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Dynamic of green stink bug *Bathycoelia thalassina* Herr (1844) (Hemiptera: Pentatomidae) population in six main cocoa growing regions in Côte d'Ivoire

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Abstract

Ivory Coast cocoa farming is threatened by the high parasite pressure due to the attacks of many insects including the green stink bug Bathycoeli athalassina considered minor. Losses due to bedbugs are estimated at 60% of the production during periods of strong outbreaks in certain regions. Variations in B. thalassina populations were assessed by sampling twice a month using the sheeting technique in six cocoa producing areas. This technique consisted of spreading tarpaulins over 24 feet of cocoa trees found in an area infested with B. thalassina. Spotted and stained cocoa trees are treated in high doses with an insecticide registered on the cocoa tree (Callifan Super 40 EC). The number of B. thalassina killed was counted on tarpaulins 5hours after treatment. The B. thalassina pullulation curves revealed two periods of strong outbreaks in the six production regions. The first period extends from June to November with a population peak ranging from 9,19 ± 2,00 to 14,56 ± 2,67 and the second from December to May with a population peak of 5,26 ± 1,99 and 9,80 ± 2,98. The B. thalassina outbreak starts during the rainy periods and gradually stops with the dry periods. These results will make it possible to make recommendations as to the periods favorable to phytosanitary interventions against this pest.

Keywords: Cocoa, production region, population dynamics, *Bathycoelia thalassina* .

Introduction

In all production areas, cocoa cultivation at all stages is threatened by the high parasite pressure due to the attacks of many insects. These include defoliators, stem and twig drillers, sucking biters and root rodents[1,2]. Insects such as cocoa mirids are the main concerns of farmers in different production areas. But some insects such as *Bathycoelia thalassina* green bugs considered as minor insects cause significant damage in the Ivorian cocoa farm. These insects cause very serious damage, greatly reducing the yield and income of the farmer. The losses due to bedbugs are estimated at 60% of the production during periods of strong outbreaks in certain regions[2,3]. With the help of their biting mouthparts which are used to perforate, the big green stink bug, *B. thalassina* attacks the cherelles and the pods. Larvae and adults (Figure-1) bite the fruit and suck the milky beans, causing the cherelle to fall.

Bedbugs inject toxic substances into plants or fruits for food, causing fruit blackening. This insect has an oval body in the shape of a shield and gives off a strong unpleasant odor. That's why they are nicknamed stink bugs. To date there is no specific control method against green bugs in the cocoa orchard in Côte d'Ivoire. Fighting methods used to control cocoa mirids also control these pests. Commonly used techniques are agronomic methods and insecticide treatments[4]. Green bugs have natural predators that are mainly birds and lizards. Some useful insects of the Order of Hymenoptera were feeding on this pest[5]. Other predatory mites and spiders would also control the population of *B. thalassina*. These predators significantly reduce the population of these insects[6-8]. Insecticide treatments against mirids remain the main means of fight against green bugs on cocoa[7]. Treatment periods are based on seasonal variations in mirid populations. Today, treatments are ineffective in most producing areas because the moth outbreaks would be different from those of green bugs. It is therefore necessary to know the periods of outbreaks of green bugs in order to establish a phytosanitary intervention schedule. It is for this reason that the present study was initiated to determine the periods of outbreak of green bugs in the main areas of cocoa production in Côte d'Ivoire.

Materials and methods

Study site: The study was conducted in the southern half of Côte d'Ivoire, which is the main cocoa zone. Sampling was carried out in the following regions: Haut-Sassandra, Sud-Comoé, Indénie-Djuablin, Lôh-Djiboua, Guémon and Nawa. These areas were covered with dense mesophilic forests. The climate is humid tropical semi-deciduous type and is characterized by 4 seasons of unequal duration[9,10]. These are 2 rainy seasons including a large rainy season from mid-march to mid-July and a small rainy season from September to November. A long dry season from December to mid-March and a small dry season that is not very marked that occurs in the month of August. The average annual precipitation is between 1200mm and 1600mm per year. Also, the average temperature of the cocoa production zone is 24°C to 32°C[11].

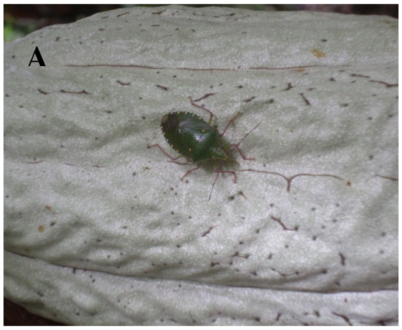

Figure 1: *Bathycoelia thalassina* on cocoa pod: A: Adult; B: Larva.

