end to mid-July with a maximum in June. The average rainfall varies from 200 to 600 mm / month. The small rainy season from September to November with an average height of between 100 and 200 mm / month. The long dry season is from December to mid-March with less than 100 mm of rain per month. The short dry season is in August. The Ivorian forest South is characterized by abundant rainfall which varies from 1200 to 1400 mm per year (Kouamé et al., 2006). The annual average temperature of the Ivorian forest south vary from 24 to 32 C. The duration of sunshine is 1,700 hours per year. The average annual relative humidity is always above 80%. The soils of southern Ivory Coast, where cocoa cultivation practice belonging to ferralsols highly desaturated.

Table 1. Localities sampled for the geographical distribution of the cocoa mirids

Districts	Regions	Localities
	Tonkpi	Man, Danané, Zouan-Hounien,
Montagnes	Guémon	Duekoué, Bangolo, Kouibly,
	Cavally	Guiglo, Zagné, blolequin, Toulepleu.
Sassandra-Marahoué	Haut-Sassandra	Saïoua, Doloa, Issia, Vavoua, Zoukougbeu
	Marahoué	Bonon, Bouaflé, Sinfra, Kouetinfla, Kononfla
Bas-Sassandra	Nawa	Buyo, Méagui, Soubré, Grand-Zattry, Gueyo, Okrouyo
	San-Pédro	San-Pédro, Grand-béréby
	Gbôklè	Sassandra, Dakpadou,
Gôh-Djiboua	Gôh	Gagnoa, Bayota, Oumé, Ouragahio, Diéguonefla
	Lôh-Djiboua	Divo, Guitry, Lakota, Hiré, Ogoudou
	Bélier	Yamoussoukro, Kocoumbo, Kossou, Djékanou
Lacs	Moronou	Bongouanou, M'batto, Arrah, Ande, Anoumaba, N'guessankro
	Indénie-Djuablin	Abengourou, Niablé, Aniansue, Bettié, Zaranou
Comoé	Sud-Comoé	Adaou, Ayamé, Nouamou, Krindjabo, Yaou
	Agneby-Tiassa	Agboville, Grand-Morié, Tiassalé, Bacanda, Morokro, Rubino
Lagunes	Mé	Alépé, Adzopé, Affery, Yakassé-Mé

Table 2. Distribution of mirids harvested in the surveyed districts

	S. singularis		*D. theobromae*		*B. laticollis*		*Helopeltissp.*	
Districts	Larvas	Adults	Larvas	Adults	Larvas	Adults	Larvas	Adults
Bas-Sassandra	1925	539	21	37	716	437	72	32
Comoé	1421	437	77	80	633	506	31	60
Gôh-Djiboua	1973	673	166	44	69	84	17	14
Lacs	1280	189	139	21	0	0	0	0
Lagunes	2057	527	24	15	310	225	12	7
Montagnes	478	166	53	10	26	38	7	5
Sassandra-Marahoué	2251	467	3	3	0	2	34	42
Total	11385	2998	483	210	1754	1292	173	160
(%)	61.69	16.24	2.62	1.14	9.50	7.00	0.94	0.87

Sampling Method

The study was conducted in 7 cocoa producing districts (**Table I**). In each district, 20 observation points were selected at 2 points per sub-prefecture or city. Localities are divided on different axes so as to better cover the district. In total 140 observation points were selected in the 7 districts of production. The criteria used for the selection of feet is the presence of at least 5 mirids or drying sheets having suffered attacks mirid. In a plot of 1 ha, 12 feet cocoa, attacked or infested mirids were chosen. In each district, 240 feet of cocoa trees were selected because 24 feet by location. A total of 1680 feet of cocoa have been selected in the 7 districts of productions. Sampling of mirids took place in the months of July, August, September, October and November of 2009 to 2013.

Collection mirids

The method used to collect mirids was the sheeting technique (Coulibaly, 1978). Tarpaulins of16 m2 area are spread out at the base of the identified cocoa. Cocoa trees wheretreated with callifan super 40 EC at the rate 25 ml/l (chemical/water), using a sprayer Cifarelli. The treatments are early morning (between 6 am and 8 pm). Cocoa treeswhere treated individually and each tree received about 1 liter mixedsolution. Collection or pickup mirids on sheets took place five hours after treatment. But before picking up mirids, cocoa trees are shaken in order to bring down all the dead insects retained in the foliage. Mirids and other insects fell on the sheets are collected using flexible stainless steel tongs type and placed in Petri dishes. Identifying and counting mirids are made directly on sheets.

