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Research Article

Impact of Green and Brown Bug Attacks on Cocoa Production in Gnagbodougnoa in Central-Western Côte d'Ivoire

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Abstract

The main known pests affecting cocoa in Côte d'Ivoire are mirids, defoliating caterpillars and stem borers. However, a study conducted in the sub-prefecture of Gnagbodougnoa in the region of Gagnoa following complaints from farmers identified the green bug, *Bathycoelia thalassina*, and the brown bug, *Pseudotheraptus devastans*, as pests of cocoa pods. The overall objective of this study is to assess the impact of attacks by these two bugs on cocoa production. The study consisted of delimiting one (1) sampling plot of one (1) hectare in three different plantations and, in each plot, five (5) 100 m ²sections arranged in a W shape. In each section, all pods and cherries attacked by bugs were counted and the attack rates determined. Losses were assessed by monitoring newly pierced cherries and pods during their maturation, determining their abortion rates and the loss of mass of beans that reached maturity after the attacks. The average attack rates were 66.66% for cherries and 62% for pods. Attacked pods abort completely after two months and only fifteen (15) out of 50 attacked pods reach maturity. The attacks led to a 36.38% loss in bean mass. The impact of green and brown bug attacks on cocoa is very significant. Better management of these factors will reduce their impact on production for optimal yield.

Keywords

Côte d'Ivoire, Cocoa, Bug, Attack Rate, Mass Loss

1. Introduction

The cacao tree (*Theobroma cacao* L.) is a tree of the Malvaceae family cultivated in many countries in the intertropical zone of America, Africa and South-East Asia [1]. In Côte d'Ivoire, cocoa cultivation accounts for around 14% of Gross Domestic Product (GDP) in Côte d'Ivoire, where it employs nearly 600,000 farmers and provides a livelihood for nearly a quarter of the population, or around 6 million people [2]. As such, this sector is the main pillar of the Ivorian economy. It provides numerous jobs in the secondary and tertiary sectors [3]. Ivorian production rose from 1.180 million tons in 2011 to over 2 million tons in 2018 [4]. The country has therefore remained the world's leading producer and exporter of cocoa beans for decades [5].

Despite this strong performance in cocoa production, farmers face several challenges, in particular pests such as defoli-

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ating caterpillars, stem borers [6] and mirids which are the essential insect pests of cocoa in the main production areas in Africa [7, 8] and even in Asia [9] that can cause up to 30% loss of production. However, farmers in the sub-prefecture of Gnagbodougnoa in the region of Gagnoa have complained about the presence of bugs other than mirids that are ravaging their cocoa pods. A study carried out in the area identified the green bug, *Bathycoelia thalassina* (Heteroptera: Pentatomidae) and the brown bug, *Pseudotheraptus devastans* (Heteroptera: Coreidae), as the two species of bugs [10]. In line with this, the present study aims at assessing the impact of attacks by these two bugs on production.

2. Material et Methods

2.1. Experimental Site

The study was conducted in the department of Gagnoa in Côte d'Ivoire. It was carried out in a rural area over a period of three months (July, August, and September) in the sub-prefecture of Gnagbodougnoa. Three (3) representative plantations were selected to cover most of the production area of Gnagbodougnoa.

2.2. Sampling Methods

In each plantation, one (1) sampling plot of 1-hectare was delimited. In each sampling plot, data collection was carried out using the ‘W’ sampling method [11, 12], used for pest monitoring in cocoa plantations. This involves delimiting five (5) sections of 100 m ²(10 m x 10 m) in each plot (Figure 1). The sections are arranged in a W shape. The sections were delimited to include a sufficient number of cocoa trees and avoid the edge effect.

