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RESEARCH ARTICLE

SEASONAL POPULATION DYNAMICS OF COCOA STEM BORER *EULOPHONOTUSMYRMELEON* FELDER (LEPIDOPTERA: COSSIDAE) IN THE REGION OF THE INDÉNIÉ-DJUABLIN IN CÔTE D'IVOIRE

[1,2,*]N'Guessan Assiènin Hauverset, [1]N'Guessan Kouamé François, [2]Kouassi Kouassi Philippe and [1,2]KouaméN' Dri Norbert

[1]CNRA, Research Station of Divo, BP 808 Divo, Côte d'Ivoire
[2]Félix Houphouët-Boigny University, UFR Biosciences, Laboratory of Zoology et Animal Biology, 22 BP 582 Abidjan 22

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ABSTRACT

Objective: The cocoa stem borer, Eulophonotusmyrmeleon Felder causes today serious damage in cocoa farm in Côte d'Ivoire. This study was conducted to determine the outbreak periods of this new lepidopteran pest in the Indénié-Djuablin region, the second largest cocoa producing area in Côte d'Ivoire.

Methodology and Results: The study was conducted from 2009 to 2013 in farmers' cocoa farms of the Indénié-Djuablin region in Côte d'Ivoire. Changes in the population density and attack rates ofE. Myrmeleon were assessed by counting fresh holes in six cocoa farms chosen in 3 localities with 2 farms in each locality. The data of Rainfall and temperature were also collected during this study. The results showed that there are two periods of severe attacks of this pest during the year, in the Indénié-Djuablin region. These periods occur from December to April with a peak in February and May to November with a peak around July-August. During these periods, the larval population level is high in the cocoa farms, indicating intense larval activities in the farms. The results also showed that the level of attack increased in 2009 than in other years. Rainfall seems to play a significant role in the population rise of the insect as periods of heavy attacks were observed after periods of high rainfalls. Similarly, the lower temperatures seemed to favor an increase in E.myrmeleon attack.

Conclusion and Applications: The results obtained in this study could be very useful for recommending control measures against larvae or adults. Indeed, periods of heavy attacks and adult emergence could be taken into account for rational insecticide application against this pest.

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INTRODUCTION

In Côte d'Ivoire, cash crops such as coffee, cocoa, palm oil and rubber occupy almost 3 296 000 ha (anonyme, 2004). With approximately 1, 794 million tons produced for the year 2014-15 (ICCO, 2015) cocoa is still, despite the gradual increase in other export products (rubber, palm oil, cotton, cashew, etc.), the first resource of the Republic of Côte d'Ivoire. It thus plays a leading role in the economic prosperity of this country. Moreover, cocoa cultivation is confronted with many biotic and abiotic constraints that limit its development that its production as well. Among these, there is the prolonged dry season, soil depletion, fungal and viral cocoa diseases and insectpests (Braudeau, 1969). For insects, the most damaging are the mirids, green bug, many inchworms caterpillars and the stem borers including *Eulophonotusmyrmeleon* Felder (Vos *et al*., 2003). The latter which formerly was known as minor pest of cocoa (Hill and Waller, 1988), has now become a real menace for the culture of cocoa. In fact, in this times, there is an increasing of damages of this pest in plantations. Attacks rates are above 25 % in some regions such as Haut-Sassandra, Indénié-Djuablin, Marahoué, etc. (N'Guessan *et al*., 2016), raising complaints from farmers (N'Guessan, 2007). Several control methods were used against this pest. Mechanic technical consisting to close holes (Anikwe, 2010), to kill the

Corresponding author: N'Guessan Assiènin Hauverset,
CNRA, Research Station of Divo, BP 808 Divo, Côte d'Ivoire

larvae inside the hole with a wire (Sonii, 2005) were used against this pest. Also, practices that were to inject inside the galleries of oil, gasoline, chloroform or the paradichlorobenzene to fight against these insects were also ineffective and difficult (Lavabre, 1970). To fight effectively against this insect, it appears necessary, even imperative to determine the periods of strong attacks in the main cocoa production regions of Côte d'Ivoire. This study on the populationdynamics of the cacao stem borer *Eulophonotusmyrmeleon*, was conducted in the region of The Indénié-Djuablin, to highlight periods of heavy attacks for control methods applications.