Sampling method: Six main cocoa producing regions were chosen for this study. In each region, three representative localities were used for bedbug sampling (Table-1).

Table-1: Localities sampled for bedbug dynamics cocoa *B. thalassina.*

Region	Localities	Villages
Lôh-Djiboua	Divo, Guitry, Lakota	Djetrankro, Arah Béhiri I et II Diékolilié, Nemelilié
Haut-Sassandra	Daloa, Zougougbeu, Issia	Djessikro, Zepreguhe Belle ville, Yobouekro Boguedia, Bemadi
Nawa	Gabiadji, Méagui, Soubré	Tonda Carrefour, Cedar Meagui, Jean Mourokikro Oupoyo, Gbletia
Indénie-Djuablin	Abengourou, Niablé, Aniansue	Adoukoffikro, Assèkro Campement Sassankouao Assakro I et II
Sud-Comoé	Adaou, Ayamé, Nouanmou	Diattokro, Babadougou Gnamienkro I et II Gaoussoudougou I et II
Cavally	Duekoué, Guiglo, Bangolo	Guezon, Glaou Goya I, Koffikro Guehiebly, Bahe-Sebon

In each locality, 2 sites made up of blocks of several neighboring cocoa farms attacked by bedbugs have been identified, making a total of six blocks of cocoa farms per region. These core sites, with neighboring cocoa farms located within the same perimeter with a radius of 2 to 3km, represented the sampling sites. At each sampling site, the level of cocoa infestation by bedbugs was evaluated twice a month in the first and third week of each month by the sheeting technique. To this end, tarpaulins with a surface area of 16 m² are spread out over 24 cocoa trees found in an area infested with bedbugs. Thus, at each sampling passage, 24 cocoa trees are covered by localities. The identified and covered cocoa trees are leached with an approved insecticide. The leaching consisted of dropping all insects from a cocoa tree foot onto a tarpaulin using a large dose of the insecticide. The insecticide used is Callifan super 40EC at the concentration of 50ml of commercial product for 12liters of water to kill all the insects housed in the sheeted cocoa trees. At each sampling passage, treatments were performed early in the morning between 7am and 8am. Already leached trees are marked with red paint. The treatments carried out at later dates were done outside the places affected by the previous treatments.

Collection of data: A count of dead *B. thalassina* on tarpaulins takes place 5 hours after insecticide treatment. For this purpose, the leafy cocoa trees were shaken to bring down all dead insects retained in the foliage. *B. thalassina* bugs were collected using soft entomological forceps, placed in Petri dishes and then counted. The number *B. thalassina* was determined by tree and month for each sampling site.

Data analysis: The collected data were subjected to an analysis of variance using the SAS General Linear Model (GLM) procedure[12] to compare the *B. thalassina* populations of the different regions. The separation of the means was performed by the Student-Newman-keuls test at the 5% threshold. The monthly mean of *B. thalassina* populations was also calculated and plotted to determine periods of heavy outbreaks.

Results and discussion

Effectiveness of *Bathycoelia thalassina* in different regions: The size of *B. thalassina* shows a significant difference between the six main cocoa producing regions in Côte d'Ivoire. *B. thalassina* with an average population of between 18,63 ± 1,49 and 2,91 ± 0,33 was low in all six production regions. The region Haut-Sassandra with 18,63 ± 1,49 individuals was the region that contains more than *B. thalassina*. This region is followed by the regions of Indenie-Djuablin (9,13 ± 0,54) and Guémon (8,87 ± 0,99). The lowest average numbers, between 5,15 ± 0,42 and 2,91 ± 0,33 individuals, were recorded in the Nawa, Sud-Comoé and Lôh-Djiboua regions (Table-2).

Table-2: Average manpower of B. thalassina in six main cocoa production areas in Côte d'Ivoire.

Different regions	Mean number of *B. thalassina* by region
Haut-Sassandra	18,63 ± 1,49 a
Indenie-Djuablin	9,13 ± 0,54 b
Guémon	8,87 ± 0,99 b
Nawa	5,15 ± 0,42 c
Sud-Comoé	4,70 ± 0,32 c
Lôh-Djiboua	2,91 ± 0,33 c

The averages followed by the same letter are statistically identical to the 5% threshold (Student-Newman-keuls).

