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Spatial and temporal dynamics of Coccinellidae (Coleoptera) and Formicidae (Hymenoptera): Two families of beneficial insects, in cotton fields in the Tchologo region (Northern Côte d'Ivoire)

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Abstract
This study was conducted to analyse spatio-temporal dynamics and the impact of rainfall and temperature on two beneficial insect-families in cotton farms in Côte d'Ivoire, Formicidae and Coccinellidae. They contribute to reduce the pest populations in the cotton farms. Data were collected in four localities treated with chemical vulgarized. Sampling, of rainfall and temperature data were collected respectively by direct counting, capture with mowing net, traps, rain gauges and thermo-hygro-meters installed. We have inventoried 7675 insects including 93% for the Formicidae and 7% for the Coccinellidae. Analysis of variance, showed that there is a significant difference in aboundance of Formicidae but there is no significant difference between the population of Coccinellidae. Rainfall and temperature have not affected the dynamics of beneficial insects populations. Knowledge of those beneficials insects is important to developt an integrated cotton pests control methods.

Keywords: Cotton, beneficial insects, Formicidae, Coccinellidae, Côte d'Ivoire

1. Introduction
Cotton is most fiber's crop grown in the world. Approximately, 26 million tons of cotton fiber are produced annually [1]. China, United States, India and Pakistan produces more than 60% of cotton fiber [2]. Worldwide, West Africa prodiuce only 5% of international production. In Africa countries the cotton contributes considerably to the employment and income of rural populations [3, 4].

Cotton play a strategic position in the agricultural economy of the savannah areas, because of his important role to the socio-economic development of these populations [4, 1]. In addition, cotton cultivation has contributed to modernize the agriculture in these areas through mechanization and crop intensification. It also contribute to the improvement of the living conditions of rural populations, the organization of cooperative movment and industrial development through the construction of factories [5, 4]. However, cotton production is faced to many constraints that deteriorate its production and causes economical drop for producers and cotton companies. In particular, the parasitism caused by insects and other arthropods is particularly important and diversified [6]. They cause a significant drope of the yield, in a proportion of 50 to 75% without phytosanitary protection [7-10]. According to Matthews [11] mentioned by Castella [12], cotton predatory insects includes no less than 1000 species, some of them are present in all production areas in the world. Several control strategies have been developed in order to maintain pest population at economically acceptable levels [13, 9]. These include chemical control, agricultural pratices and varietal control. However, although many studies have shown the importance of beneficial insects in the context of integrated protection. This method is still very limited and vulgarised in rural areas in Côte d'Ivoire, particularly in cotton growing zones. A better knowledge of the main beneficial insects present in cotton fields in Côte d'Ivoire and particularly in the Tchologo region and their role in crop protection should be a first step towards developing an integrated pests control program in a context of reducing pesticide use and environment preservation. The main objective of the present study was to evaluate the spatio-temporal dynamics and the impact of the rain and temperature on Formicidae and Coccinellidae populations. Specifically, the objective is to forecast population variations and to understand the environmental influences on their dynamics. This will allow the action of beneficial insects to be taken into account in an integrated pest management program.

2. Materials and Methods

2.1 Study sites

The work was realized in the cotton cultivation areas, (9° 35′ 00″ north, and 5° 11′ 00″ west) located in the north of Côte d'Ivoire (Figure 1). The climate is Sudanese type with two main seasons. A dry season from November to April characterized by harmattan with peaks in December and February and a rainy season from May to October with peaks in August and September. Annual rainfall fluctuates between 1000 mm and 1400 mm (Figure 2).

