Short Research Article

INFLUENCE OF CLIMATIC PARAMETERS ON THE INCIDENCE OF BLACK POD ROT OF COCOA TREES IN CÔTE D'IVOIRE

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ABSTRACT

Cocoa farming is very important to Côte d'Ivoire's economy, but the heavy pressure of black pod rot is causing a considerable drop in production, which is unfavorable to sustainable cocoa production. This disease is caused by *Phytophthora palmivora*, which is rife in all cocoa-producing areas. The aim of this study was to determine the impact of the disease in seven localities in the Agnéby-Tiassa region of south-eastern Côte d'Ivoire. To do this, three plots were identified in each locality, based on the presence of black pod rot and the accessibility of the field. A 900 m^2 was delimited in each plot, then 100 trees were randomly numbered to monitor the disease's evolution. A weekly count of the number of pods affected by black pod rot and healthy pods was carried out for seven months to assess the incidence of the disease in the different localities. Climatic parameters such as temperature, humidity and rainfall were recorded in each locality to determine their effects on black pod rot. The results showed a positive correlation between black pod rot rates and climatic parameters. Hierarchical ascending classification separated the localities into three groups, with Azaguié having the highest rate of black pod rot (34.78%) and the lowest rate of rot (6.59%) recorded in Loviguié. The study highlighted the threat posed by black pod rot to cocoa production in the Agnéby-Tiassa region, and the urgent need to develop sustainable control strategies.

Keywords : Keywords: Cocoa, black pod rot, incidence, *Phytophthora palmivora*, climatic parameter, Agnéby-Tiassa

1. INTRODUCTION

Cocoa production occupies an important place in the Ivorian economy, with an annual output of over 2.230 million tonnes in 2023 (STATISTA, 2023). In macroeconomic terms, it accounts for over 50% of export earnings and contributes 10% to Gross Domestic Product (GDP). It also generates two-thirds of direct and indirect employment, according to the FAO (Faostatistique, 2017). Since 1977, Côte d'Ivoire has been the world's leading producer of cocoa beans, with almost 40% of global production. However, several constraints pose a real threat to Côte d'Ivoire's ability to maintain its position as the world's leading producer of cocoa beans. Indeed, orchards in Côte d'Ivoire are subject to heavy pressure from pests (insects) and diseases such as swollen shoot and black pod rot. The latter is caused by *Phytophthora* spp. and, according to Kébé et al. (1999) and Coulibaly et al. (2017), could lead to a 25-60% loss in cocoa production if no phytosanitary measures are taken. Black pod rot caused by the Oomycete *Phytophthora* spp. is one of the most widespread and economically damaging cocoa diseases in all cocoa-producing countries in the world (Wood and Lass, 1985). The disease is characterized by the appearance of a small translucent spot on the cortex, which turns black pod rot within 24 to 48 hours. After two weeks, the pod is totally destroyed and can no longer be eaten (Coulibaly *et al*., 2013). Weather conditions in hot, humid countries such as Côte d'Ivoire are favorable to the proliferation of fungi. According to KKouakou *et al* (2013), the contamination and spread of fungi depends on a complex interaction of climatic factors such as temperature, humidity and endogenous species.

In Côte d'Ivoire, several control methods are used to control this pest, including chemical control, biological control and integrated pest management. However, the use of chemical pesticides remains the most widespread. But this practice is becoming increasingly controversial due to the harmful effects of these pesticides on the environment, biodiversity and human health. In a context of climate change, a fungicide must take into account not only its effectiveness, but also respect for and maintenance of biodiversity and sustainable management of natural resources. In this situation, isn't the use of biofungicides desirable? That's why this study aims to find sustainable biological control methods for black pod rot, in order to ensure production quality and quantity in an increasingly demanding market. And this would not be possible without determining the health status of plantations. In this study, we will assess the incidence of black pod rot in seven localities in the Agnéby-Tiassa region of Côte d'Ivoire.