MATERIALS AND METHODS

Study site

The studies were conducted in 2009-2013 in the region of the Indénié-Djuablin. This region which is located in the eastern part of the country, is one of the main regions of production in Côte d'Ivoire, with about 7.1% of the national production (Esso, 2009). Three localities in this region of production of cocoa were chosen (Abengourou, Niablé and Aniassué) sampling of the insect.

Sampling method

In each selected locality, 2 sampling sites consisting of at least 1 ha cocoa, attacked by the stem borer, *E. myrmeleon*, have been identified, a total of six cocoa farms. In each cocoa farms, 3 blocks of 100 cocoa trees have been delineated and trees were numbered from 1 to 100 using oil painting of red color, 300 cocoa trees by elementary plot, and a total of 1800 cocoa trees observed throughout the cocoa farms monthly. All selected cocoa farms have undergone any insecticide application during the study.

Observations

In each elementary plot, numbered cocoa trees have been inspected monthly, knowing that *Eulophonotusmyrmeleon* larvae can excavate tunnels in the cocoa tree for 3 months (Entwistle, 1972). The recent holes were counted up to a height of 3 m (within sight) on the marked cocoa trees; they were recognizable by the presence of reddish waste which escaped from the holes on the trunks. The presence of waste shows that a lively and active larva bores into the trunk. All recent openings were systematically counted without considering the previous count. Thus, the number of holes counted at each crossing was a cumulative number. Climate data (precipitation and temperature) were collected 2 times a day (morning and afternoon) on the weather stations of the Agence Nationaled'appui au Développement Rural (ANADER) in the concerned localities.

Analysis of data

Data collected, including the density of holes (number of recent holes per tree) and the rate of attacks (number of attacked trees) were subjected to analysis of variance using the GLM (General Linear Model) of SAS 9.2 software procedure. The comparison of means was carried out by Waller Duncan K-ration T-test test, at the threshold of 5%. In addition, the average number of holes per tree was determined and represented graphically for evaluating seasonal damage or population level depending on the rainfall and the temperature.

RESULTS

Observations on *Eulophonotusmyrmeleon* attacks on cocoa farms in the region of Indénié-Djuablin indicated variations in population density of larvae and the rate of attacks of this pest in this part of the Côte d'Ivoire. The populations of larvae of this pest were 3.98 fresh holes per tree in Abengourou, 2.87 fresh holes per tree in Niablé and 0.87 fresh holes tree in Aniassué (Table 1). Also, the attack rate was 2.99; 2.10 and 0.72% respectively in Abengourou, to Niablé and Aniasué. Variance analysis has revealed significant differences (P <0.05) between the three localities sampled in relation to the rate of attacks and the population density of larvae *Eulophonotusmyrmeleon* in cocoa farms. Damage vary from one locality to another. Indeed, the results revealed that the population of larvae and rates attacked are found to be higher in cocoa the locality of Abengourou, means in the locality of Niablé and lower in the locality of Aniassué.

Table 1. Population Density of larvae and attack rate *Eulophonotusmyrmeleon* in cocoa farms in the region of Indénié-Djuablin

Sampled localities	Population density of larvae (fresh holes per tree)	Attack rates (%)
Abengourou	3.98 ± 0.38 a	2.99 ± 0.30 a
Niablé	2.37 ± 0.24 b	2.10 ± 0.20 b
Aniassué	0.87 ± 0.17 c	0.72 ± 0.12 c

Means followed by the same letter in a column are statistically identical to the 5 % threshold (Waller Duncan K ratio t- test)

Furthermore, the level of the population density of larvae was higher in 2009 with 5.41 fresh holes per tree compared to 2010, 2011, 2012 and 2013 with respectively 1.59; 1.60; 1.58 and 1.84 fresh holes per tree. The population density of larvae is almost identical between these past four years. Similarly, the attack rate was relatively higher in 2009 with 4.40% compared with 2010, 2011, 2012 and 2013. The attack rate also remained unchanged from 2010 to 2013; 1.14%. 1.19%; 1.23% and 1.52% (Table 2). Analysis of variance revealed significant differences (P<0.05) between the sampling years with regard to the rate of attacks and *Eulophonotusmyrmeleon* larval population.