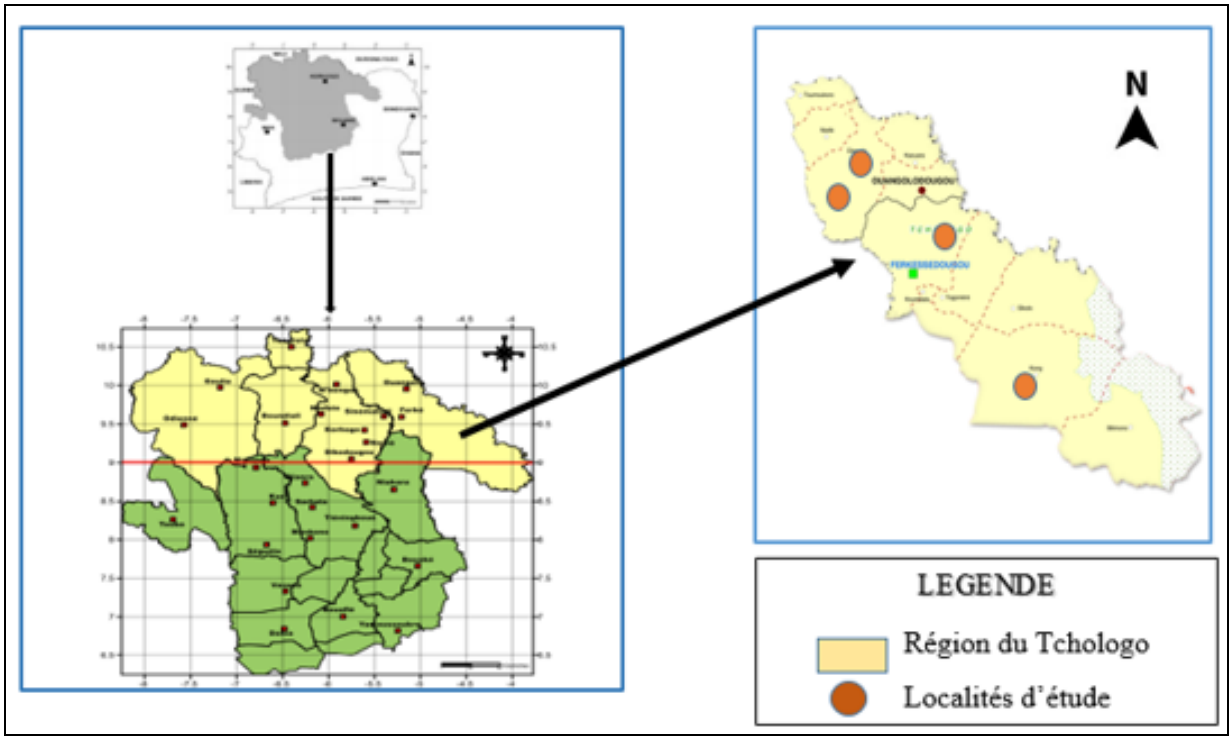

Fig 1: Study sites

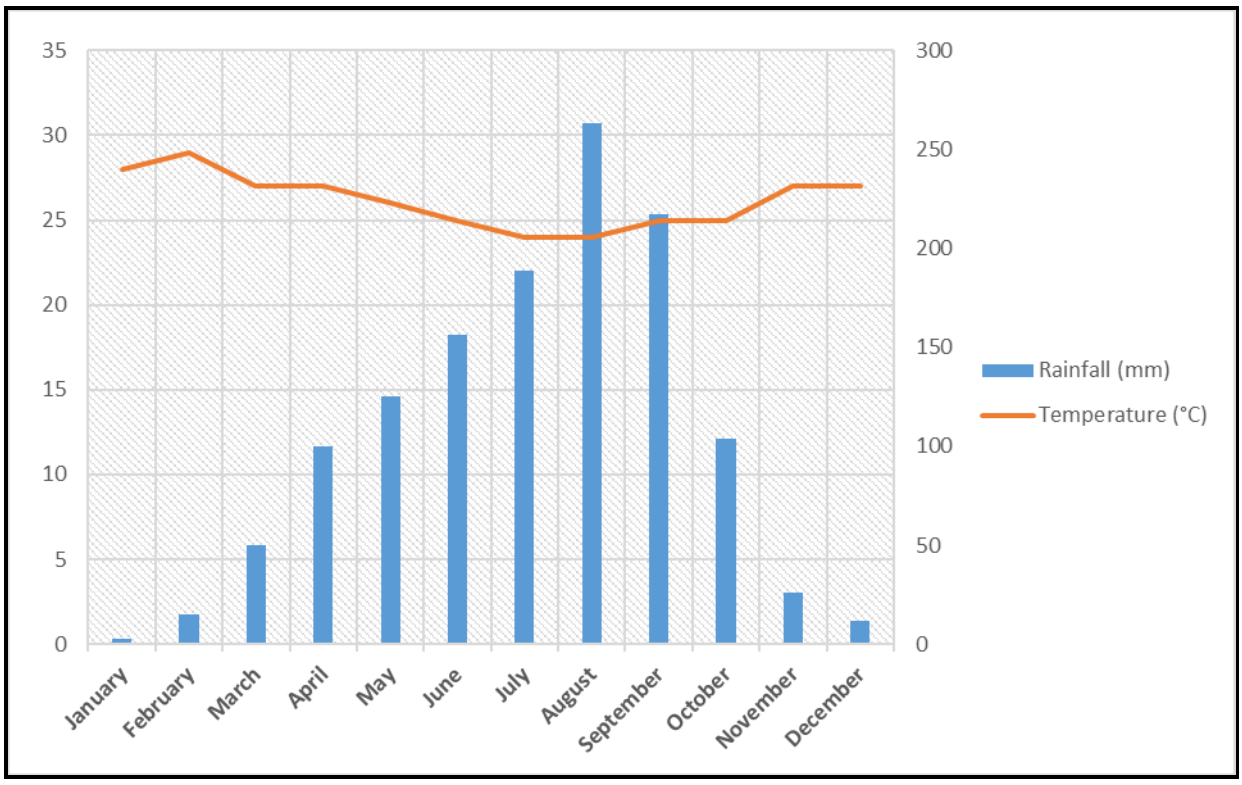

Fig 2: Umbro-thermal diagram

2.2 Choice of plots by sites

In the Tchologo region, four (4) cotton production areas were selected and forty (40) farmers plots were chosen, with ten (10) plots per zone. The farmer plots were distributed proportionally over the main sowing periods in the region. Each observation plot measures a quarter (¼) of a hectare, or (2500 m^2).

2.3 Insects sampling

Capture with mowing nets and collection by hand method have been used for the sampling. According to Kumar [14] a significant number of samples can justify the precision of the results obtained. Insect collections were made between July and October 2018, using a mowing net and pitfall, during the period of insect activity in the cotton farms. All samples were collected at least 10 m from the field borders, in order to capture only insects living inside the plots. Adult of Coccinellidae were captured using mowing nets or by hand. Formicidae and Coccinellidae larvae were captured using plastic pitfall inserted into the ground and filled with a preservation liquid. In each plot, two traps were placed 10 m from each other. The datas were collected every week between July and October. On each observation plot, a series of 15 counts of beneficial insects was also carried out on average from 30th days after rising, at regular intervals of one week, until the 128th day of the plant cycle. Beneficial insects were counted plant by plant, on a sample of 30 plants taken in groups