2. MATERIAL AND METHODS

2-1 Study sites

The present study took place in seven sub-prefectures of the Agnéby-Tiassa region, Côte d'Ivoire: Azaguié, Agboville, Céchi, Grand-Morié, Loviguié, Oress-Krobou and Rubino (Figure 1). In each sub-prefecture, three villages or camps were identified (Table I). Located in the southern forest region of Côte d'Ivoire (6°North - 4°West), the Agnéby-Tiassa region covers an area of 9,080 km². This region is located in the south-east of Côte d'Ivoire and belongs to agroecological zone I as defined by Halle and Bruzon (2006). It is a humid forest zone with altitudes ranging from 0 to 200 m, an annual rainfall of between 1,400 and 2,500 mm and an average temperature of 29°C. The soil is clayey and ferralitic with low desaturation. Cocoa plantations are aging and characterized by high levels of black pod rot (Assiri *et al*., 2009).

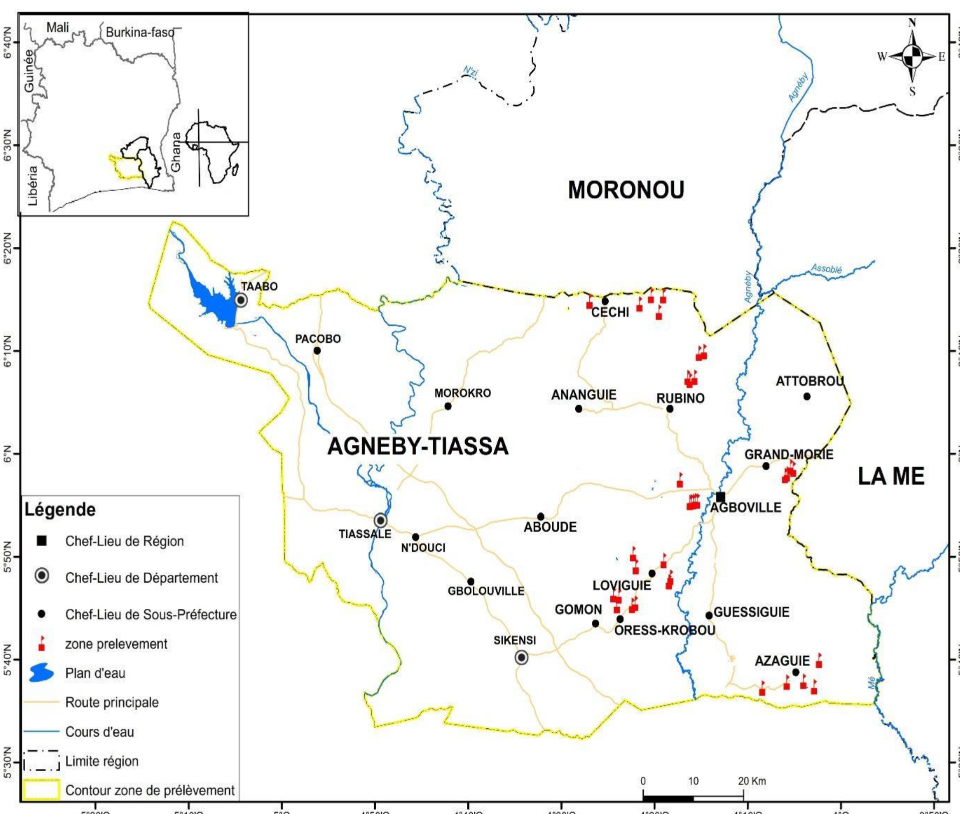

Figure 1: Map of the seven Agnéby-Tiassa sub-prefectures and pod sampling zones

TABLE I: STUDY LOCALITIES AND VILLAGES IN THE AGNÉBY-TIASSA REGION

Sub-Prefectures	Villages/Camps	Distance between sous-prefectures and camps (Km)
Agboville	Mure	3-5
	Scaf	
	Gbalekro	
Grand-Morié	N'Tchago	15
	Grand Moutcho	
	Akpéssenou	
Rubino	Allépila 2	15
	M'bochimpo	
	Kochimpo	
Céchi	N'Da MPO	7
	Kouamé Kankro	
	Kouamékro	
Loviguié	Wahin	12
	Loviguié 1	7
	Loviguié 2	7
Oress-Krobou	Piste Agboville	6
	Piste Aboudé 1	
	Piste Aboudé 2	
Azaguié	Azaguié Abbé	11
	Azaguié gare	4
	Makoudjé	7

2-1 Plant material

The plant material used consisted of immature green pods naturally affected by black pod rot. Most of these pods came from village plantation cocoa trees, made up of Ghana cocoa varieties, French cocoa varieties and selected hybrid cocoa trees (Mercedes) popularized in farming areas. These are the Amelonado and Criollo varieties.

