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Distribution of anthracnose disease in orchards in the mango production area in northern regions of Côte d'Ivoire

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Résumé

Anthracnose disease is one of the main major biotic constraints to the marketing of mango in Côte d'Ivoire. The objective of this work is to report on the distribution of mango anthracnose disease in the mango production basin in northern Côte d'Ivoire. This study focused on 740 mango trees spread over 20 orchards, consisting mainly of the Kent variety. These orchards are located in three (3) study locations, namely the Bagoué, Tchologo and Poro regions. The study consisted of evaluating the incidence and severity of anthracnose in leaf, fruit and branch organs of 740 mango trees in 20 orchards in the three study regions. The data collected that are the index of severity of anthracnose disease on leaves, twigs and fruits, the incidence of anthracnose disease on leaves, twigs and fruits have made the subject to descriptive analysis and ACP. The ascending hierarchical classification (CAH) and multivariate analysis completed the data analysis. The results obtained revealed a similarity in the presence of anthracnose disease in the three (3) regions but with a predominance of the severe or major type over the level of mild or marginal contamination. Neither region appears to be the epicenter of the spread of the disease at the current stage of anthracnose disease progression. This disease infects more fruits and is preserved in the vegetative organs that are the leaves and twigs. Three groups of orchards were structured by ACP and CAH based on the current course of anthracnose disease. These three groups of orchards are all present in the three study regions. Group 3 orchards presented marginal infections. The epidemiological surveillance of these orchards will thus make it possible to better understand the evolution of anthracnose disease and to develop agroecological control approaches against its spread.

Introduction

The mango is the most consumed tropical fruit after the banana **(Gagnon, 2007).** It is cultivated in many tropical and subtropical countries **(Gagnon, 2007; Litz, 1994)**. In 2017, global mango production was estimated at 51.99 million tonnes **(FAO, 2017)**. Asia alone accounts for 72% of this production, led by countries such as India, China and Thailand. Then come Africa with 16% and Latin America with 10%. In Africa, Nigeria, Kenya and Tanzania are the largest mango producing countries. Nigeria is Africa's largest producer, and alone accounts for 11% of African production **(FAO, 2017)**. In Côte d'Ivoire, mango exports generate more than CFAF 7 billion in revenue (local sale and export) and provide producers with around CFAF 1 billion in annual income

(Assovie, 2012). With an export of over 32,600 tonnes compared to 22,700 in 2015 and 9,800 tonnes in 2011, Côte d'Ivoire became the third largest supplier to the European market in 2016 **(Mieu, 2017; FAO, 2017)**. However, Ivorian mango production is threatened by enormous phytosanitary constraints linked to attacks from insects and biotic agents, including Colletotrichum gloeosporioides (Penz.) (**Kouamé et al., 2011)**. The causative agent of mango anthracnose **(Onyeani et al., 2012).** This pathology is the most damaging and the most widespread in all mango production areas **(Chrys, 2006; Pandey et al., 2012)**. In addition, surveys by Hala and Coulibaly (2006) revealed the resurgence of certain diseases in mango orchards in the north of Côte d'Ivoire. According to these studies, anthracnose is the main disease in these orchards. The disease incidence can reach 100% in areas with heavy rainfall with high humidity **(Arauz, 2000)**. Since then, very few studies have been carried out to assess the distribution of anthracnose in mango orchards in the mango production basin in northern Côte d'Ivoire. Given the economic importance of the damage caused by anthracnose in mango orchards, the present study proposes to assess the distribution of anthracnose and to structure the mango orchards of the mango production basin in the north of the region. Ivory Coast.

1-**Materials and methods**

1.1-Experimental sites

The mango orchards in the mango production basin are located in the Poro, Tchologo and Bagoué regions in northern Côte d'Ivoire. Thus, the mango orchards of the departments of Korhogo, Ferkéssédougou, Sinématiali and Boundiali were the sites of the study. The climate in these regions is marked by two seasons including a short rainy season which begins from May to October and a long dry season which extends from November to April with a dry wind from November to March. The average annual rainfall varies between 1000 and 1400 mm in these departments. The vegetation consists of wooded savannah.

1.2- Plant material

The plant material used in this study is composed of 372 twigs or individuals, from 720 mango trees spread over 20 orchards of at least 2 hectares. 2880 branches including 40 branches per mango tree made up of the observation equipment. These twigs are composed of the twig itself, leaves, flowers and fruits according to 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.