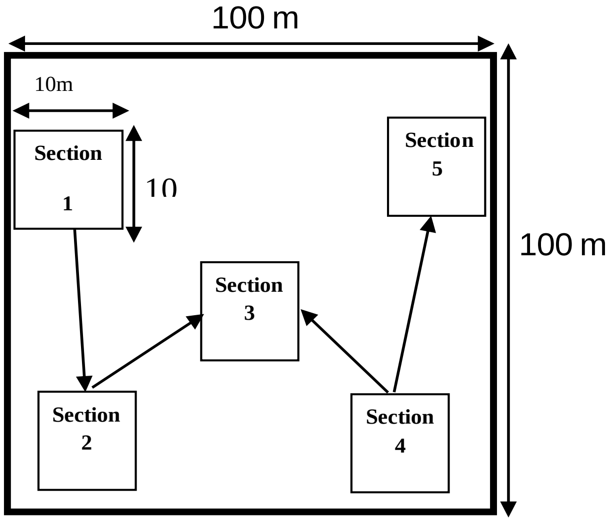

Figure 1. *Sampling in «W» [11, 12].*

2.3. Observations

In each section, the cocoa trees were carefully examined, tree by tree, to count all the pods and cherries attacked by bugs up to a height of 2 metres above the ground [13].

The attack rate per section was calculated using the following formulas:

$$\text{Rate of attack cherries} = \frac{\text{Number of attack cherries}}{\text{Total Number of cherries per section}} \text{X100} \qquad (1)$$

$$\text{Rate of attack pods} = \frac{\text{Number of attack pods}}{\text{Total Number of pods per section}} \text{X100} \qquad (2)$$

Losses were assessed by monitoring newly pierced cherries and pods during their ripening period. New attacks by bugs are characterised by the release of a small amount of sap. In each section, ten (10) cherries and ten (10) pods were identified, marked, and then monitored every two (2) weeks over a period of three (3) months to observe their development and fate.

Losses were estimated as the rate of aborted cherries and pods according to the following formulas:

$$\text{Rate of aborted cherries} = \frac{\text{Number of aborted cherries}}{\text{Total Number of monitored cherries}} \text{X100} \qquad (3)$$

$$\text{Rate of aborted pods} = \frac{\text{Number of aborted pods}}{\text{Total number of monitored pods}} \text{X100} \qquad (4)$$

The abortion speed of cherries and pods was also calculated using the following formula:

$$V_a \frac{N_t - N_0}{t} \qquad (5)$$

V_a= Abortion speed ((Number of cherries or pods) /unit of time)

N_0= Number of cherries/pods aborted at time t_0

N_t= Number of cherries/ pods aborted at time t_0+t

At the end of the three (3) months of monitoring, the beans from the attacked pods that had reached maturity were harvested, dried and weighed. The relative mass losses of the beans were then calculated for each plot using the formula developed by Pearce *et al*. (2022) [14].

$$\text{Relative loss (\%)}\ \frac{\text{Reference mass} - \text{Observed mass (weighed)}}{\text{Reference mass}} \tag{6}$$

2.4. Data Analysis

The data collected were subjected to several analyses. A descriptive analysis revealed the variability and average values of attack rates (by plot and stage of development) and abortion rates and speeds (according to time and stage of development). After verifying the normality of the data, the Kruskal-Wallis test was used to see if there was a difference between the different plots. When there was a difference, Dunn's post-hoc test was used to classify them. The same method was also used for abortion rates and speeds over time. As for the stages of development, the Mann-Whitney test was used to see if the difference was statistically significant.

3. Results

3.1. Description of Damage Caused by *B. thalassina* and *P. devastans*

The bugs (*B. thalassina* and *P. devastans*) attack developing cherries and ripening pods. The attacked cherry turns yellow and stops growing when the attacks are severe, then turns brown and finally black (Figure 2). The attacked pod has blackish spots in the areas that have been attacked. The opening the attacked pods reveals beans damaged by the bugs' bites. The longer the bugs feed on a pod, the more the beans inside the pods are destroyed (Figure 3). The attacked pod also turns yellow depending on where the pod was attacked, either at the base or at the apex of the pod.