2-2 Methods

2-2-1 Plot identification and preparation

The study was carried out from September 2018 to September 2019 in the Agneby-Tiassa region, specifically in the sub-prefectures of Agboville, Grand-Morié, Rubino, Céchi, Loviguié, Oress-Krobou and Azaguié. In each sub-prefecture, experiments were carried out in three villages (Table I). In each village, the trial plots were selected following a black pod rot survey. In each of the selected plots, a 900 m^2

was delimited and 100 cocoa trees were randomly marked using the method of Mpika (2009).

2-2-2 Climatic data collection

In order to establish the relationship between climatic factors and the development of cocoa pod black pod rot, thermohygrometers (Easy Loger USB brand) and manual rain gauges were installed in the fields of each locality. Temperature and relative humidity were recorded every 30 minutes, while rainfall was recorded daily from September to December 2018 and from June to September 2019.

2-2-3 Assessment of the incidence of cocoa pod brown rot in selected plots

The evaluation of the incidence of brown pod rot consisted of a weekly count of the number of healthy and diseased pods in the plots identified in the various localities. Assessments were carried out on 100 trees previously identified and marked. The experience lasted seven months. The rate of rotten pods was calculated using the following formula:

$$\mathrm{TPB} = \frac{\mathrm{NCP}}{\mathrm{N}} \mathrm{~X~} 100$$

With TPB: Black pod rot; NCP: Number of rotten pods; N: Total number of healthy and rotten pods.

2-3 Statistical analysis

Principal component analyses (PCA) and hierarchical ascending classifications (HAC) using R software version R3.03 were carried out to highlight the correlation between climatic parameters and the incidence of black pod rot.

3. RESULTS AND DISCUSSION

3 Results

3-1 Black pod rates and climatic parameters in cocoa trees

Climatic data in general, and rainfall in particular, influenced black pod rot proliferation (Table II). Temperature and average relative humidity varied very little in the seven localities studied. The highest temperature value (26.08 °C) was recorded in Grand-Morié, while the lowest value (24.71°C) was observed in Azaguié. Similarly, the lowest relative humidity value (87.46 %) was recorded in Rubino, while the highest value (92.01 %) was recorded in Agboville. Average rainfall data varied considerably from one locality to another, with the highest average annual rainfall recorded in Azaguié, at 1,722 mm. On the other hand, the lowest average annual rainfall value of 926 mm was recorded in Agboville (Table I). Average black rot rates were calculated by plot and locality. These rates varied from one locality to another, with the highest rot rate (34.78%) recorded in Azaguié and the lowest rot rate (6.59 %) in Loviguié.

2-2 Correlation between climatic parameters and black rot rate

Principal component analysis of the data revealed two dimensions (dim1 and dim2) with respective inertia rates of 54.6 % and 35.1 %. The total inertia rate is therefore 89.7 %. This means that 89.7 % of the total variability of the individual clouds is represented in the plane (Table III). In addition, the colors of the variables indicate their level of contribution to the construction of the components. The variables: black pod rot, rainfall and relative humidity (POURR, PP and HR respectively) contributed strongly to the formation of the factorial axes (Figure 2). On the other hand, the lowest contribution was obtained with the temperature variable (Temp). This means, in fact, that variables with a high contribution better characterize the localities.

For the first component (Dim 1), positive correlations were observed between variables such as POURR, PP and HR. These variables are negatively correlated with the Temp variable. On the second component (Dim 2), a weak positive correlation was observed between the

temperature and black pod rot variables (Temp and POURR). The correlation between temperature and rainfall (Temp and PP) was weakly positive. On the other hand, a negative correlation was observed between the variables POURR, PP, Temp and relative humidity HR. In this order, the localities in bright red are those that are best represented in the factorial plane. They are the ones that can best be interpreted by the collected variables. Thus, Azaguié, Oress-krobou, Agboville, Loviguié and Rubino are the most discriminating localities. They were followed by Céchi and Grand-Morié (Figure 3).
Variables were superimposed on individuals or localities (Figure 4). The variables POURR, PP and HR characterize the Azaguié locality. This means that the highest rate of black pod rot was recorded in Azaguié. This rate was positively influenced by rainfall, but only slightly by relative humidity. Temperature had relatively little influence on black pod rot in this locality.
The localities of Agboville, Oress-krobou, Céchi and Loviguié are characterized by high temperature, low black pod rot rates, rainfall and relative humidity. The rate of black rot is high in Rubino and Grand-Morié, despite high temperatures, low rainfall and low relative humidity.
The dendrogram (Figure 5) resulting from the ascending hierarchical classification (AHC) was produced. Three groups of localities were obtained according to their similarity. The first group consists of the Azaguié locality, characterized by a high rate of black pod rot, high rainfall and low relative humidity.