of 5 consecutive plants per row, following the sequential method known as the 'diagonal' method [15]. beneficial insects were collected by four (4) agents from the Research and Development Department of the cotton company. They have been trained for this purpose. Rainfall and temperature datas were also collected.

2.4 Data analysis

The data obtained were subjected to a one-factor analysis of variance (ANOVA 1) at the 5% threshold and ecological indices of gama and alpha diversity were determined using Past 3.2.6 software.

3. Results

3.1 Data sampling

We have inventoried 7675 insects (Table 1). The Formicidae is the most important family with 6373 individus collected, that represent 93% of the insects. The highest numbers of insects were collected in Kong (59%) and Diawala (19%) localities. Specifically, the species *Camponotus maculatus*, *Camponotus sericeus* and *Messor galla* are more abundant with respectively (28%, 26% and 24% species), followed by *Pheidole* sp (10% species). Coccinellidae are present with 1302 species, that represent 7% of all insects captured. *Cheilomenes sulphurea* is the most important species in all the cotton plots with 1044 individus collected, it represents 80% of the Coccinellidae. *Delphatus pusillus* is the least abundant with 61 individus, which is 5% of the total number of Coccinellidae. The localities of Kong (722 individus) and Korokara (277 individus) have the highest number of Coccinellidae of all species combined. Diawala (186 individus) and Kaouara (117 individus) have the lowest abundance of Coccinellidae.

