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Distribution of Bacterial Disease in the Main Mango Production Areas of Côte d'Ivoire

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Bacterial disease is a major biotic constraints of mango production in Côte d'Ivoire. The objective of this study is to assess the distribution of mango bacteriosis disease in mango production areas in northern Côte d'Ivoire. This study focused on 720 mango trees, of the Kent variety, spread over 20 orchards. These orchards are located in the Bagoué, Tchologo and Poro regions in northern Côte d'Ivoire. The study consisted of determining the incidence and severity of bacterial disease on the leaves and fruits of mango trees. Data on the incidence and severity index of bacterial disease on leaves and fruits were subjected to descriptive analysis followed by PCA. Then, the ascending hierarchical classification (CAH) and multivariate analysis completed the data analysis. The results

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obtained did not reveal any dissimilarity of the presence of the bacterial disease in the three (3) regions studied. On the other hand, a predominance of the severe or major type of bacterial disease over the level of slight or marginal contamination has been demonstrated. None of the three main regions (Poro, Tchologo and Bagoué) of mango production in Côte d'Ivoire appears to be the center of bacterial disease dispersion at the current stage of bacterial disease progression. The level of incidence and severity of this disease is similar between fruits and leaves. The Principal Component Analysis and the Ascending Hierachical Classification completed by the MANOVA made it possible to structure the mango orchards into three (3) homogeneous groups. Group 2 orchards (VB4, VB8, VB7 and VF2) presented a moderate level of incidence and severity on leaves and fruits.

Keywords: Mango tree; bacterial disease; spatiale distribution; tchologo; Bagoué; Poro; Ivory Coast .

1. INTRODUCTION

Globally, mango production was estimated at around 48.3613 million tonnes in 2017 [1]. This production is largely dominated by India which alone accounts for 41% of world production (Pacir, 2013; [1]. West Africa is ranked 7th world producer with a mango production of around 1.5 million tonnes per year, which represents 3.8% of world production (ITC, 2011; [2]. Third supplier to the European market, Côte d'Ivoire is also the leading African mango exporter, far ahead of other West African countries. Ivory Coast experienced record exports in 2016 and 2017, with more than 30,000 tonnes shipped to Europe [3]. Representing 4% of Ivorian GDP, mango is the third fruit exported by the country behind bananas and pineapples (N'Dépo et al., 2009). It generates more than 10 million euros in income in the northern areas where it is cultivated [3]. However, the yields of Ivorian orchards still remain low, of the order of 3 to 7 t/ha compared to those of India which are of the order of 10 to 15 t/ha [3]. This low yield could be explained by the environment which is favorable to the proliferation of. However in Côte d'Ivoire, besides fungal diseases, bacteriosis is one of the most dominant diseases in mango cultivation [4]. Bacteriosis disease damage is observed in all mango-producing regions [5]. According to Hamza [6], high relative humidity (> 90%) promotes the development and the proliferation of diseases such as bacteriosis [7,8]. In view of the above, it has proved necessary to determine the health status of bacteriosis in mango production areas in northern Côte d'Ivoire. It is in this perspective that the present study proposes to evaluate the distribution of the bacterial disease and to structure the mango orchards of the mango production basin, according to the presence of this disease, in the north of the Côte d'Ivoire.

2. MATERIALS AND METHODS

2.1 Experiment Sites

The present study was carried out in three regions of northern Côte d'Ivoire, Baguoué, Tchologo and Poro. These regions constitute the mango production basin in the Ivory Coast. Thus, the mango orchards of the departments of Korhogo (12.500 km2), Ferkéssédougou (3.220 km2), Sinématiali (680 km2) and Boundiali (4.302 km2) were the sites of the study. The climate in these departments is tropical with more rainfall in summer than in winter. The average annual temperature in Korhogo is 26.5 °C and the average annual precipitation is 1286 mm. The average annual temperature in Ferkessédougou is 26.4 °C. On average, 1260 mm of precipitation falls per year. The average annual temperature in Boundiali is 26.1 °C. Each year, precipitation averages 1.441 mm (Anonymous, 2016). The Poro region is located 635 km from Abidjan north of the Ivory Coast, the Department of Korhogo is the capital of the Poro region and the Savanes district.

The soils in the study area are of the ferralitic type. However, hydromorphic soils are observed [9].

2.2 Plant Material

The plant material used in this study is made up of 28,200 twigs or individuals, including 40 twigs per mango tree, from 720 mango trees spread over 20 orchards of at least 2 hectares, which made up the observation material. These twigs are made up of the young stem or non-leafy twig, leaves, flowers and fruits depending on the stage of development of the mango tree. The 720 mango trees spread over the 20 orchards were identified during surveys carried out in the peasant orchards of the departments of Ferkéssédougou, Korhogo, Sinématiali and Boundiali. The mango trees in these peasant orchards have a planting period of 10 years.