1.3- Méthods

1.3.1- Prospecting and choice of orchards

The prospecting was carried out in the peasant orchards of the departments of Ferkéssédougou, Boundiali, Korhogo and Sinématiali. During this prospecting, mango orchards with 10 years of planting 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 according to a 10 out of 10 system was delimited. At the level of each plot, 144 branches of 36 mango trees were evaluated according to the diagonal and median method. 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. This approach is inspired by the strategies developed by Maxted et al. (1997) to conduct eco-geographic surveys and according to the method of Diouf et al. (1999) to conduct ethnobotanical surveys. The incidence and severity of anthracnose were evaluated on the twigs themselves or young stems, leaves and fruits in order to determine the spatial distribution of anthracnose in the mango production basin 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.

1.3.2- Data collection

According to the Dangneli principle of experimentation (2003 and 2012), in this study, each tree or mango tree represents the plot. The twigs are the individuals of the plot.

Thus, at the level of each plot, 40 twigs were marked in the North-South and East-West axes at the rate of 20 twigs in each axe. These twigs or individuals were observed according to the parameters of severity and incidence. These observations were carried out during a cropping year comprising the rainy and dry seasons and at two stages of development of the mango tree are the vegetative and fruiting stages in order to assess the spatial distribution of the anthracnose disease. Thus, data collection focused on the incidence and severity of anthracnose disease on leaves, twigs and fruits.

1.3-3-Evaluation of the severity index (SI) of anthracnose disease

La sévérité de l'anthracnose sur les organes attaqués a été évaluée suivant l'échelle de notation de Cardoso et *al*. (2004) (**Tableau I**). La notation a consisté à attribuer un pourcentage aux organes malades selon la distribution, l'intensité des symptômes et le nombre d'organe atteint. La sommation des notes de sévérité au niveau de chaque rameau marqué dans les deux directions de l'arbre a été effectuée afin de faire une moyenne. Pour plus apprécier l'état épidémiologique des maladies, l'indice de la sévérité (Is) a été calculé à l'aide de l'équation de Kranz (**1988**).

Tableau I: Echelle de notation de sévérité de l'infection

Échelle	Pourcentage de la surface infectée (%)	Symptômes
0	0	Absence de symptôme
1	1-5	Infection faible
3	6- 10	Infection modérée
5	11- 25	Infection légèrement sévère
7	26-50	Infection sévère
9	> 50	Infection très sévère

1.3.4-Evaluation of the severity index (SI) of bacterial disease

Severity was assessed every two weeks on the leaves, fruits and panicles of the ten twigs marked on either sites of the N-S and E-W axes.

The evaluation approach resulted in a visual rating scale ranging from 0 to 9 (Groth et al., 1999; Cardoso et al., 2004 ; Silué et al., 2018).

The anthracnose disease severity index was determined according to the formula of Kranz, (1988) and Dianda et al. (2018) according to the following formula.

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

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

1.3.5- Assessment of the incidence (Ic) of anthracnose disease

The disease was diagnosed using descriptions of symptoms made by Dodd et al., (1997), Arauz (2000), Akem (2006), Telemans (2012) and Yah et al. (2013). The incidence was determined as the ratio of the number of infected individuals to the total number of individuals observed as a percentage. The impacts were determined according to the following formula (Cooke., 2006;Aka et al., 2009 ; Zahri et al., 2014):

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

A scale adapted to that used by Bhagwat et al. (2015) for the discrimination of mango varieties infected with anthracnose allowed to qualify the level of incidence of anthracnose disease. This six-grade scale (0-5) is defined as follows: 0 (no symptoms); grade 1 (1-10%: 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).

This evaluation focused on ten twigs marked on each side of the N-S and E-W axes to be seen and carried by hand.

1.3.6-Statistical analysis of the data collected

Data entry and graphs were performed with Excel 2016 software. Statistica 10 software was used to perform descriptive analyzes. These analyzes were performed to assess the spatial distribution of anthracnose disease in mango orchards in the mango production basin regions. Thus, to structure the orchards according to the distribution of this disease, the ascending hierarchical classification (CAH), following the orientation of the principal component analysis (ACP) was carried out to structure the orchards.