The analysis of the growth curves of the *B. thalassina* green bug in the regions of Haut-Sassandra, Sud-Comoé, Indenie-Djuablin, Lôh-Djiboua, Guémon and Nawa (Figure-2) allowed to distinguish two periods of strong outbreaks.

A first period runs from December to May and a second from June to November for the six regions.

For the Haut-Sassandra region, the peaks were recorded in March 2011, July 2011, April 2012, November 2012, May 2013, October 2013, April 2014, August 2014, April 2015 and August 2015.

In Indénie-Djuablin, the peaks were in February 2011, October 2011, March 2012, November 2012, March 2013, October 2013, March 2014, September 2014 and April 2015.

The Lôh-Djiboua peaks were February 2011, September 2011, September 2012, March 2013, August 2013, March 2014, September 2014, January 2015 and August 2015.

In Sud-Comoé peaks were recorded in January 2011, September 2011, August 2012, September 2013, August 2014, April 2015 and August 2015.

The peaks in the Nawa region were in March 2011, October 2011, May 2012, December 2012, March 2013, September 2013, April 2014 and November 2015.

Peaks of Guémon were recorded in March 2011, November 2011, April 2012, October 2012, December 2012, September 2013, January 2014, July 2014, December 2014 and July 2015.

Peaks of outbreaks varied from region to region. The breeding season from December to May has a peak in January, February, March and April. The period of outbreaks from June to November has a peak in July, August, September, October and November depending on the region. The mean curve of *B. thalassina* outbreak (Figure-3) confirms the two periods of strong outbreaks from June to November and from December to May in the six major cocoa producing regions.