Table 1: Distribution of insects inventoried by order, families and species according to localities in the Tchologo region

Order	Families	Species	Korokara	Diawala	Kaouara	Kong	Total areas
Hymenoptera	Formicidae	*Camponotus maculatus*	32	313	149	1272	1766
		Camponotus acvapimensis	88	8	0	199	295
		Camponotus sericeus	233	486	107	826	1652
		Paltothureus tarsatus	32	0	0	18	50
		Messor galla	172	351	102	928	1553
		Pheidole sp	177	67	134	232	610
		Monomorium dakarense	32	19	0	355	406
		Monomorium afrum	41	0	0	0	41
Coleoptera	Coccinellidae	*Cheilomenes sulphurea*	216	157	117	554	1044
		Cheilomenes propinqua vicini	38	19	0	140	197
		Delphatus pusillus	23	10	0	28	61
Total			1084	1430	609	4552	7675
Percentage of Formicidae			74%	94%	68%	84%	93%
Percentage of Coccinellidae			26%	6%	32%	16%	7%

3.2 Spatial distribution of Formicidae and Coccinellidae

Presence of Formicidae was observed in all the plots. The highest abundance of insects was recorded in Kong, with dominance of the species *Camponotus maculatus* (1272 individus), *Camponotus sericeus* (826 individus), *Messor galla* (928 individus) followed by *Pheidole* sp and *Monomorium dakarense* respectively with 232, 355 individus. All the species were observed in all sites with mixed numbers. However, at Kaouara the lowest abundance of insects was recorded with total absence of *Camponotus acvapimensis*, *Paltothureus tarsatus*, *Monomorium dakarense* and *Monomorium afrum* (Figure 3). The specific richness (S) of Formicidae is important in all the localities. The The highest number of species was recorded in Korokara (8 species), followed by Kong (7 species). Shannon wiener (H') and Pielou (E) index values trend in the same direction as the specific richness (Table 2). Analysis of variance show that there is significant difference beetween abundance of species captured in the localities (df = 31, F = 4.08 and P = 0.015). Coccinillidae was captured in all the localities. *Cheilomenes sulphurea* is the most abundant specie with mixed numbers. *Delphatus pusillus* is rare in the plots with an absence in Kaouara locality. Korokara, Diawala and Kong sites, recorded the greatest specific richness with 3 species while in Kaouara locality only one species was captured (Figure 4). The low values of Pielou equitability index vary between 0.48 and 0.61 (Table 3). Its show that the distribution of Coccinellidae in the different localities is not equal between them. Analysis of variance show that there is no significant difference between abundance of species captured in the localities (df = 11, F = 0.99 and P = 0.44).