Table II: Average temperature, average relative humidity, average rainfall and average rate of black pod rot of cacao pods in seven locations studied

Localities	**Temperature (°C)**	**Relative humidity (Hm)**	**Total rainfall (mm)**	**Black pod rot (%)**
Azaguié	24,71	91,50	1722	34,78
Agboville	25,76	92,01	926	6,75
Céchi	25,24	90,74	1171	10,61
Rubino	25,70	87,46	1037	24,79
Oress-krobou	25,48	90,73	1015	10,06
Loviguié	25,48	90,40	1050	6,59
Grand-Morié	26,08	89,30	1349	24,04

Table III: Eigenvalue matrix and correlation between variables and principal axes after relative PCA

	Axe1	Axe2	Axe3	Axe4
Eigen value	2,18	1,40	0,35	0,06
% total variance	54,62	35,11	8,72	1,55
Total accumulated variance	54,62	89,72	98,45	100
Temp	26,17	16,20	57,55	0,07
HR	1,54	61,82	26,29	10,34
PP	41,95	0,57	13,88	43,60
POURR	30,34	21,41	2,27	45,98

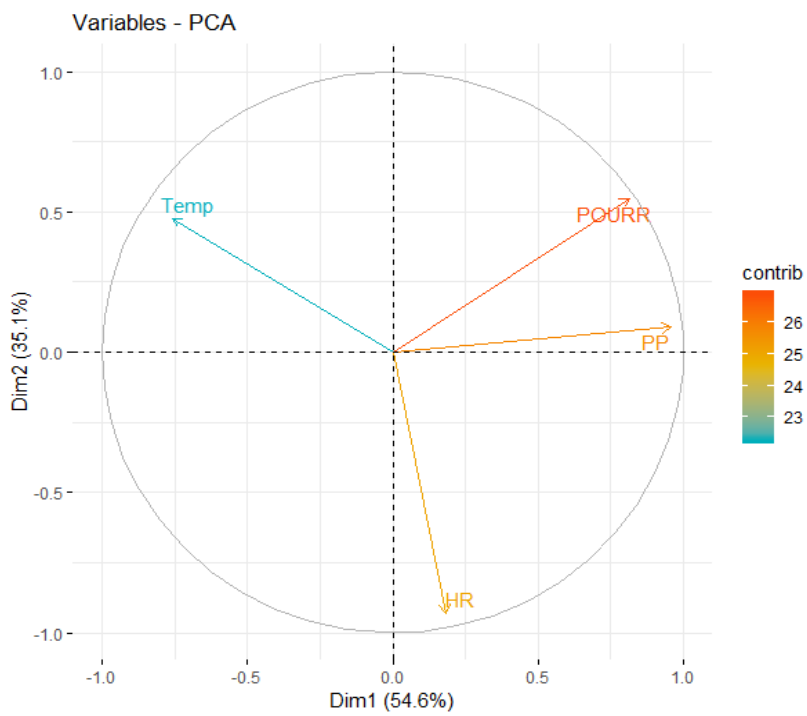

Figure 2 Correlation circle for climatic parameters
The colors indicate the level of contribution of the variables
PP: rainfall, HR: humidity, Temp: temperature, POURR: black pod rot

The second group comprises localities such as Agboville, Loviguié, Oress-krobou and Céchi, characterized by low levels of black pod rot, rainfall, relative humidity and high temperature. Finally, the last group includes Rubino and Grand-Morié, characterized by high levels of black pod rot, high temperatures, low rainfall and low relative humidity (Figure 3).