Table 2. Population density of larvae etattack rates of *Eulophonotusmyrmeleon* for 5 consecutive years in cocoa farms in the region of Indénié-Djuablin

Sampling years	Population density of larvae (fresh holes per tree)	Attack rates (%)
2009	5.41 ± 0.71 a	4.40 ± 0.57 a
2010	1.59 ± 0.18 b	1.34 ± 0.14 b
2011	1.60 ± 0.15 b	1.19 ± 0.11 b
2012	1.58 ± 0.16 b	1.23 ± 0.13 b
2013	1.84 ± 0.17 b	1.52 ± 0.13 b

Means followed by the same letter in a column are statistically identical to the 5 % threshold (Waller Duncan K ratio t- test)

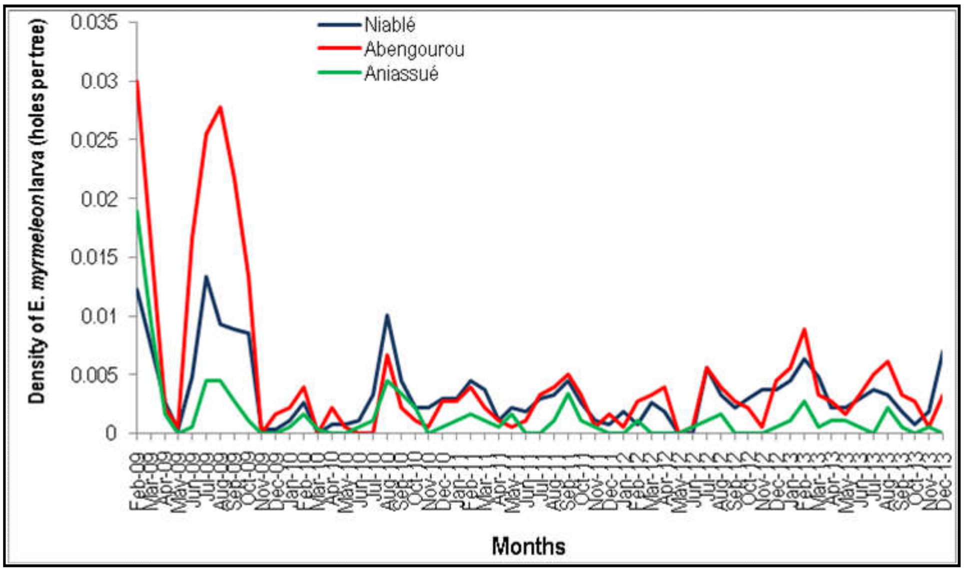

Figure 1. Seasonal variation in larval population density of *Eulophonotusmyrmeleon* in three localities in the Indénié-Djuablinregion

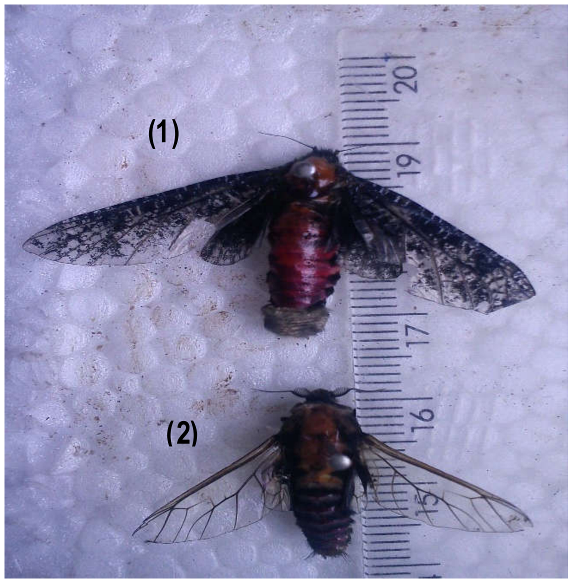

Figure 2. *Eulophonotusmyrmeleon* larvae **Figure 3. *Eulophonotusmyrmeleon* adult female (1) et male (2)**