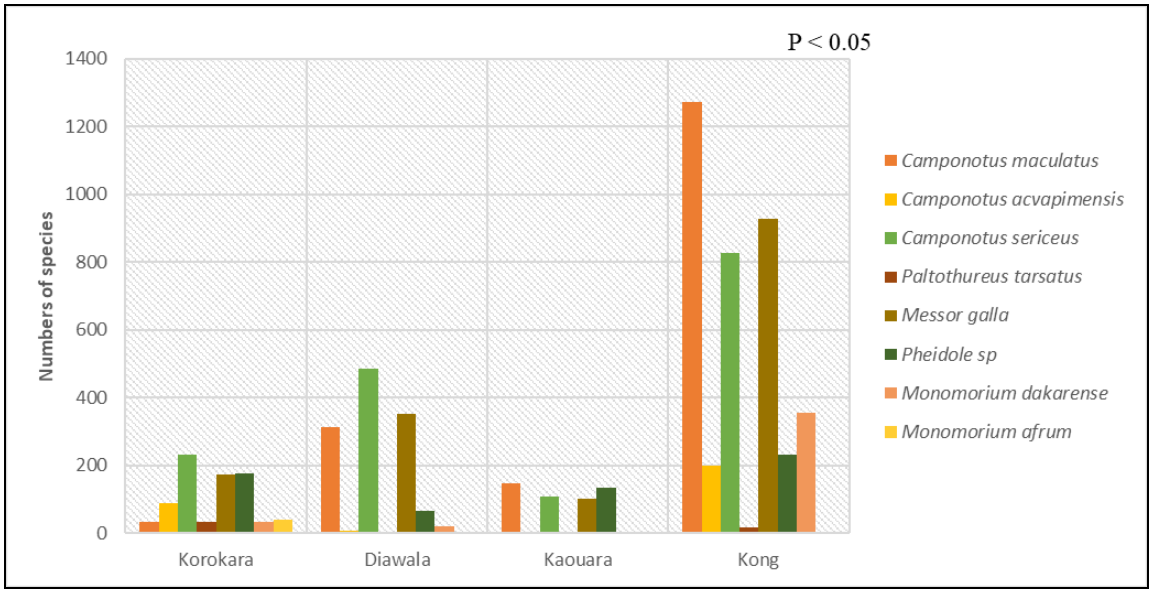

Fig 3: Spatial distribution of Formicidae

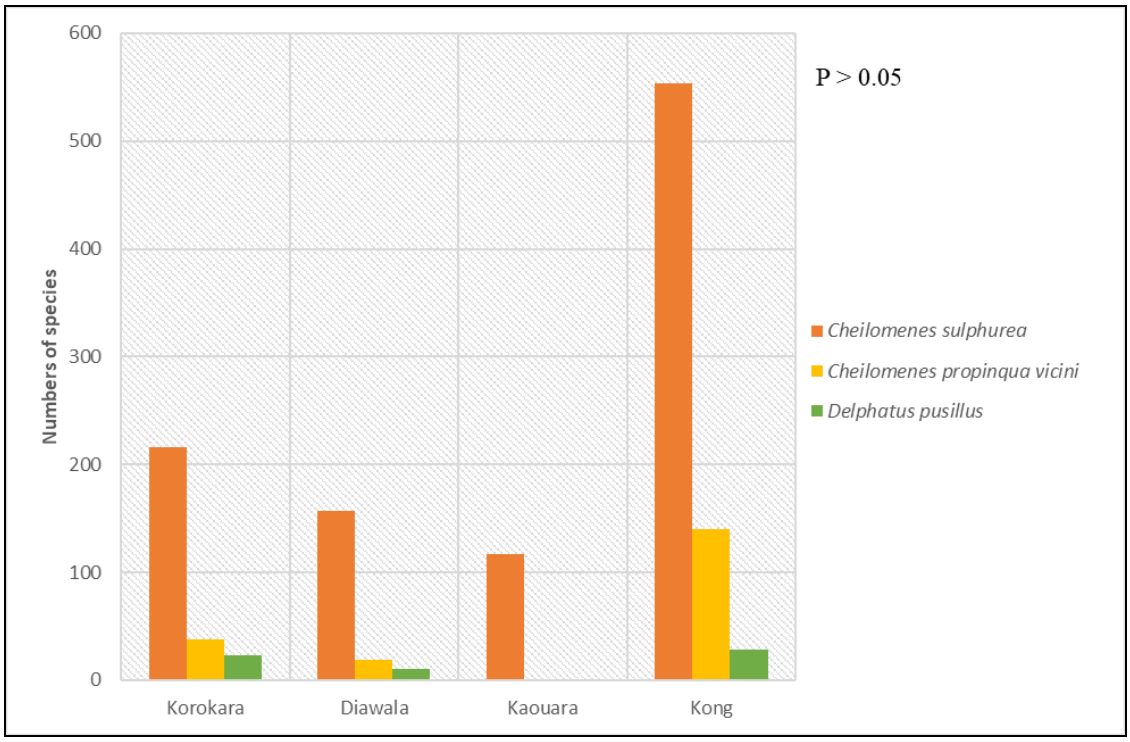

Fig 4: Spatial distribution of Coccinellidae

Table 2: Ecological index of Formicidae

Localities	Specific Richness (S)	Individus (N)	Shannon Weaner (H')	Pielou equitability (E)
Korokara	8	807	1.798	0.864
Diawala	6	1344	1.292	0.721
Kaouara	4	492	1.374	0.991
Kong	7	3830	1.610	0.827