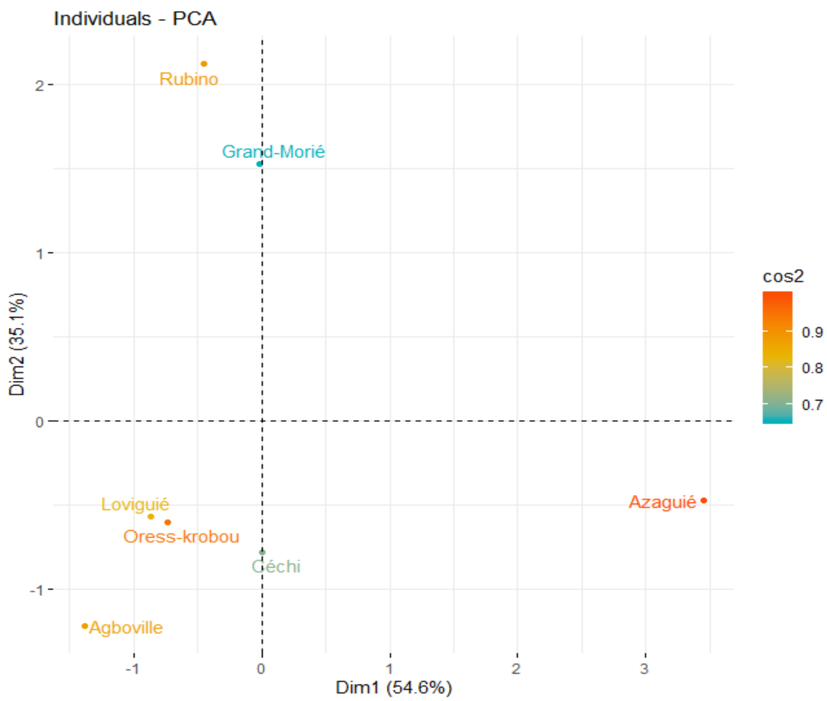

Figure 3: Dispersion of locations in the factorial plane Colors indicate quality of representation (Cos²) of localities

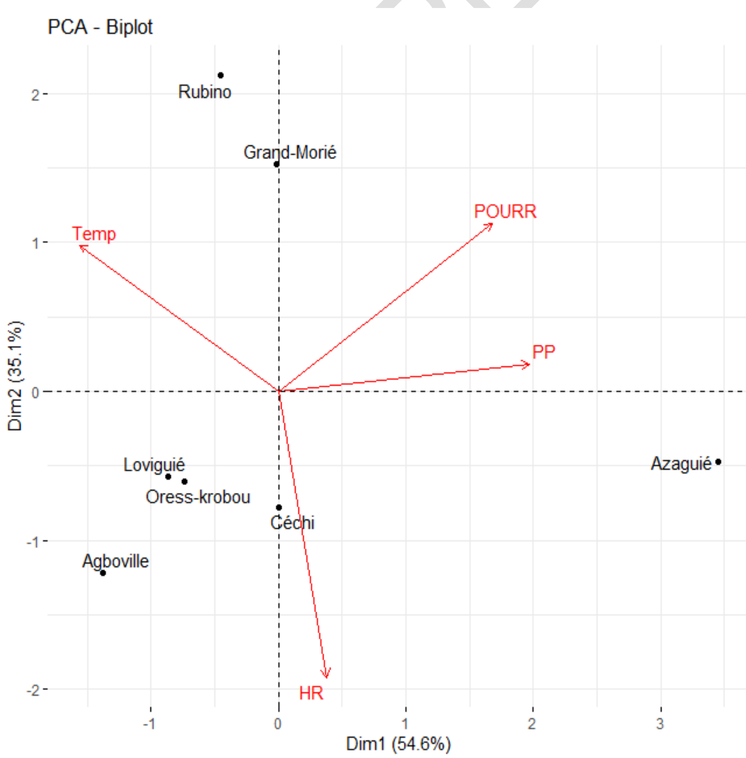

Figure 4: Relationship between localities and climatic parameters in the factorial plane
Red and black indicate climatic parameters and localities respectively