Data Analysis

The data were analyzed using descriptive statistics withXLSAT software (2015). Multivariate analysis was applied to the data: correspondence analysis (CFA) was performed. The aim is to produce a representation in a unique landmark categories in rows and columns to highlight their respective positions. Any attraction and repulsion among districts and mirids were identified.

RESULTS

Inventory of mirids species in different regions

Sampling conducted in the orchard has raised 4 species of mirids. These are *Sahlbergellasingularis* Hgl (1895), *Distantiellatheobromae* Dist (1909), *Bryocoropsislaticollis* Schum (1917) OdonielliniTribe and *Helopeltis sp.*, MonaloniiniTribe.

Distribution of collected mirids

In 7 districts sampled cocoa production, 18455 mirids were collected. These individuals were grouped into four species: *S. singularis*, *D. theobromae*, *B. laticollis* and *Helopeltis sp. S. singularis* is the most abundant species with 14383 individuals representing 77.93% of the collected mirids. It is followed by B. laticollis with 3046 or 16.50% of the workforce mirid. As for the species *D. theobromae* and *Helopeltis sp.*, their numbers were respectively 693 and 333 be 3.76 and 1.81% of the workforce mirid (**Table II**). In all districts *S. singularis* and *D. theobromae* larvae staffing were higher than adults. Concerning *B.laticollis,* larvae numbers were lower in the districts of Gôh-Djiboua, Montagnes andSassandra-Marahoué. *B. laticollis*larvae were 0.82(Gôh-Djiboua) and 0.76 Montagnes) times lower than adults. In the districtSassandra-Marahoué.*B. laticollis*larvae were not harvested.

The number of adult was 2 people in the district. The numbers of larvae *Helopeltis sp.*,were 0.52 (Comoé) and 0.81 (Sassandra-Marahoué) times lower than adults. *B. laticollis* and *Helopeltis sp*. were not collected during the study in the district of Lakes. If we consider 7 districts, in *S. singularis* the number of larvae was 3.8 times higher than the number of adults. In the other three species the coefficient of variation were respectively 2.3 (*D. theobromae*), 1.36 (*B. laticollis*) and 1.08 (*Helopeltissp*).

Geographical distribution of different species of mirids in cocoa farms ofCôte d'Ivoire

The counting of insects from the sampled sites has identified two groups of species of mirids:

- The first consists of 2 species mirids (*S. singularis* and *D. theobromae*) encountered in seven districts. *S. singularis* was collected in all the 140 plots leached in the seven districts of cocoa production in Ivory Coast. *D. theobromae* was collected in 85 plots of seven districts of Ivorian cocoa production. But itsabsence was noticed in several localities of districtSassandra-Marahoué and Lacs. In the District of the Lacs, this species was absent from localities N'Guessankro, Ande, Arrah, Bongouanou, Djékanou and Koussou. In the districtSassandra-Marahoué, this species has not been collected in Vavoua, Zoukougbeu, Gadouan, Bonon and Sinfra (Figure 2).
- The second group includes *B. laticollis*and *Helopeltis sp.*, which were collected in six districts except Lacs's one. *B. laticollis* was encountered in 68 plots of these districts. It was harvested in all localities sampled leached plots in the districts along the coast; except for areas of San-Pedro and Buyo in the district of Bas-Sassandra, the city of Niablé in the district of Comoé and localities Rubino, Morokro and Affery in the district Lagoons. In the Gôh-Djiboua, it was collected in the towns of Gagnoa, Guitry, Divo and Lakota. At the district of Montagnes, *B. laticollis* was found in plots Cavally regions and Tonkpi. In the District of Sassandra-Marahoué, she was met in the locality of Zoukougbeu in Haut-Sassandra (Figure 2).
- *Helopeltis sp.*, was collected in Blolequin, a town in the Cavally region **(**district desMontagnes**)**. It was harvested in Bouafle and Zoukougueu in districtSassandra-Marahoué. At the Bas-Sassandra and Comoé, it was recorded in all plots with the exception of San-Pedro and Buyo. It is in the plots of Gagnoa, Lakota, DivoandGuitry it was collected in the Gôh-Djiboua. At the district level Lagunes, *Helopeltis sp.*, was registered at Bacanda, Tiassalé, Agboville and Alépé. In total, *Helopeltis sp.*, was collected in 52 plots (**Figure 3**).