Table 3: Ecological index of Coccinellidae

Localities	Specific Richness (S)	Individus (N)	Shannon Weaner (H')	Pielou equitability (E)
Korokara	3	277	0.673	0.612
Diawala	3	186	0.533	0.485
Kaouara	1	117	0	
Kong	3	722	0.643	0.589

3.3 Weekly fluctuations of Formicidae and Coccinellidae

The most important peak of Formicidae captures started the last week of july (143 individus of Formicidae) in Korokara (Figure 5a). Formicidae abundance droped in October compared to the captures of Coccinellidae which were observed during the period of the study, from july to October. Weekly fluctuations of the two beneficial insects families observed in Diawala locality (Figure 5b) show that the number of insects observed varies according to the weeks. The most important peak of Formicidae were reached during the second week of August, 2018. Indeed, this important population would be due to the infestation of cotton plots by aphids in August. In Kaouara plots, Formicidae populations were present during the study period, Coccinellidae were observed from July to the end of September with two peaks in August, the most important one (36 individus) during the 3rd week of August 2018 (Figure 5c). In Kong cotton plots, Formicidae and Coccinellidae were observed from the beginning of the inventories. The first peak of Formicidae was observed as early as the third week of capture (602 individus). The number of Coccinellidae was relatively constant from the beginning to the end of the observations in October 2018.