2.3 Methods

2.3.1 Prospecting and choice of orchards

The survey was carried out in the peasant orchards of the departments of the study (Fig. 1). During this prospecting, mango orchards with 10 years of plantation were sought. These prospected mango orchards mainly consist of the Kent variety. To this end, 20 orchards were selected following the prospecting. In each orchard selected, a block of one-hectare plots comprising 100 mango trees spaced 10 m apart from each other was demarcated. At the level of each plot, 1440 branches of 36 mango trees were evaluated according to the diagonal and median method [10]. These tree populations were studied using the traveling inventory method combined with the diagonals and medians method. Each tree or individual has been marked/colored, numbered and georeferenced using GPS to conduct eco-geographic surveys [11]. and according to the method of Diouf et al. [12] to conduct ethnobotanical surveys. The incidence and severity of bacteriosis were evaluated on leaves and fruits in order to determine the spatial distribution of bacteriosis in the mango production area and to structure the orchards of the three regions of the mango production area. The fruits studied were all at the harvest or physiological maturity stage.

2.3.2 Collection of data

According to the experimental principle of Dangneli et al. (2003), in this study, each tree or mango tree represents the plot. The twigs are the individuals of the plot, so at each plot, 40 twigs were marked in the North-South and East-West axes at the rate of 20 twigs in each ax. These twigs or individuals were observed according to the parameters of severity and incidence. These observations were made during an agricultural campaign including the two stages of mango development, the vegetative and fruiting stages, in order to assess the spatial distribution of the bacterial disease. Thus, data collection focused on the incidence and severity of anthracnose on leaves, twigs and fruits.

2.3.3 Assessment of the severity index (SI) of the bacterial disease

Ten (10) twigs were marked on each side of the NS and EO axes for sight and hand. The severity was assessed on the leaves and fruits of each tree according to the rating scale of [13,5]. (Table 1). Severity was assessed using a visual rating scale ranging from 0 to 9; Grade 0: no symptoms; grade 1: 1 to 5%; grade 3: 6-10%; grade 5: 11-25%; Grade 7: 26 to 50%; Grade 9:> 50% (Table 1). The scoring therefore consisted in assigning a percentage to the diseased organs according to the distribution, the intensity of the symptoms and the number of organs affected. The summation of the severity scores at each marked branch in both directions of the tree was performed in order to obtain an average. The severity index of the observed diseases was determined according to the formula of Kranz (1988) cited by Dianda et al. [14] below.

$$\boldsymbol{Is} = \sum \left(\frac{Xi \times ni}{N \times Z}\right) \times 100$$

Is: Severity incident; Xi: severity i of the disease on the organ; ni: number of organ of severity i; N: total number of organs observed; Z: highest severity scale (9).

Table 1. Infection severity rating scale

Scale	Percentage of infected surface (%)	Symptoms
0	0	No symptoms
1	1-5	Low Infection
3	6- 10	Moderate infection
5	11- 25	Slightly severe infection
7	26-50	Severe infection
9	> 50	Very Severe infection

2.3.4 Assessment of the incidence (Ic) of bacterial disease

The incidence was determined as the ratio of the number of sick people to the total number of individuals observed as a percentage. The impacts were determined according to the following formula from Aka et al. [15] and Zahri et al. [16]:

$$Ic = \frac{\text{Number of organs attacked on the date of observation}}{\text{Total number of organs in the plot orbit}} \times 100$$

This evaluation focused on ten (10) branches marked on either side of the NS and EO axes to be viewed and carried by hand. A scale adapted to that of Bhagwat et al. [17] was used to qualify the level of incidence of bacteriosis on each tree Cardoso et al [13] This six-level scale (0-5) is defined as follows: 0 (no symptoms); grade 1 (1 to 10%: low incidence); grade 2 (11-20%: moderate incidence); grade 3 (21-30%: medium or intermediate incidence); grade 4 (31-50%: high incidence); grade 5 (> 50%: very high incidence).

1.3.5 Statistical analysis of the data collected

Excel 2016 software was used for data entry and for the construction of graphs [10]. Statistica version 10 software was used for descriptive analysis of the data, for comparison tests of means [18] Pearson's correlation test was performed with SPSS 16.0 software to establish a relationship between the incidence of bacteriosis and agromorphological parameters [10]. Finally, principal component analysis (ACP) and ascending hierarchical classification (CHA) supplemented by multivariate analysis (MANOVA) were performed to structure the mango orchards into different groups [18].