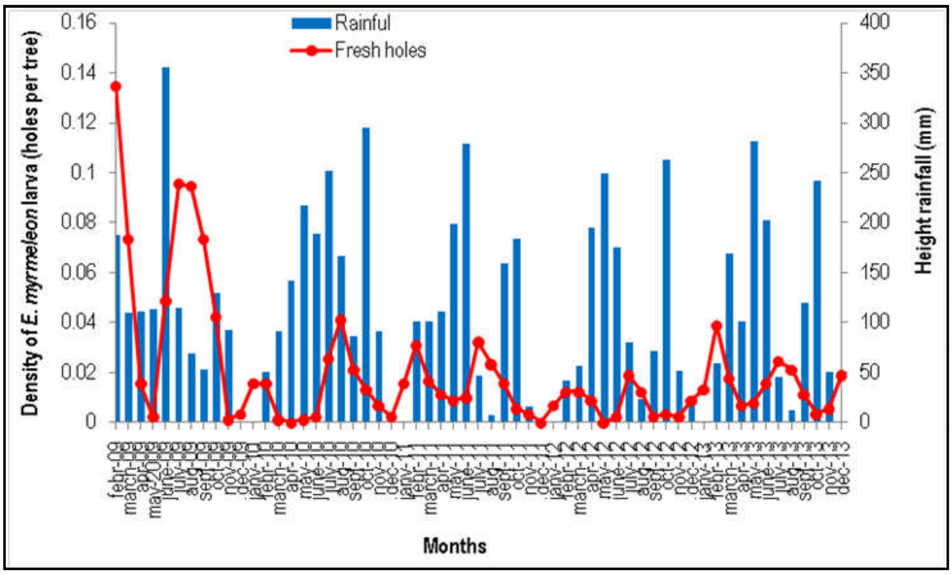

Figure 4. Seasonal variation of population density of *Eulophonotusmyrmeleon* larvae according to rainfall pattern in cocoa farms of Indénié-Djuablin region

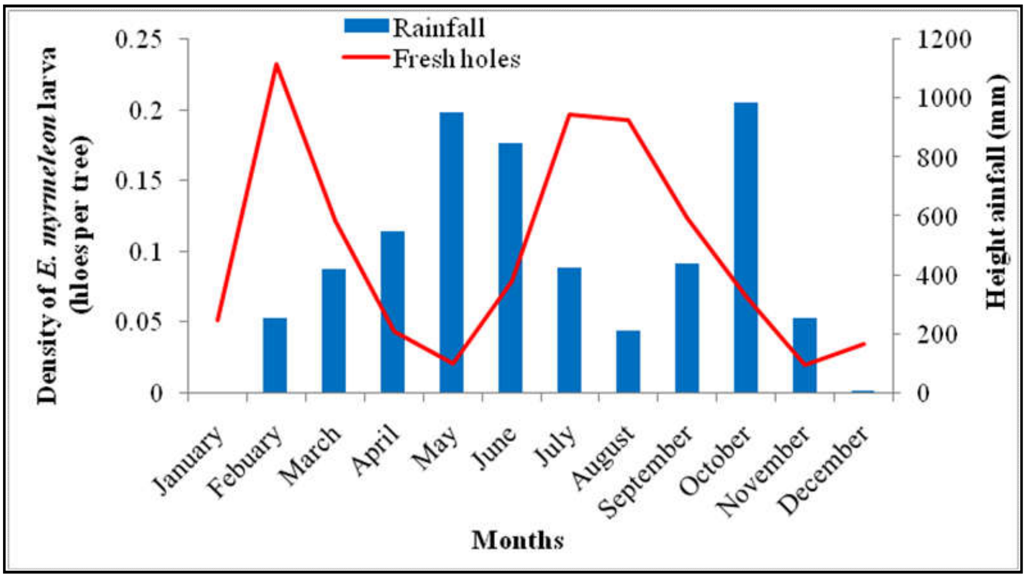

Figure 5. Monthly variations in the larval population density of *Eulophonotusmyrmeleon* in cocoa farms of Indénié-Djuablin depending on the rainfall