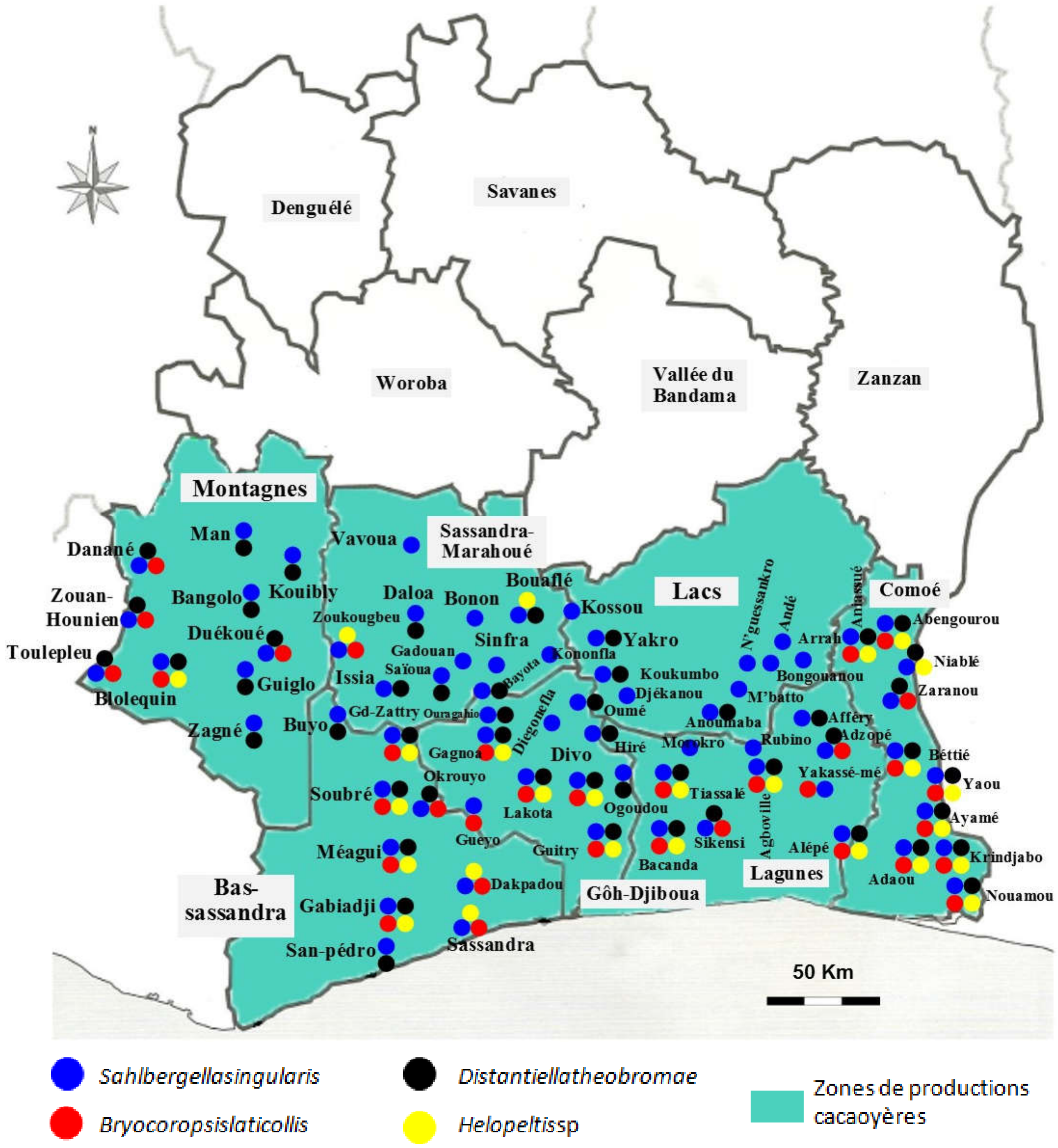

Figure 2. Geographical distribution of miridsspecies in the cocoa orchards of Côte d'Ivoire