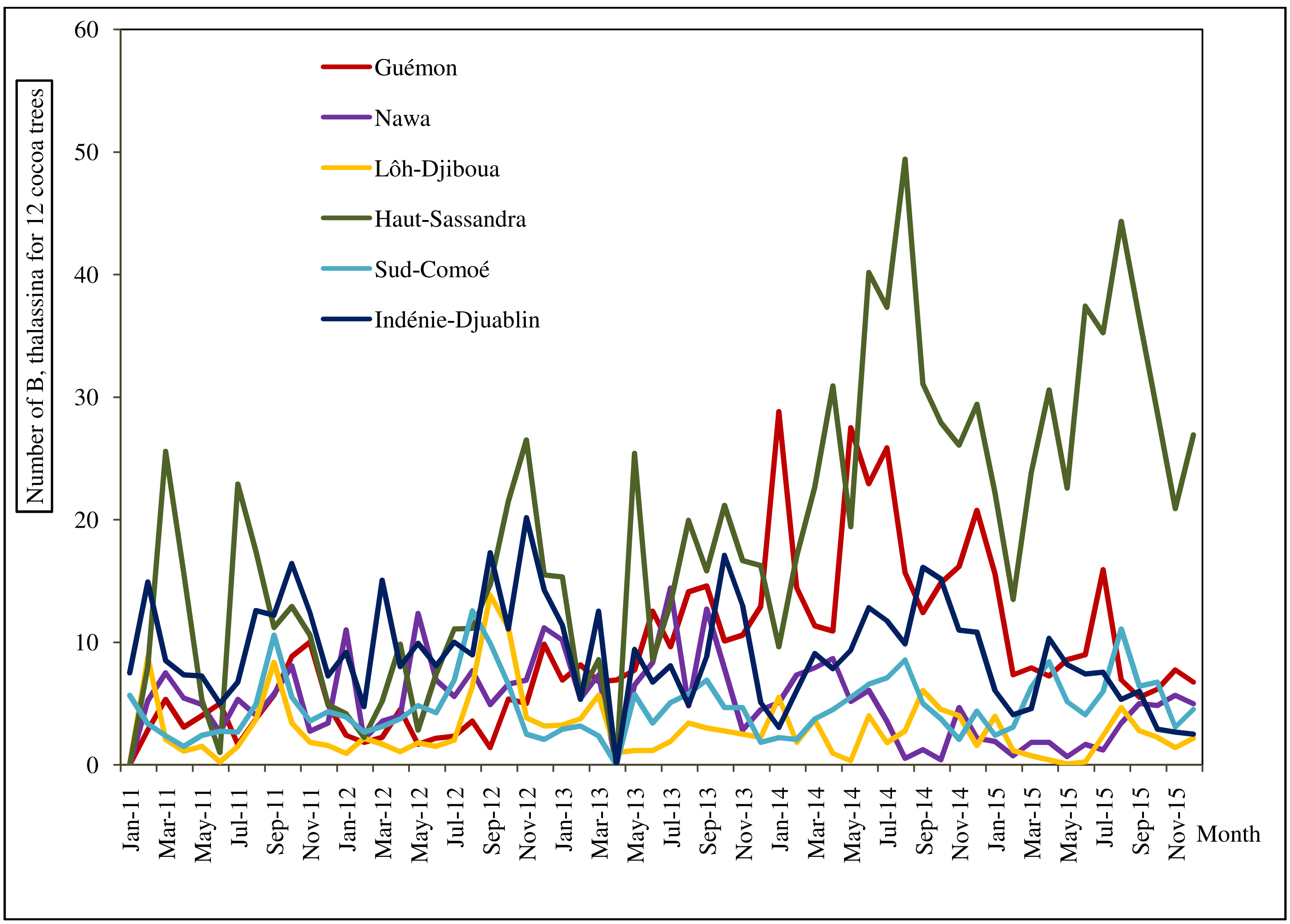

Figure-2: Seasonal variation of the *B. thalassina* population in six cocoa growing regions in Côte d'Ivoire.

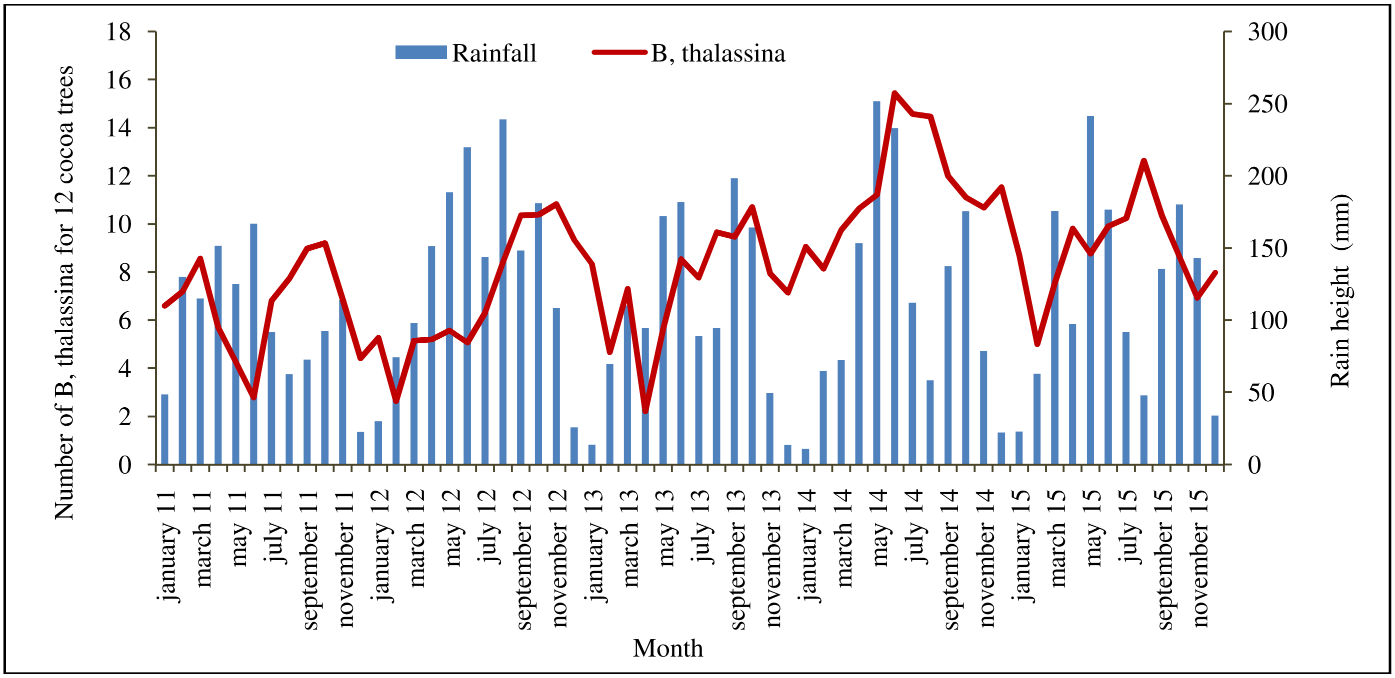

Figure-3: Seasonal variation of *B. thalassina* population in cocoa and rainfall in six regions of Côte d'Ivoire.