3. RESULTS

3.1 Incidence and Severity Index of Bacterial Disease According to the Leaf and Fruit Organs of Mango

The comparative profiles (Figs. 1 and 2) of the severity index and the evaluation of the incidence of bacterial disease according to the organs revealed that the values of the indices of severity and the incidence of bacteriosis are similar in leaves and fruits in 720 mango trees from 20 orchards evaluated in the three study regions. These bacterial disease infection severity index and incidence values oscillated between slight values of marginal type which are between 11 and 25% and severe values of major type distributed between 26 and 50%. These values are also very similar between regions regardless of the location of the orchard. Thus, the leaves and fruits of orchards VB4, VB7, VB8, VF2, VF5, VS1 and VK2 have defined severity index and incidence values therefore of marginal type, while the leaves and Fruits of VB1, VB2, VB3, VB5, VB6, VF1, VF3, VF4, VF6, VS2, VS3, VS4 and VK1 all exhibited severity indices and severe or major type incidences.

3.2 Average Incidences and Severity Indices of Bacterial Disease According To Mango Orchards

The results presented in Figure 3 revealed severity indices and incidences made up of light values (marginal type) between 11 and 25% and severe values (major type) which evolved between 26 and 50%. These results (Fig. 3) showed that the types of severity and incidence indices (marginal and major) of mango bacterial disease are statistically similar in the three study regions; Bagoué (Is = 28.26 ± 4.57; Ic = 33.60 ± 5.78), Poro (Is = 30.85 ± 5.44; Ic = 36.51 ± 5.93) and Tchologo (Is = 31.93 ± 6.11; Ic = 29.48 ± 5.22). However, within the same region, the distribution of bacterial disease was heterogeneous. Thus, orchards VB4 (Is = 10.35 ± 6.24; Ic = 8.72 ± 6.24), VB7 (Is = 7.41 ± 4.22; Ic = 7.82 ± 5.845), VB8 (Is = 11.24 ± 6.28; Ic = 8.73 ± 4.15), VF2 (Is = 7.9 ± 6.22; Ic = 5.74 ± 4.27), VF5 (Is = 17, 2 ± 5.21; Ic = 15.165 ± 4.73), VS1 (Is = 21.33 ± 4.95; Ic = 12.42 ± 5.88), VK2 (Is = 23.7 ± 5.65; Ic = 17.61 ± 6.18) expressed the severity index (IS) and incidence (Ic) values of marginal type while orchards VB1 (Is = 33.44 ± 6.44; Ic = 38.66 ± 4.9), VB2 (Is = 47.27 ± 4.38; Ic = 34.875 ± 5.79), VB3 (Is = 53.96 ± 8.01; Ic = 49.325 ± 6.97) , VB5 (Is = 35.80 ± 5.67; Ic = 35.22 ± 3.50), VB6 (Is = 48.47 ± 7.64; Ic = 46.16 ± 4.95), VF1 (Is = 45.46 ± 7.5; Ic = 51.21 ± 6), VF3 (Is = 34.36 ± 4.40; Ic = 27.22 ± 4.82), VF4 (Is = 50.28 ± 5 , 23; Ic = 36.375 ± 6.48), VF6 (Is = 36.39 ± 6.40; Ic = 41.16 ± 5.02), VS2 (Is = 43.41 ± 5.92; Ic = 39 , 21 ± 5.91), VS3 (Is = 57.2 ± 4.8; Ic = 42.10 ± 4.7), VS4 (Is = 39.32 ± 5.09; Ic = 45.39 ± 6 , 89) and VK1 (Is = 34.09 ± 6.28; Ic = 25.45 ± 5.91) all have p presented signs of severity and severe or major type incidence. The major or severe type of bacterial disease was distributed in 65% of the orchards and predominated over the mild or marginal type distributed in 35% of orchards (Fig. 3).