Distribution of mirids by the seven districts production

A correspondence analysis (CFA) helped separate the different species of miridstowardseven cocoa producing districts. F1 axes (88.99% of the total inertia) and F2 (10.51% of the total inertia) have represented 99.50% of the total variability (Figure 3). The best-represented districts on the F1 axis were Lagunes (cos^2 = 0.995), Comoé (cos^2 = 0.972), Bas-Sassandra (cos^2 = 0.933), Gôh-Djiboua (cos^2 = 0.882), Montagnes (cos^2 = 0.826), Lacs (cos^2 = 0.809) and Sassandra-Marahoué (cos^2 = 0.770). The most important districts in the definition of this axis were Comoé (contribution of 32.8%), Lacs(15.7% contribution), Gôh-Djiboua (contribution of 14.00%) and Montagnes (contribution of 12.10%). Variables *B. laticollis* (cos^2 = 0.986), *S. singularis* (cos^2 = 0.878) and *D. theobromae* (cos^2 = 0.611) were best represented on the F1 axis. Their contribution was 79.4% for *B. laticollis*, 14.5% for *D. theobromae* and 6.10% for *S. singularis* (Figure 3). *S. singularis* is found in all districts, but very represented in the Gôh-Djibouaand Sassandra-Marahoué. *B. laticollis* and *Helopeltis sp.*, are abundant in the districts of Comoé, Lagunes and Bas-Sassandra. *D. theobromae* is more concentrated in the districts of Lacs and Montagnes.

DISCUSSION

The 4 species of mirids known in the orchard cocoa in Ivory Coast (N'Guessan and Coulibaly, 2000) have been observed in our study. The species *Sahlbergellasingularis*Hgl(1895) is present in all production regions. In addition, their population level was significantly higher than those of other species. Its population represents 77.93% of the total population of all mirid species.*S. singularis* is as the predominant species of the Ivorian cocoa orchard. Nguyen-Ban (1977), N'Guessan (2005) revealed that *S. singularis* is the species most common mirid cocoa orchard of Côte d'Ivoire. Babin et *al.*, (2008) in Cameroon, showed that *S. singularis* is the most important pest of Cameroonian cocoa tree orchard. In Nigeria, Anikwe (2010) and Asogwa et al. (2010) reported that *S. singularis* would be the most damaging kind of mirids Nigeria cocoa plantations. The presence of this species throughout the cacao orchard could be due to the fact that cocoa provided a favorable environment for the development of these mirids. Indeed, *S. singularis* is a species that also feeds on fruits well as the vegetative parts of the cocoa tree (Ayenor et al., 2004). In fact, this ecological niche serve as shelter, food substrate and support for the development of its offspring. *S. singularis* would be present in the primary forest of West Africa on hosts belonging to the same taxonomic family as cacao. With the disappearance of primary forests, this species would be accommodated in cocoa.

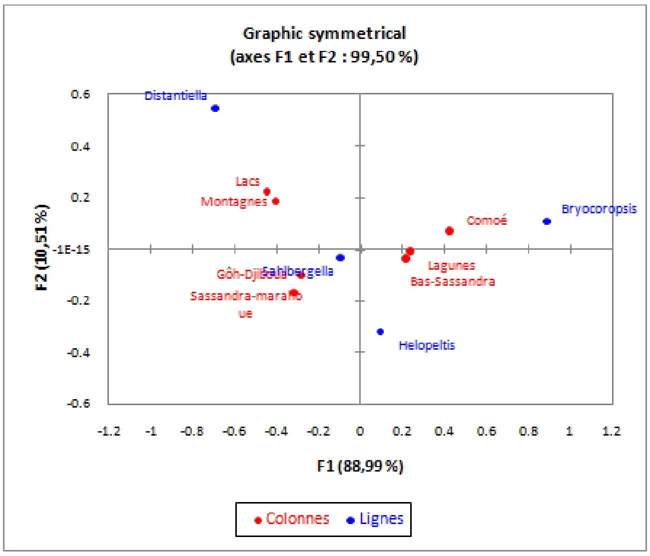

Figure 3. Distribution of four species by the seven districts.

This hypothesis would also explain the relatively high effective *D. theobromae* in cocoa. Furthermore, the results of our inventory revealed that *Distantiellatheobromae*Dist (1909), is less present in the cocoa orchard. The population of *D. theobromae* was 3.76% while the species has virtually the same biology and ecology that same *S. singularis* (Babin, 2009). Mahob et *al.,* (2010) claimed that *S. singularis*and *D. theobromae* were the two most important mirid species of West African cocoa orchard. But the workforce may raise *D. theobromae* recorded in our harvest would hold to the fact that this species would develop preferentially on young feet cocoa. But the Ivorian cocoa orchard is aging (Assiri, 2010).