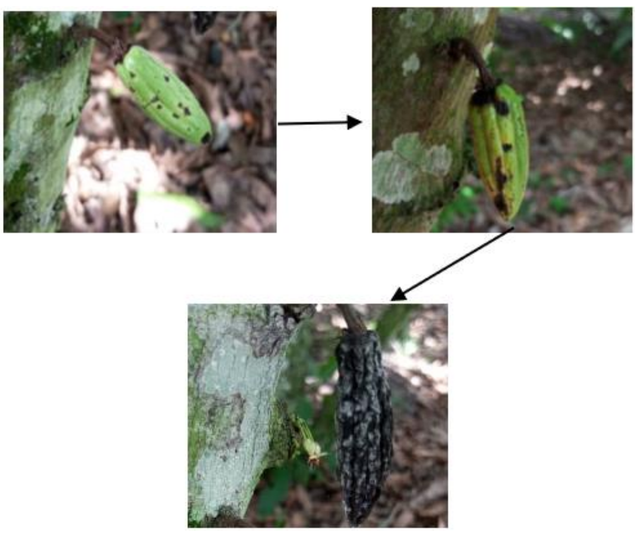

Figure 2. *Evolution of the Incidence of Bug Attacks on Cherries.*

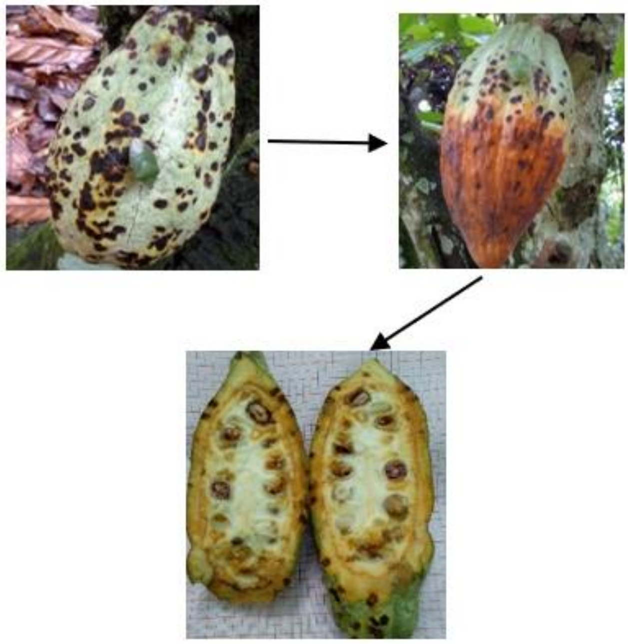

Figure 3. *Damage Caused by Bug attacks on Pods and Beans.*

3.2. Assessment of Bug Attacks

There is a very high average attack rate for both cherries and pods (>50%). Furthermore, there is no significant difference between the attack rates of the two stages of development, although cherries are slightly more affected (66.66%) than pods (62%) (Table 1). Nevertheless, there is a very significant difference ($p<0.000$) between plots (Table 2). Plot 3 has the highest average attack rate, with over 80%.

Table 1. *Average Values of Attack rates (%) of Cherries and Pods.*

	Min-Max	Mean ±SD	CV (%)	p-value
Pods	30 – 100	62 ±16,56	26.7	0.499
Cherries	20 – 100	66.66 ±25.54	38.3	

Table 2. *Average Values of Attack Rates (%) per Plot.*

	Min-Max	Mean ±SD	CV (%)	p-value
Plot 1	20 - 70	52 ±16.19^{b}	31.1%	
Plot 2	30 – 70	55 ±13.54^{b}	24.6%	< 0.0001
Plot 3	70 – 100	86 ±15.05^{a}	17.5%	

3.3. Assessment of Production Losses Due to Bug Attacks

3.3.1. Abortion Rate and Speed According to Fruit Development Stage (Cherry and Pod) and Time

There is a significant difference between cherries and pods in terms of abortion rate (p=0.045) and abortion speed (p=0.0012) (Figure 4).