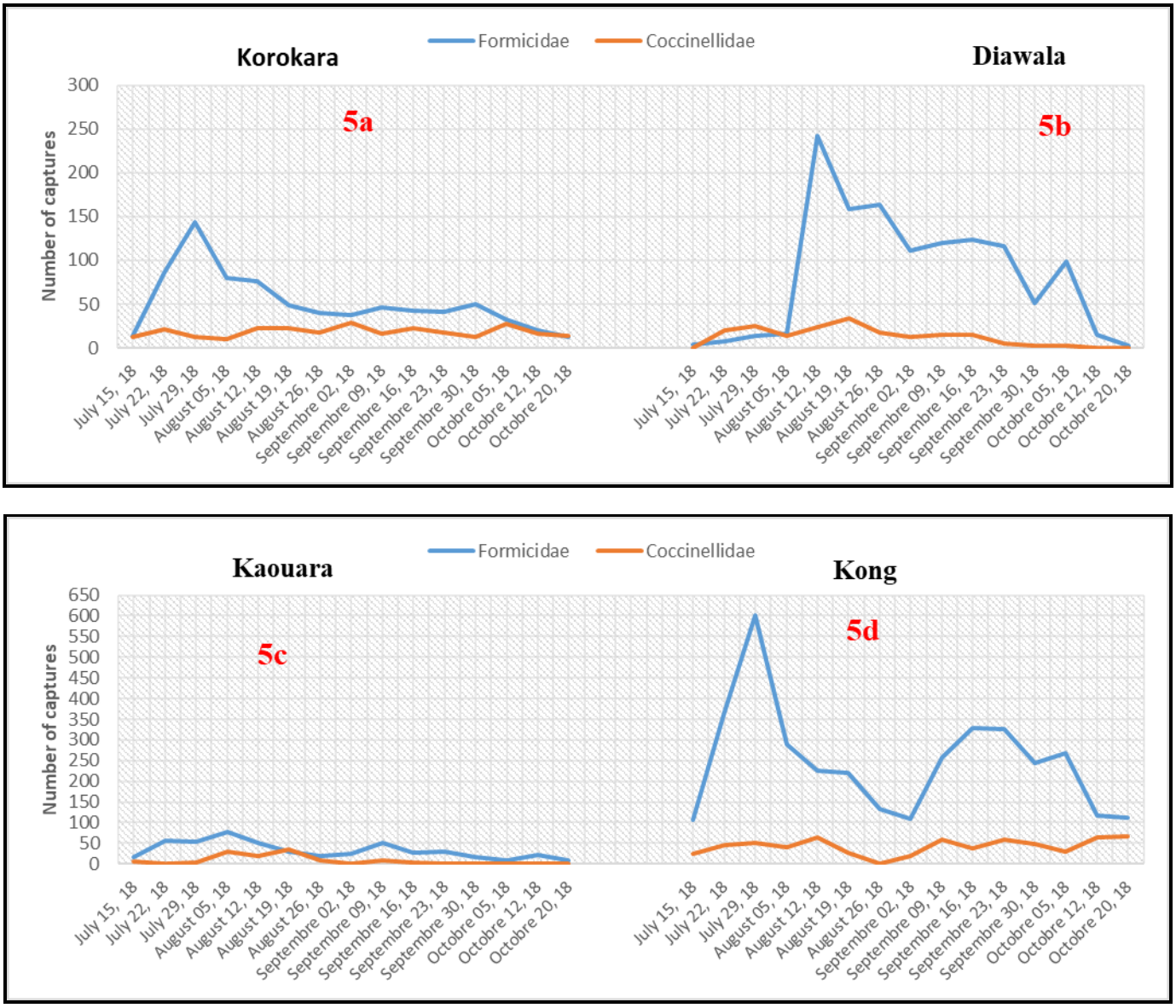

Fig 5: Weekly fluctuations of Formicidae and Coccinellidae

3.4 Influence of Rainfall on Population Dynamics

August and September 2018 were more watered. Overlay graphs of the temporal distribution of Formicidae and Coccinellidae and the evolution of rainfall shows that peaks of insects populations are independent of rainfall in all localities (Figure 6). The dynamics of the Formicidae and Coccinellidae are not influenced by rainfall.

3.5 Influence of temperature on population dynamics

Temperature data were relatively constant over the study period. The temperature fluctuated between 24 °C and 26 °C. Overlaying the graphs (Figure 6) shows that there is no coincidence between the temperature variations recorded during the surveys and the fluctuations of the Formicidae and Coccinellidae populations.