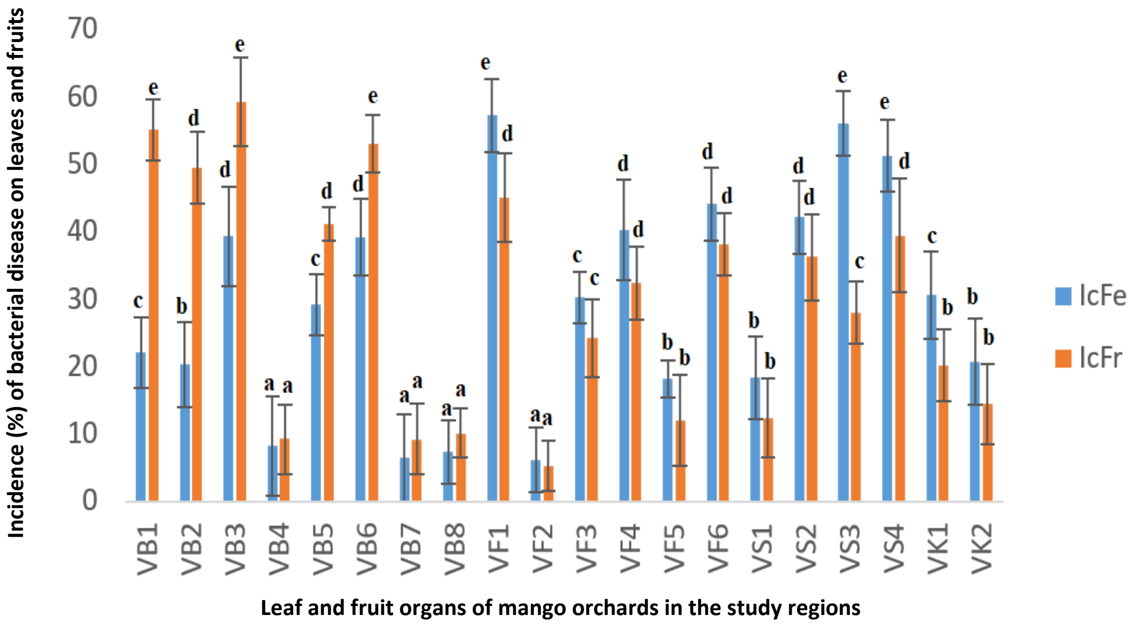

Fig. 1. Comparative profile of the incidence according to the leaf and fruit organs of mango trees

IcFe: Incidence of bacterial disease on leaves; IcFr: Incidence of bacterial disease on fruits. V: orchard; B: Boundiali; F: Ferkéssédougou; S: Sinematiali; K: Korhogo; Fe: leaf; Fr: Fruit; IS: severity index. Graphs of the same color with the same letter are statistically identical

3.3 Principal Component Analysis of the Distribution of Bacterial Disease

Principal component analysis PCA (Figs. 4 and 5) was defined by the first two axes which explain 95.15% of the total variability observed. The observed variability is, on the one hand, expressed negatively by IsFr and IcFr. On the other hand, this variability is expressed positively in IsFe and IcFe.

3.4 Structuring of Orchards According to the Distribution of Anthracnose in the Three Regions by Ascending Hierarchical Classification and Multivariate Analysis (MANOVA)

The Ascending Hierarchical Classification (CAH) made it possible to structure the orchards studied into 3 groups (Fig. 6) according to the method of Ward (1963). Group 1 is made up of 11 orchards (VB1, VB5, VB2, VB3, VB6, VF1, VF4, VS2, VF6, VS4 and VS3). Group 2 contained four orchards namely VB4, VB8, VB7 and VF2. The third group consisted of five orchards (VF3, VK1, VF5, VS1 and VK2). The mango trees from group 1 orchards showed a level of severe infection (with severity and incidence index values between 40 and 45%) and slightly severe for those from group 3 orchards with values of severity and incidence index between 16 and 30%. However, the mango trees in group 2 orchards expressed a moderate level of infection with severity and incidence index values between 7 and 10%.

Multiple analysis of variance (MANOVA) (Table 2) made it possible to characterize three groups according to the four variables (incidence on leaves and fruits and severity index on leaves and fruits) which showed significant differences ($P < 0{,}05$) between the three groups formed. Thus, group 1 is characterized by orchards whose leaves and fruits presented a high value for the severity index (IsFe=45,06±9,65^{c} ; IsFr=44,21±9,38^{c}) and incidence (IcFe=40,15±12,39^{c}; IcFr=16,68±5,32^{c}) of the bacterial disease. Those in group 2 expressed a moderate presence of the disease on leaves and fruits with incidence (IcFe=7,03±0,92^{a} ; IcFr=8,47±2,13^{a}) and severity index (IsFe=8,35 ± 1,40^{a} ; IsFr=10,12±3,21^{a}) values between 7 and 10%. Group 3 orchard mango trees exhibited mildly severe bacterial disease severity index (IsFe=30,31±8.57[b] ; IsFr=21,96±7,05[b]) and incidence values on leaves and fruits (IcFe=23,65±6,29 [b]; IcFr=16,68±5,32[b]).