The highest abortion rate (36%) was recorded in cherries at both 2 weeks and 1 month, compared to a rate of 26% recorded in pods at 1.5 months (Table 3).

The abortion rate was very high (9) among cherries and was only observed at 2 weeks. Among pods, it did not vary significantly and remained low and stable between 2 and 3 weeks (Table 3).

3.3.2. Loss of Bean Mass Due to Attacks

In addition to the losses recorded in terms of cherries and aborted pods, a loss of bean mass was noted in pods that were able to reach maturity despite the attacks.

Thus, the average loss rate recorded per pod across all plots is estimated at 36.38%, with an average bean mass loss of 25.57±5.908g (Table 4).

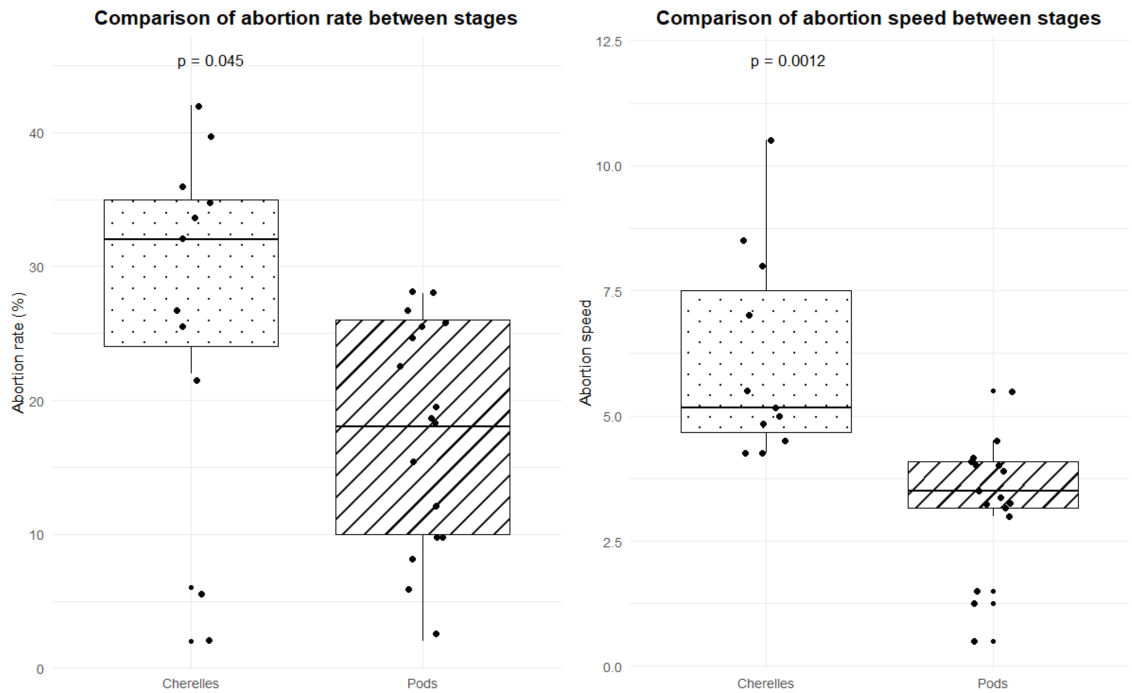

Figure 4. Rates of Abortion and Speed of Cherries and Pods.

Table 3. Rate and Speed of Abortion according to Time.