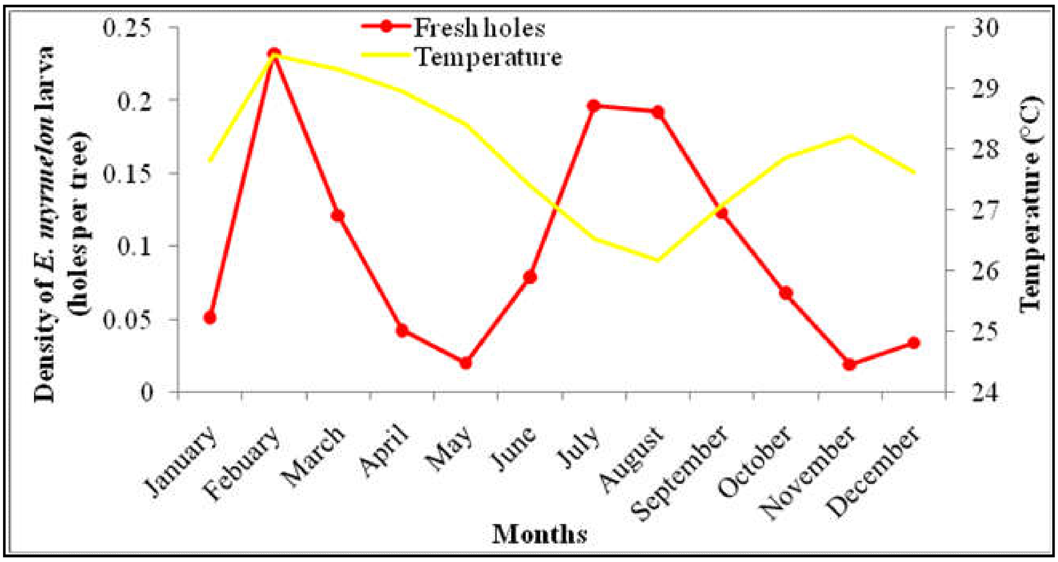

Figure 6. Monthly variations in the larval population density of *Eulophonotusmyrmeleon* in cocoa farms of Indénié-Djuablin depending on the temperature

The analysis of the curves of outbreaks of *Eulophonotusmyrmeleon* in the localities of Abengourou, Niablé and Aniassué allowed to distinguish two periods of heavy attacks during the year (Figure 1). Thus, in the locality of Abengourou, periods of heavy attacks spread from December to March with a peak in February and May to November with a peak in August. In the locality of Niablé, periods of heavy attacks spread from December to April with a peak in February or in March and from June to November with a peak in July or August. In the locality of Aniassué, heavy attacks occur from December to March with a peak in February and from June to November with a peak around July-August or September. In total, the monitoring of the dynamics of populations of *Eulophonotusmyrmeleon* in the region of the Indénié-Djuablin revealed two periods of heavy attacks during the year (Figures 4 and 5). These periods spread out from January to April with a peak in February and from June to October with a peak around July-August. These periods correspond to the moments where the larvae population level is high in the cocoa farms. The first phase of the attacks begins in the month of January, increases to a peak in February, and then dims up to the month of April. A second phase began in June with a peak around July-August, and then decreases until November. Beyond these two periods, the attacks are negligible during the periods from April to June and from September to December each year. During periods of heavy attacks, the larvae bore into the trunks and stems of cocoa trees (Figure 2). The first adults appear in plots (Figure 3) from the month of April, and then later in the month of September, that is to say, three months after the start of the attacks in January and June. In addition, precipitation appear to affect the population dynamics of these insects. Rainfall data showed that in our study, precipitation levels were higher in the months of April, May and June on the one hand, and September and October on the other hand (Figures 4 and 5). The analysis of the evolution of attacks of *Eulophonotusmyrmeleon* in this region of the country depending on rainfall reveals that periods of strong attacks appear after periods of heavy precipitation (Figures 4 and 5)

The average temperatures recorded during the 5 years of observation ranged from 26° C to 29° C (Figure 6). Low temperatures are observed in the months of July, August and September and the highest in February, March and April. Indeed, the period of heavy outbreak of *Eulophonotusmyrmeleon* coincides with the lowest temperatures of the year, while the small period coincides with highest temperatures (Figure 6).

DISCUSSION

The results of the observation son damages caused by the cocoa stem borer *Eulophonotusmyrmeleon* in the region of the Indénié-Djuablin indicated significant changes in population densities of larvae and the rate of attacks of this pest. These variations could be explained by the fact that certain environments are more favourable to the development of these insects (Leroux *et al*., 2013). According to these authors, most insects, due to their high mobility, can conquer other environments that are favourable as existing not ecological or physical barriers. Also, our results show that the population density of larvae and the rate of attacks have also varied from one year to the other. N'Guessan (2007) indicated that in Côte d'Ivoire, attacks that had started in the eastern region of the country, quickly progressed to the West. This could explain the level of population and the rate of attacks higher in 2009 than in other years. Indeed, in recent years, the cocoa loop located to the East of the country, knows a reverse situation following deterioration in the conditions that prevailed over the introduction of coffee and cocoa (Aloko-N'Guessan *et al*., 2014). Degradation of the cocoa farms in this region would result in the migration of pests to most environments, these last years. In this region, two periods of heavy attacks were observed during the year. These results are consistent with those obtained by N'Guessan *et al*. (2010) and N'Guessan *et al*. (2014), which had identified also two periods of this pest outbreaks respectively the areas of Sud-Bandama and Haut-Sassandra in Côte d'Ivoire. However, these periods of overgrowth not overlap from one region to the other. In effect, N'Guessan *et al*. (2010) showed that in the region of Sud-Bandama, periods of heavy attacks extend from May to August and from November to February. Then N'Guessan *et al*. (2014) indicated that in the region of Haut-Sassandra, periods of heavy attacks extend from January to April with a peak February and from June to October with a peak in August.