The population peaks were recorded in October 2011 (9,19 ± 2,00), November 2012 (10,82 ± 2,18), October 2013 (10,7 ± 2,32), July 2014 (14,56 ± 2,67) and August 2015 (12,63 ± 2,91) for the breeding season from June to November and in March 2011 (8,56 ± 0,42), January 2012 (5,26 ± 1,99), March 2013 (7,29 ± 2.28), January 2014 (9,05 ± 2,32) and April 2015 (9,80 ± 2,98) for the December outbreak of may.

The analysis of the evolution of the rainfall during the study years revealed two not very distinct rainy periods. The first runs from March to July and the second from September to November (Figures-3). The period from December to April is dry. The months of December and January are the driest months during which the rainfall is very low. The analysis of the *B. thalassina* pullulation curve in relation to the rainfall regime showed that the outbreak occurs during the rainy periods and stops gradually when the rainfall decreases. But the relationship between changes in *B. thalassina* populations and rainfall was not obvious.

Discussion: The analysis of *B. thalassina* populations gave a significant difference between the six main production areas. But the population of *B. thalassina* remains very low in these areas. This low rate could be explained by the disappearance of the plant cover. In fact, the Ivorian forest, which was estimated at 16 million hectares at independence[13], is currently less than 2 million hectares in 2000[14]. The low presence of *B. thalassina* in the main cocoa producing areas could be explained by the presence of natural enemies. Although *B. thalassina* secretes odoriferous glands very smelly as a defense but it would be attacked by several other useful insects such as Hymenoptera feeding on this pest. Some predatory mites and spiders may also control the population of this pest[5]. For Kumar[8], only 2% of the populations of this insect reached adult size when exposed to their natural enemies in the wild. Also the low presence of *B. thalassina* in the cocoa tree is explained by the variability of the host plants of this insect. But for Owusu-Manu[7]*B. thalassina* would be a fast sailing boat and would disperse mainly in the search for alternative plants and laying sites which would reduce the population in the cocoa tree. The high population of *B. thalassina* in Haut-Sassandra may be due to the use of pesticides in the cocoa farm. These results corroborate those of Kumar[8] who claimed that the antimiride insecticides commonly used in cocoa farms exert undesirable effects on the natural enemies of the bug, which favored the development of these insects in this region.

With respect to monthly changes in *B. thalassina* populations, our results revealed two periods of strong outbreaks in most production areas. These periods run from June to November and from December to May each year. These results corroborate those of Owusu-Manu[7] who asserted that the general rule of population fluctuation is the existence of two well-defined periods that would be linked, one to the great rainy season and the other to the short season. In fact, the first studies carried out by Owusu-Manu[7] indicated that there were two peaks of *B. thalassina* outbreak following rainy periods. According to this author the peak of outbreaks would be in February or march for the period of outbreaks from December to May and September, October or November for the period of outbreaks from July to November.

The population level of *B. thalassina*, which is weak from December to May, is due to the long dry season. Our results reveal that the short dry season is also weak in the six regions. These situations can be explained by the climatic disturbances of recent years. Indeed, the climate that was bimodal in Côte d'Ivoire in most production areas except in the west has certainly changed due to climatic disturbances[15]. Several studies have highlighted the direct or indirect impacts of climate change on pests[16,17]. Also the population level of *B. thalassina* which is well marked from June to November would be consecutive to the great rainy season. The main cause of the phenomenon of fluctuation of *B. thalassina* populations is therefore due to trophic factors, especially fruits and greedy. However, it should be noted that in the cocoa tree, the trophic factors themselves are conditioned by climatic factors, particularly the rainfall that favors regrowth and fruit production. Similarly, high temperatures can cause dehydration and drying of tissues and a reduction in the amount of sap that is the main food of *B. thalassina*. This situation could be explained by the presence or absence of sufficient food for these pests according to the month. The increase in the number of *B. thalassina* can be explained by a water enrichment of the plants due to the high rainfall from March to June and from August to November.

Conclusion

Our study revealed that the population level of *B. thalassina* differs from one region to another. Haut-Sassandra region contains more *B. thalassina* in Côte d'Ivoire. The regions of Nawa, Sud-Comoé and Lôh-Djiboua were the least populated in *B. thalassina*. Also two periods of strong outbreak of *B. thalassina* green bugs were highlighted in the six production regions. The first period extends from June to November with a peak of *B. thalassina* population in august, September and October depending on the year and region. The second extends from December to May with a peak of population in the month of February or March. These results should make it possible to make recommendations on the periods of possible phytosanitary interventions. Indeed, it is necessary to make insecticide application tests according to the outbreaks to determine the periods of treatment against these insects.

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