POURR: Black pod rot, RH: Relative humidity, Temp: Temperature, PP: Rainfall

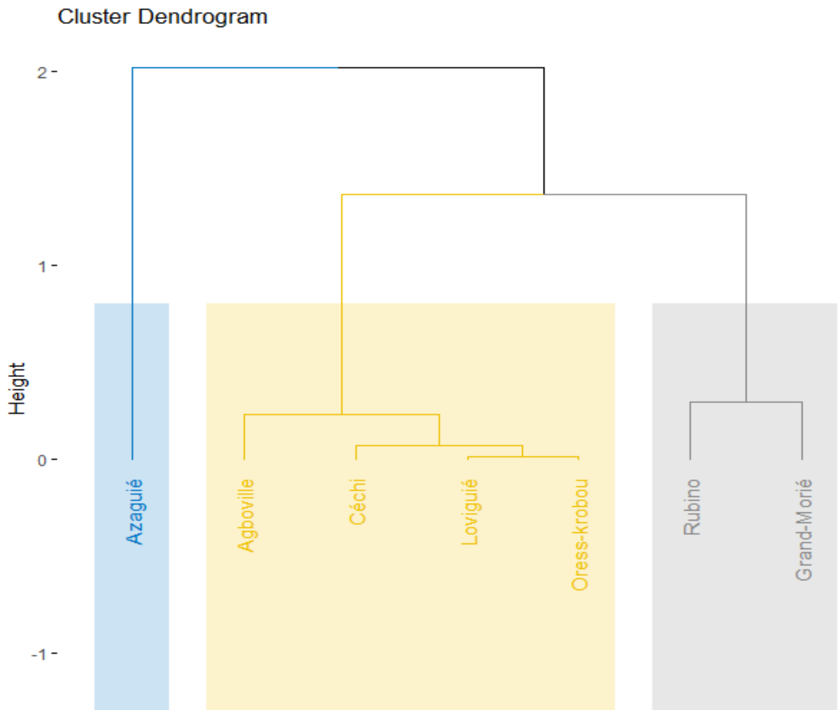

Figure 5: Relationship between locations and variables collected in the factorial design

Blue: Group 1; Orange: Group 2; Purple: Group 3

III Discussion

Evaluation of the brown rot rate with climatic parameters in the Agnéby-Tiassa region of Côte d'Ivoire showed that the Azaguié locality is the most affected by this disease with the highest rainfall value. The lowest rot rates were recorded in Céchi, Agboville, Loviguié and Oress-krobou. After Azaguié, Rubino and Grand-Morié were the worst affected. As for temperature and humidity, values varied very little in all localities. These results could be explained, on the one hand, by the fact that in these localities, cocoa trees are ageing and poorly maintained (no or infrequent cleaning of plots). In fact, a cocoa orchard that is too old, with a density of 1333 cocoa trees/ha or less, is not very productive and is more vulnerable to pests and diseases. Assiri *et al* (2009), describing the agronomic characteristics of cocoa orchards in Côte d'Ivoire, found that over 60% of orchards were between 11 and 30 years old.

On the other hand, the proliferation of black pod rot is due to poor management or a total absence of phytosanitary treatment. In fact, the results of our surveys in the Agnéby-Tiassa region showed that very few growers use fungicides to treat black rot. Paradoxically, even when fungicides are used, they are very often poorly applied. Added to this is the fact that sanitary harvesting is not carried out regularly, and pod shells are left in the fields after shelling. This represents a real source of inoculum for *Phytophthora* spp. and other diseases. Good management of phytosanitary measures included in integrated pest management considerably.

In general, climatic parameters influence the proliferation of pathogens in cocoa trees. Principal component analysis (PCA) has shown that black rot rates are strongly and positively correlated with rainfall and relative humidity, while temperature is strongly and negatively correlated with these three parameters. This means that the higher the amount of rainfall and relative humidity, the higher the rate of black rot. Conversely, the higher the temperature, the fewer rotten pods. This is probably why Azaguié recorded the highest rate of rot with the greatest amount of rain.

Ndoumbe-Nkeng (2002), Ndoumbe-Nkeng et al. (2009) and Ngoh Dooh *et al*. (2015) proved that climatic parameters (rainfall, humidity and temperature) were essential for the dissemination and germination of *P. megakarya* spores. Indeed, in areas with high rainfall in Cameroon, the rate of black pod rot was higher than in areas with high temperatures. According to Rotem (1978) and Duniway (1979), maturation and germination of *Phytophthora* spp. sporocysts depend on conditions of moisture, humidity and temperature. On the other hand, desiccation and strong solar radiation are unfavorable and lethal.

4. CONCLUSION

Black pod rot is present and significant in all the locations studied. Moreover, the rate of rot is strongly influenced by climatic parameters, but with variable effects from one locality to another. Azaguié recorded the highest rate of black rot. This study shows the urgent need to develop sustainable control methods for this disease in order to ensure optimum cocoa production in this region.

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