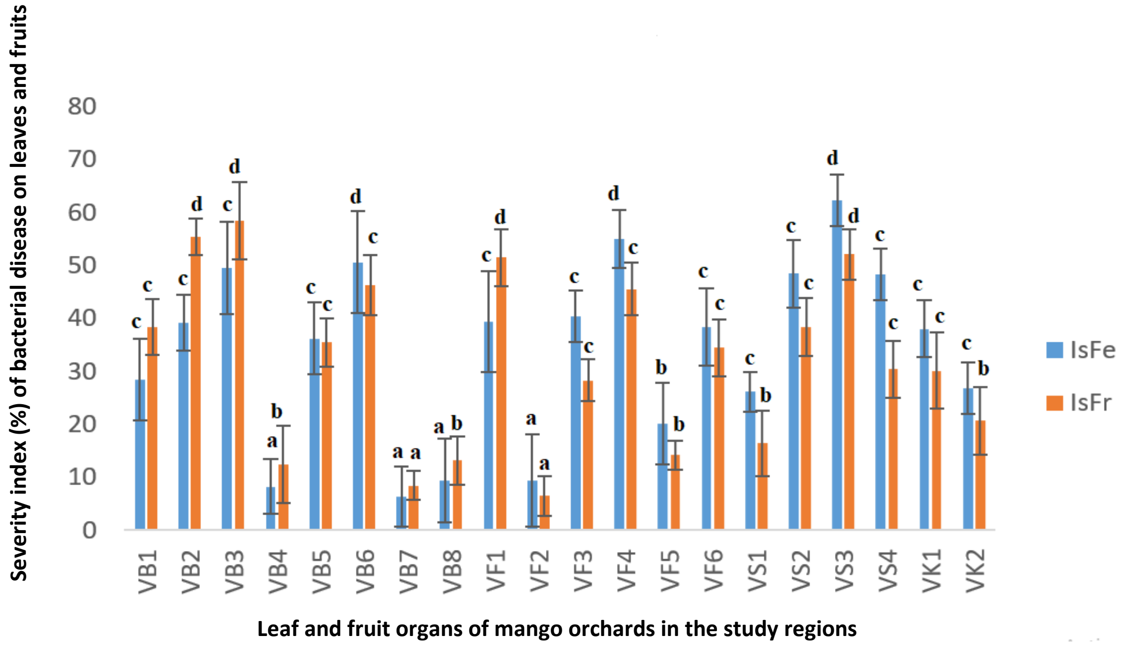

Fig. 2. Comparative profile of the severity index according to the leaf and fruit organs of mango trees

IsFe: Severity index of bacterial disease on the leaves; IsFr: Severity index of bacterial disease on fruits; V: orchard; B: Boundiali; F: Ferkéssédougou; S: Sinematiali; K: Korhogo; Fe: leaf; Fr: Fruit; IS: severity index. Graphs of the same color with the same letter are statistically identical

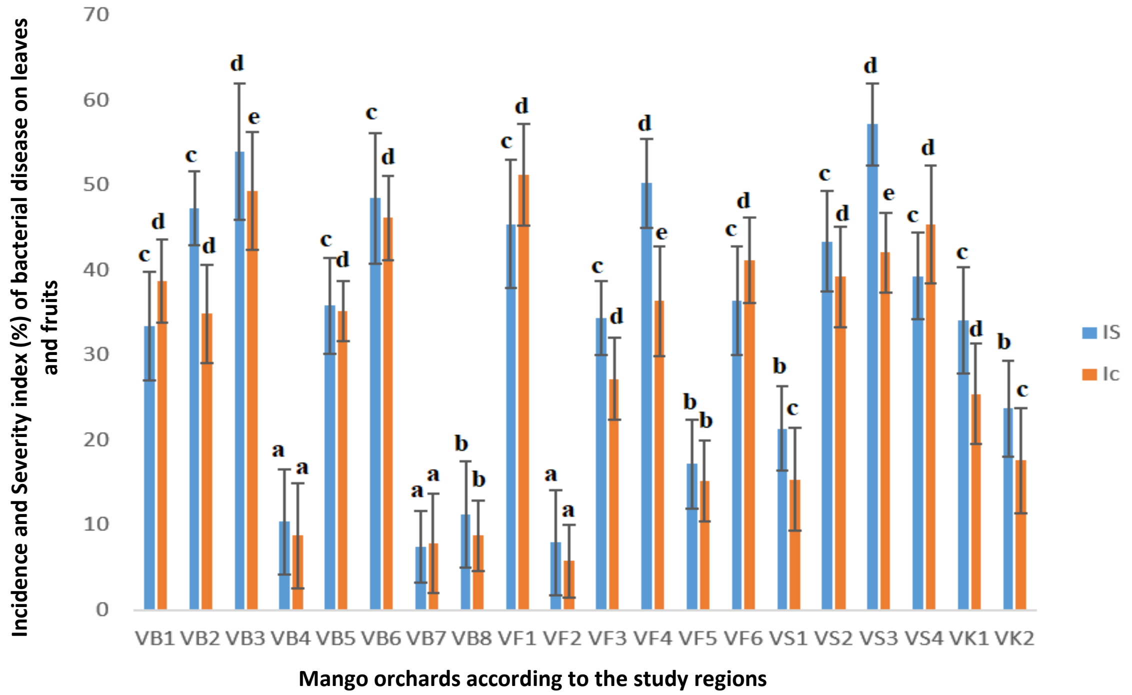

Fig. 3. Comparative profile of incidence and severity index according to mango orchards

Is: Severity index of bacteriosis; Ic: Incidence of bacteriosis; V: orchard; B: Boundiali; F: Ferkéssédougou; S: Sinematiali; K: Korhogo; Graphs of the same color with the same letter are statistically identical