Several factors can explain the differences between *Eulophonotusmyrmeleon* outbreak periods in a given region. Indeed, climatic factors are likely to affect the population of this pest in the cocoa farms in various production regions. According to Stenseth *et al*. (2002); Tylianakis *et al*. (2008); Van der Putten *et al*. (2010); climate change is affecting the distribution and abundance of plant and animal species, but also the interactions between species of an ecosystem. This would be observed in *Eulophonotusmyrmeleon* in cocoa-producing regions. Rainfall data showed variations in precipitation from one period to the other levels. The analysis of the evolution of the attacks of *Eulophonotusmyrmeleon* in this region of the country based on rainfall shows that periods of heavy attacks appear after periods of heavy rainfall. The differences between the periods of heavy attacks of *E. myrmeleon* observed between two regions can be explained in part by changes in climatic factors from one region to the other. However, the direct effect of precipitation on insects seems minor (Bale *et al*., 2002). Also, according to Sentis (2012), the heavy rainfall can change the phenology and the nutritional quality of the plant, therefore causing, a significant impact on the population dynamics of phytophagous insects. Thus, fluctuations in pest populations would be influenced by trophic factors. In addition, extreme weather events result in major infestations of pests. For example, the heavy infestations of phytophagous mites in berry crops occur typically during periods of drought. These situations may be caused by the reduction or elimination of natural enemies during episodes of extreme weather (Leroux *et al*., 2013), the source of outbreaks after the heavy rainfall.

The results have indicated that the outbreak periods extend from January to April with a peak in February and from June to October with a peak in August. Our results are similar to those obtained by N'Guessan *et al*. (2014) in Haut-Sassandra region. These similarities could be explained by the intensity of the rainfall and the effect of temperature. Also, the period of *Eulophonotusmyrmeleon* heavy out break coincides with the lowest temperatures of the year, then the small period coincides with warmer temperatures. Indeed, the increase in temperature accelerated the development of insects. According to Minko (2009), the increase in temperature globally translates into a decrease in the duration of the development, also of embryonic that Larval and therefore on the complete biological cycle. Also, extreme temperatures have adverse effects on the biology of insects, reducing the rate of growth of their populations (Yocum *et al*., 1991; Davis *et al*., 2006; Mironidis and Savopoulou-Scott, 2008). This could explain the small period of outbreak of this pest. Addition climatic factors, certain factors, including the presence of natural enemies may be causing cyclic fluctuations in the populations of several insects. These natural enemies may vary from one region to another, themselves influenced by climatic conditions. According to Vos *et al*. (2003), the *Glyptomorpha* Hymenoptera and *Beauveria* and *Hirsutella* entomopathogens fungi cause death of larvae of *Eulophonotusmyrmeleon*. There are also parasites which are very small insects that lay their eggs and develop into larvae of *Eulophonotus*. Parasitized caterpillars feed more fairly, but will survive until the release of parasites (Sonii, 2005). Which gradually lead to the death of these. Some cultural practices can cause changes in populations of many insects. According Anikwe (2010) cultivation practices of plugging holes of *Eulophonotusmyrmeleon* followed by chemical appplications reduce populations of this pest in cocoa farms. Also, the use of insecticides based on imidacloprid, thiamethoxam, or thiamethoxam associated lambdacyhalothrin has ensured satisfactory control larvae of *E. myrmeleon* (Kouassi, 2005).

Conclusion

The results of the study of the population dynamics of *Eulophonotusmyrmeleon*in Indénié-Djuablin region in Côte d'Ivoire revealed two periods of outbreaks during the year. These periods are spread out from January to April with a peak in February and June to October with a peak around July-August These results may be useful for decision making with regard to phytosanitary measures against the larvae and adults of this pest. In fact, periods of heavy attacks and periods of adult emergence could be taken into account in any rational application of insecticide.

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