Also the diet of the insect could be mentioned. Indeed *D. theobromae* may have the ecological niche of another plant to move dry periods during which flushes and fruiting cocoa are rare. In this contest, studies have shown that plants are more diversified alternative hosts for *S. singularis* for *D. theobromae* (Piart, 1977). The low presence of *D. theobromae* could be explained by the gradual disappearance in the forest host plants as *Ceibapentandra* (Bombacacée) and *Adansoniadigitata* (Bombacacée). According toPiart (1977), *D. theobromae* tends to mark a preference for *C. pentandra* when this plant is present in a cocoa attacked. To support this assertion, Piart raised the laboratory larvae and adults of *D. theobromae* on sections of cocoa twigs and cheese. He realizes that the larvae and adults of *D. theobromae* mark a clear preference for *C. pentandra*. But according Gidoin et al., (2014), miriddensity decrease as *D. theobromae* when some randomized forest trees were present compared to an aggregate distribution. According toLavabre (1961), the primary habitat of *D. theobromae* seem to located in Ghana, therefore its conquest of the Ivorian cocoa was not yet effective. Moreover, (Decazy, 1977) showed that the number of eggs laid by *D. theobromae* was higher when females fed on the pods. This may explain the low level of population when the pods are rare on the trees after the great harvest.

*Bryocoropsislaticollis*Schum (1917) represented 16.50% ofmirid harvested in the Ivorian cocoa orchard. *B. laticollis* is the second largest species of the Ivorian orchard. These results differ from those of Nguyen-Ban (1977), which showed that the two most important species in Côte d'Ivoire were *S. singularis*and *D. theobromae*; they accounted for 54.9 and 45.1% of the overall population mirid listed in ten cocoa producing areas. Our results also showed that *B. laticollis* seems to prefer the coastal area where the cocoa trees have fruited throughout the experimental period, due to the high relative humidity (75-83%) of air. This increase is similar to that of Collingwood (1977a) which reported that B. laticollis feeds and breeds on the fruit of the cocoa tree throughout the year due to a more favorable climate linked to the shorter dry period. PIART (1978),also indicated that the climate of the southern Ivory Coast is Guinean forest type with a still high relative humidity and rainfall varying from 1600 to 2500 mm; these conditions being favorable to fruition cocoa and therefore the reproduction of this mirid. This author argues, moreover, that *B. laticollis* has a preference for high humidity areas.

Helopeltis sp. represented 1.81% of mirids collected during this study. This low population rate *Helopeltis sp.* in the cocoa grove could be explained by the fact that the trial period does not correspond to the period of heavy infestations of this species. Also the low *Helopeltis sp.* be explained by the presence of plants such as cashew (*Anacardiumoccidentale* L) area in cocoa in Ivory Coast. For the cashew apple this plant would be appreciated by this species choice situation. Thus the presence of more cashew trees attract this species (Asokan et al., 2012). The rarity of this species in the orchard may be due to the presence of many predators, including *Dolichoderusbituberculatus*Mayr (1862) which would exert a positive control on Helopeltis (Collingwood, 1977b). Ants of Oecophylla and some reduvidaes as *Cosmolestespictipes* and *Euagorusplagiatus* are considered potential predators *Helopeltis* (Collingwood, 1977b and Lavabre 1977). Olotu et *al.*, (2013) showed that *Oecophyllalonginoda* exerted a positive control in this case. Also, according to Caswell (1962), the progressive depletion Helopeltis sp. in the orchard cocoa is due to the adoption of the technique of cocoa in the sun.

Conclusion

Leaching made within seven cocoa producing districts of Côte d'Ivoire revealed the presence of four species of mirids*S. singularis*, *D. theobromae*, *B. laticollis* and *Helopeltis sp*. The distribution of these species in the orchard varied from one district to another. Thus, *S. singularis* was listed species in all areas of production and more widespread in the latter with a workforce of 14,383 people, or 77.93% of total collected insects. *Helopeltis sp*., with an attendance rate of 1.81% was the least represented here. Between these two species ranged *B.laticollis*and *D. theobromae* with 16.50 and 3.76% respectively of the total harvested mirids. *B. laticollis* representing the second most important species is present in the coastal area, especially in the districts of Bas-Sassandra, the Comoé, Lagunes and Gôh-Djiboua. It is also located in the district of the Montagnes. *D. theobromae* is localized in all production districts sampled with a lower effective. *Helopeltis sp.* was observed in the districts of Bas-Sassandra, Comoé, Sassandra-Marahoué, Gôh-Djiboua and Lagunes. Knowledge of the geographical distribution of population'smiridsin these 7 production districts allow the establishment of a chemical control schedule in the protection of the Ivorian cocoa orchard.

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