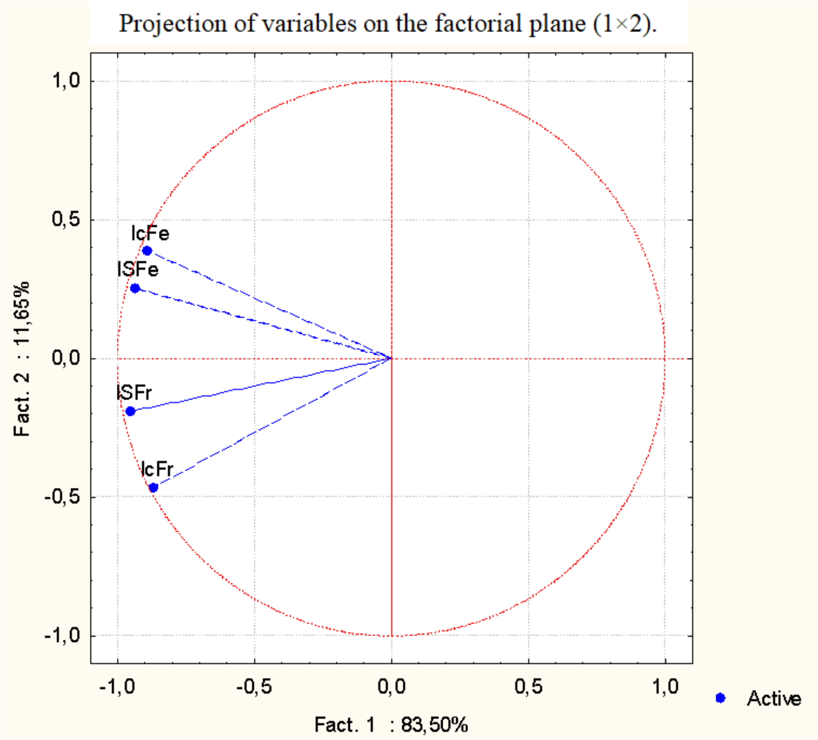

Fig. 4. Projection of the incidence and severity index variables along axes 1 and 2

4. DISCUSSION

The evaluation of the distribution of bacterial disease in the mango orchards of the study regions revealed a strong presence of the disease with a predominance of the severe type of incidence and severity to the detriment of mild infections in the basin of mango production. Indeed, the result presented in Fig. 3 revealed severity indices and incidences which oscillate between light values between 11 and 25% (marginal type) and severe values (major type) between 26 and 50%. The results (FIG. 3) showed that the types of severity and incidence index (marginal and major) of mango bacteriosis are distributed in the three regions where the orchards surveyed are located. Thus, orchards VB4, VB8, VB7, VF2, VF3, VK1, VF5, VS1 and VK2 expressed values of severity index (Is) and incidence (Ic) of light while orchards VB1, VB5, VB2, VB3, VB6, VF1, VF5, VS2, VF6, VS4 and VS3 all presented an index of severity and incidences of severe or major type. Otherwise 45% of the orchards had a mild or marginal impact of mango bacterial blight disease and 55% of the orchards had a severe or major type. This predominance of major type (High severity) of bacteriosis suggests that it represents one of the main threats to mango production in Côte d'Ivoire. In addition, the prevalence of severe type infections according to Cardoso et al. [19] would explain why the Kent variety is one of the most sensitive to the causative agent of bacteriosis. Indeed, according to the work of [20] bacterial disease would represent one of the main biotic constraints in the production and marketing of mango in Côte d'Ivoire. Furthermore, leaf organs and fruits exhibited similar degrees of distribution in bacterial attacks in all study regions. As a result, the leaves would be refuge areas for the pathogen to spread to the fruit at the right time. Indeed, Febina [21] showed that Xanthomonas sp can overwinter in leaf litter remaining on the ground. In favorable weather, new bacteria disseminated by wind and rain will contaminate living leaves by penetrating their stomata. The lesions caused on the leaves will in turn allow the spread of a secondary inoculum from which the fruits are attacked. Therefore, bacteriosis would behave like anthracnose which according to the work of Silué et al. [22] similarly attacked the leaves and fruits of the plant. However, the results of the distribution of bacteriosis suggests a harmonious evolution between the regions and that none of the regions seems, at the current stage, to be the center of dispersion of mango bacteriosis (Bagoué (Is = 28.26 ± 4 , 57; Ic = 33.60 ± 5.78), Poro (Is = 30.85 ± 5.44; Ic = 36.51 ± 5.93) and Tchologo (Is = 31.93 ± 6.11; Ic = 29.48 ± 5.22)) in the mango production area in the north of Côte d'Ivoire. Thus, contrary to the work of Yah et al. [23] bacteriosis, along with anthracnose, is the main mango disease in the mango basin in Côte d'Ivoire. In addition, the Poro region, through the departments of Korhogo and Sinématiali, has always been the spearhead of mango production in Côte d'Ivoire. Thus, this harmonious spatial distribution of the disease could result from a rapid dispersion of the bacteriosis which would have spread over time from the Poro region as the center of dispersion. In addition, the rapid dispersion of mango bacteriosis could be explained by the fact that the pathogen, Xanthomonas sp, is very present in tropical areas because the environment (temperature, relative humidity and precipitation) of these areas would be favorable to its proliferation. This assertion agrees with that of Chrys [24] who asserts that this pathology is one of the most damaging and most widespread in all production areas.