	Rate of Aborted Cherries (%)	Rate of Aborted Pods (%)	Speed of Aborted Cherries (Number of cherries/Unit of time)	Speed of Aborted Pods (Number of pods/Unit of time)
2_Weeks	36±0.053 a	13,9±0.141	9±1.323 a	3.118±3.536
1_Month	36,7±0.031 a	16±0.087	4,583±0.382 b	2±1.25
1,5_Months	24.7±0.023 ab	26,7±0.012	5,889±0.977 b	3,556±0.822
2_Months	11.8±0.028 b	18±0.092	5,073±0.412 b	3,792±0.361
2,5_Months	-	16±0.092	-	-
3_Months	-	15,3±0.064	-	-
Pr > F(Model)	0.004	0.477	0.000	0.421

Table 4. Estimation of Mass Losses in Beans from Attacked Pods that Have Reached Maturity.

	Number of Pods Reaching Maturity after Attacks	Average Weight of Beans per Pod (g)	Loss of Mass of Beans (%)
Pods Heathy (Control)	-	40	-
Plot 1	07	32.38	19.05%
Plot 2	18	22.57	43.57%
Plot 3	22	21.77	45.58%
Average	15.67 ±7.767	25.57 ±5.908	36.38% ±14.77

4. Discussion

The high attack rate of cocoa cherries and pods, exceeding 50%, demonstrates the significant high parasitic pressure from brown and green bugs in this area. These bugs should therefore no longer be considered minor pests of cocoa in Côte d'Ivoire. Furthermore, the absence of any significant difference in the rate of attack between cherries and pods demonstrates the voracity of these bugs and their lack of selectivity in terms of the stage of development of the cocoa fruit. Studies conducted by Yédé *et al.* (2009) [13] have shown that bugs of the Pentatomidae and Coreidae families, to which the green and brown bugs respectively belong, are present in Cameroonian cocoa orchards. According to the authors, their presence is due to a dietary preference for cocoa trees and favourable conditions in cocoa orchards.

However, the incidence of high rate of bug attacks has a different impact on the fate of cherries compared to pods. In fact, bug attacks cause direct abortion of cherries after two weeks, with the highest speed and rate of abortion. These results are consistent with those of N'guessan *et al.* (2016) [6], Vanhove *et al*. (2019) [15] and Asitoakor *et al*. (2024) [8] who indicate that damage caused by other bugs to cherries and pods causes deformation followed by fall. The high speed of abortion of attacked cherries thus demonstrates their fragility, which can be explained by their very juvenile stage compared to older pods. At this stage, the organs are still very tender and very sensitive to bug bites, as demonstrated by Doh *et al.* (2014) [16] on young coconuts attacked by *Pseudotheraptus devastans*. Research conducted by the Coffee and Cocoa Council (2018) [17] has also shown that attacks by *B. thalassina* cause deformation, yellowing, and falling of the cherries, as well as the formation of blackish spots on the pods. Furthermore, although they do not cause as significant a rate of abortion as in the case of cherries, attacks by bugs cause considerable damage to the beans in pods that reach maturity.

It is worth noting the depreciation the pods with blackish spots and the deterioration of beans, which could be explained by the fact that when feeding, these bugs inject a toxic substance that promotes necrosis of tissues such as the epicarp and beans. Indeed, Mitchelle (2004) [18] states that heteroptera cause damage to plant tissue through which their stylets pass while feeding. Similarly, Vanhove *et al*. (2019) [15] and Asitoakor *et al*. (2024) [8] which mention that when the bugs feed, they insert their mouthparts into pods and soft tissues, by simultaneously sucking in the juice and secreting saliva causing lesions on the attacked parts and the lesions serve as entry points for pathogens such as pods rotting. Let us note that all these necroses would therefore explain the mass loss of beans from the attacked pods. The damage caused by these two (2) bugs appears to be severe enough to impact the mass of the beans.

5. Conclusion

The impact of green and brown bugs, which mainly attack cherries and pods, is very significant. In addition to causing the total abortion of cherries and some pods, their attacks provoke in the latter a mass loss of their beans. In Côte d'Ivoire, most studies focus heavily on the damage caused by mirids. This study shows that bugs, long considered minor pests, have now become a threat to cocoa. These results will enable better management of these pests in order to reduce their impact on cocoa production and achieve optimal yield.