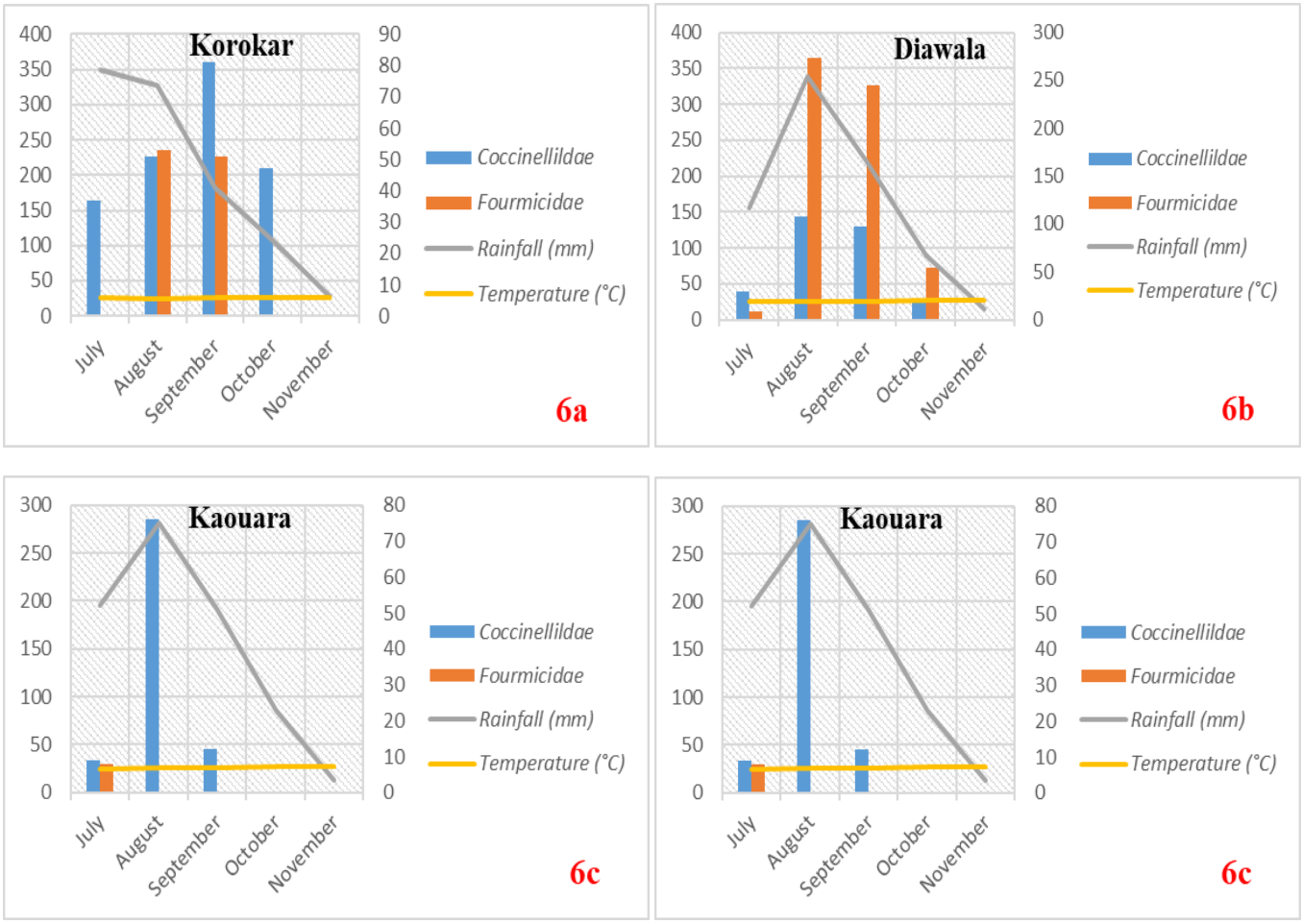

Fig 6: Influence of rainfall and temperature on the dynamics of Formicidae and Coccinellidae

4. Discussion

This work, conducted in 2018, made it possible to collect an important but probably non-exhaustive population of beneficial insects of Coleoptera and Hymenoptera from cotton plots in the Tchologo region. These are: *Camponotus* sp, *Pheidole* sp and *Messor* sp for Formicidae and *Cheilomenes* sp and *Delphatus* sp Coccinellidae. These results are similar to those obtained by Sigrist *et al* (1994) [16] in a study of the non-intentional effects of pesticides on beneficial insects of cotton in Chad. The work done by Galva (1993) [17] had also noted the presence of several beneficial insects in the cotton fields in northern Cameroon, including several species of Formicidae and Coccinellidae. Also, according to Hamiti and Bouchaala (2013) [18], the role of biocontrol crop species is important. They have the advantage to be non-toxic. The study of the spatio-temporal dynamics of the two families of the beneficial insects of cotton is by alternating high and low population densities according to time and space. Density fluctuations of insects populations observed during the study has been done according to the areas and the species. Thus, peaks of Formicidae and Coccinellidae were observed between August and September in all localities. Tuo's work in 2013 [19] showed that the peaks of palm entomofauna species vary according to the study site. In order to appreciate the influence of climatic factors on the two families of cotton beneficial insects, the variation of rainfall and temperature graphs in relation with time were compared for each family. This analysis showed that climatic factors did not significantly influence insect dynamics in the cotton plots. These results are confirmed by Mariau *et al*. (1991) [20] and Tuo (2013) [19] who indicated that there is no significant relationship between the emergence of insects in general and climatology. The beneficial insects studied were observed throughout the cotton cycle, which could be explained by the fact that during the development cycle the climate influences the development of the plants that serve as a biotope, Chararas, (1959) [21] for the insects. According to Koné *et al* 2017 [22], the parasite distribution currently observed in the cotton production areas could be due to high rainfall intensity.

5. Conclusion

From the present investigation it can be concluded that Formicidae and Coccinellidae are among the most importants beneficial insects presents in cotton farms. After the investigation in 2018, 1798 specimens have been recorded. The spatial distribution analysis show that the Formicidae and Cocciellidae are present in all the study localities durins the cycle of the cotton plants and then the climatic factors don't influence their abondance. It would therefore be important to take into consideration the action of beneficial insects in the development of cotton pest control programs in Côte d'Ivoire.

6. Acknowledgement

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