The leaves would behave as organs of conservation of the inoculum of the causative agent of the bacteriosis. The leaves would behave like organs to preserve the inoculum of the causative agent of bacterial disease. The severity index and the incidence values of orchards VK1, VK2, VS1, VB4, VF5, VB8, VF2 and VB7 did not contribute to the variability expressed by the principal component analysis (ACP). This analysis is in agreement with that of the ascending hierarchical classification (CAH) which structured the mango trees of these orchards in 3 group. The mango trees of group 2 would present moderate or marginal values of index of severity and incidence of the bacterial disease. The maintenance of these orchards could include a good approach of agroecological measures not favorable to the propagation of the causative agent of the bacterial disease.

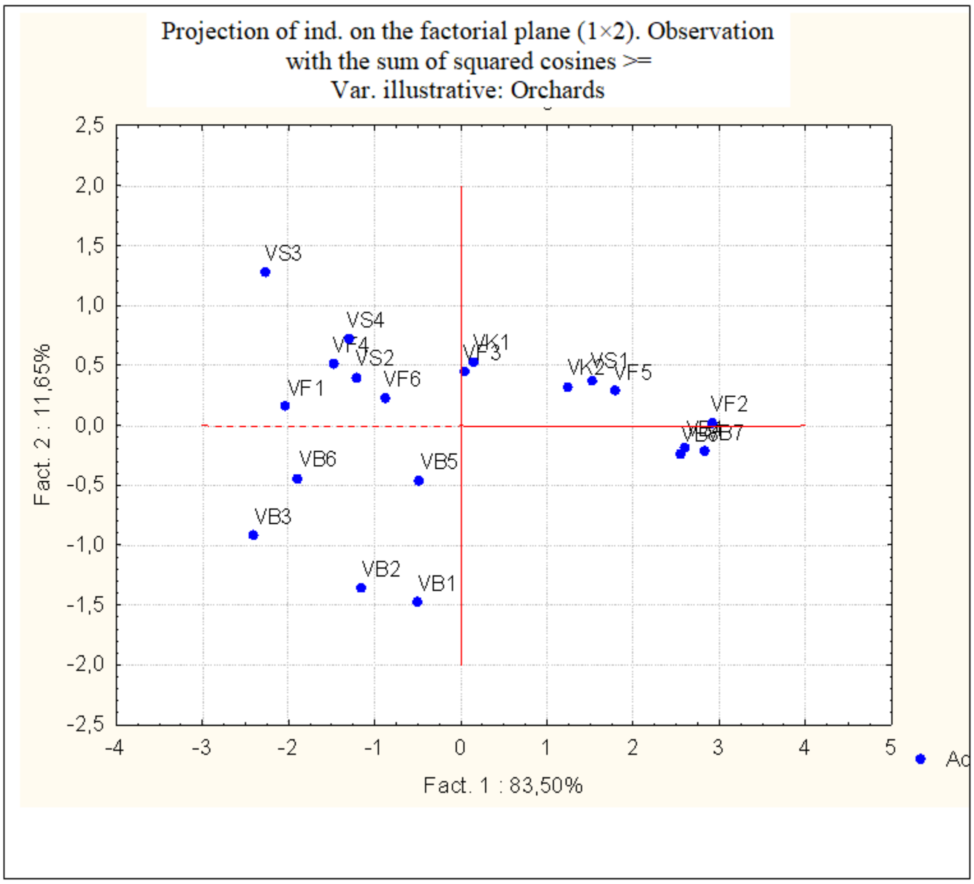

Fig. 5. Distribution of orchards in factorial plans 1 and 2

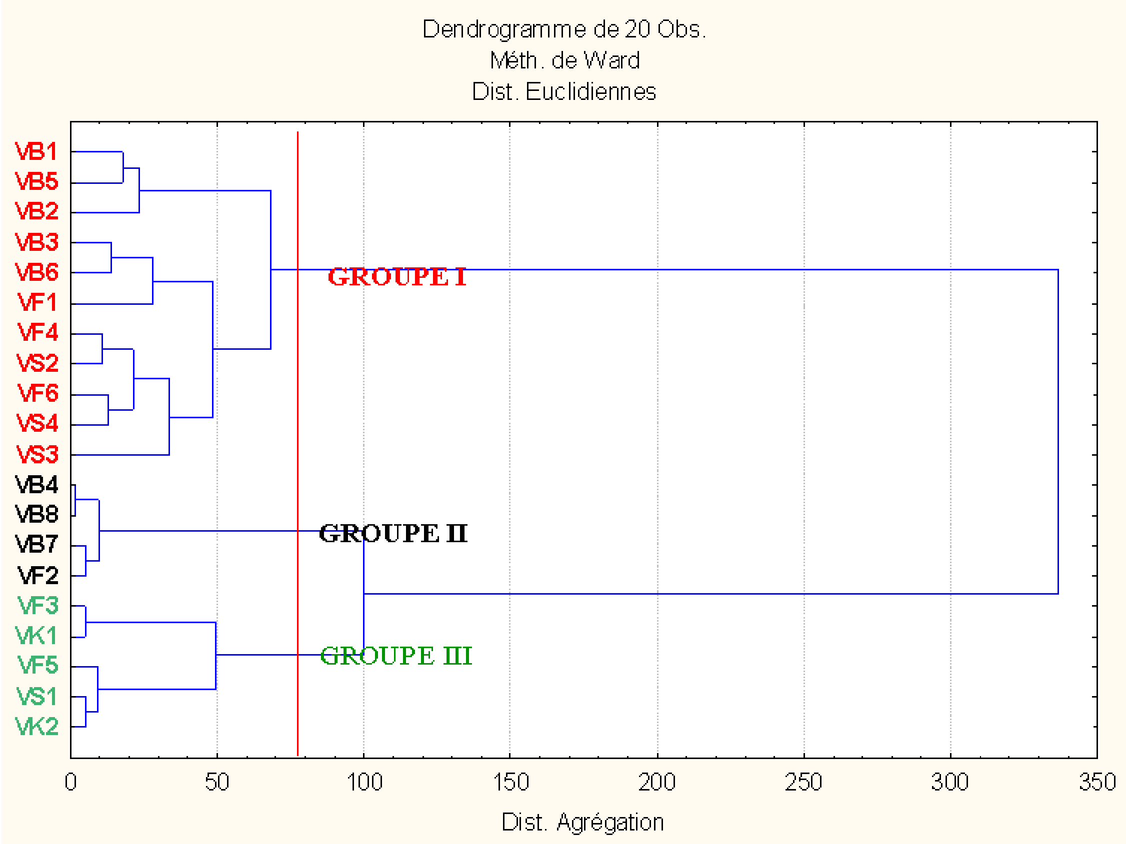

Fig. 6. Structuring of groups of mango orchards by the Ascending Hierarchical Classification (ACH)

Table 2. Characterization of groups by multivariate analysis (MANOVA)

Variables	Group I	Group II	Group III	F	p
IsFe	45,06±9,65 ^{c}	8,35 ± 1,40 ^{a}	30,31±8.57^{b}	27,89979	**0,000004s**
IsFr	44,21±9,38 ^{c}	10,12±3,21 ^{a}	21,96±7,05^{b}	31,08012	**0,000002s**
IcFe	40,15±12,39 ^{c}	7,03±0,92 ^{a}	23,65±6,29^{b}	17,22752	**0,000082s**
IcFr	43,42±9,90 ^{c}	8,47±2,13 ^{a}	16,68±5,32^{b}	36,21091	**0,000001s**

*ns **:** not significant, s: significant, P: probability, F: Fisher*

5. CONCLUSION

The present study noted a similar spatial distribution of the bacterial disease in the mango production basin in Côte d'Ivoire. In addition, the results made it possible to retain a predominance of the major type in terms of the severity and incidence index of the bacterial disease to the detriment of the marginal type. In addition, the leaves appear to be refuged for the inoculum of the causative agent of bacteriosis. None of the three regions appears to be the center of the spread of mango bacterial disease in the production area in northern Côte d'Ivoire. ACP and CAH supplemented by multivariate analysis (MANOVA) made it possible to structure the mango orchards into three (3) groups. Group 1, consisting of orchards VB1, VB5, VB2, VB3, VB6, VF1, VF4, VS2, VF6, VS4 and VS3, is distinguished by severe infection and a high incidence of bacteriosis on leaves and fruits. Group 2 was distinguished by the orchards VB4, VB8, VB7 and VF2, having low severity and low incidence of bacteriosis on leaves and fruits. Group 3 contained five orchards (VF3, VK1, VF5, VS1 and VK2), which showed slightly strong severity and incidence index values on leaves and fruits. The architecture of mango trees in group 2 orchards shows better resilience for agroecological protection of crops against bacterial disease.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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