Abbreviations

GDP Gross Domestic Product

Author Contributions

Doh Franceline: Formal Analysis, Methodology, Resources, Software, Validation, Visualization, Writing – original draft

Coulibaly Tenon: Conceptualization, Methodology, Resources, Supervision, Validation, Writing – review & editing

Kone Siela: Validation, Visualization, Writing – review &

editing

N'Goran Konan Simeon: Data curation, Investigation, Methodology, Writing – review & editing

Conflicts of Interest

The authors declare no conflicts of interest.

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Biography

Doh Franceline holds a Ph.D. in Biology and Plant Protection with a specialization in Applied Entomology. She is an Assistant Professor at Peleforo Gon Coulibaly University (UPGC) in Korhogo, Côte d'Ivoire. Dr. Franceline DOH is a member of the shea sub-project within the Competitive Value Chains for Employment and Economic Transformation Project and a researcher at the African Center for Research and Applications on Shea (CRAK), contributing to studies on insects associated with shea trees and training initiatives for women and youth. As a consultant for the Agro Sustainable Development Cabinet, Dr. DOH supports GLOBAL G.A.P and GRASP certification audits for fruts export companies. Her earlier research at the National Center for Agronomic Research (CNRA) focused on pest management and biopesticides, particularly *Pseudotheraptus devastans* and *Oryctes monoceros*. She has authored and co-authored several technical reports and publications in the fields of entomology, pest management, and sustainable agricultural practices.

Coulibaly Tenon is a teacher and researcher in the Department of Animal Biology, from the Training and Research Unit in Biological Sciences at the Peleforo Gon Coulibaly University. He obtained his PhD in Tropical Ecology at the University Félix Houphouët Boigny in 2014. Recognized for his exceptional contributions, today Master of Conferences of the Universities of CAMES since 2022. In recent years, he has been an international consultant. In recent years, he has been an international consultant on sustainable agriculture standards (Rainforest Alliance, Better Cotton, Cacao Promise...). It conducts research on current topics related to integrated pest management of crops and dwellings, agroecological systems, circular energy and insect production for animal feed

Kone Siela is a professor and researcher in the animal biology department of the Biological Sciences Unit at Peleforo Gon Coulibaly University in Korhogo (Côte d'Ivoire). He obtained his doctorate (specialty: agricultural entomology) at the Nagui Abrogoua University of Abidjan (Ivory Coast) in 2019. Then, he was recruited in 2023 as an Assistant at Peleforo Gon Coulibaly University of Korhogo.. He is the author of various scientific publications, notably on cashew tree pests. His research work, although addressing crop pests, is mainly focused on borers and other insects of the trunk of species. He is a member of the Société Entomologie Côte d'Ivoire (SECI) with participation in various scientific symposiums.

N'Goran Konan Simeon holds a master's degree in applied Zoology and Sustainable Development, specializing in Applied Entomology and Sustainable Development, from the Peleforo Gon Coulibaly University of Korhogo. He has three years of experience in the agricultural sector. He currently serves as a Group Administrator within a cooperative society. His responsibilities include data supervision and analysis, technical support for producers, and mentoring of farmer field schools.

Research Field

Doh Franceline: Pest management, Plant extracts with insecticidal effects, Edible insects, Insects in the circular economy, biological control with predators

Coulibaly Tenon: integrated pest management of crops, agroecological systems, circular energy and insect production, Biological control with predators, Sustainability of agricultural systems, Improvement of sustainable agricultural practices.

Kone Siela: Natural predators of insect pests, Interactions in agricultural and forest ecosystems, Essential oils with insecticidal properties, Taxonomy of insects, agricultural and forest ecosystems

N'Goran Konan Simeon: Sustainability of agricultural systems, Improvement of sustainable agricultural practices, Valorization of biological resources