2- Results

2-1-Severity index and incidence of anthracnose according to the leaf, twig and fruit organs of mango orchards

The comparative profiles (Figures 1 and 2) of the severity index and the evaluation of anthracnose according to the organs revealed that the values of the severity indices and the incidence of anthracnose are highest in fruits some or the region of 720 mango trees in the 20 orchards assessed. These anthracnose severity and incidence index values oscillate between mild values of marginal type which include between 11 and 25% and severe values include 26 and 50% of major type. These values are also very similar between regions regardless of the location of the orchard. Thus, the leaves, twigs and fruits of orchards VB4, VB7, VB8, VF2, VF5, VS1 and VK2 defined values of severe indices (IS) and of incidences (Ic) light therefore of marginal type (Figures 1 and 2) while leaves, twigs and fruits of VB1, VB2, VB3, VB5, VB6, VF1, VF3, VF4, VF6, VS2, VS3 and VK1 all exhibited severity indices and severe incidences or major type. In view of the results (Figures 1 and 2) presented below, the preferred target organ of the causative agent of anthracnose disease is the fruit. This prevalence of anthracnose disease for the fruit is similar to all mango orchards in the three regions.

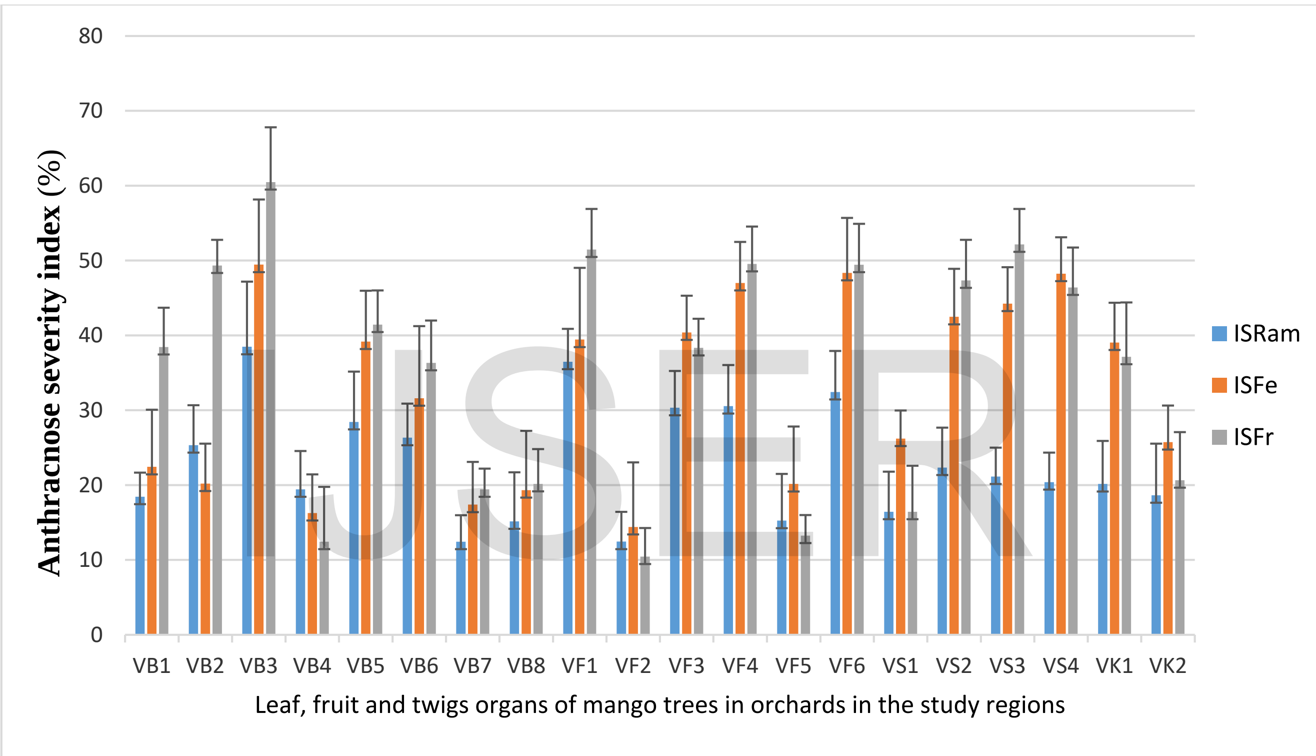

Figure 1 : Comparative profile of the severity index of anthracnose according to the organs

V: Orchards ; B: Boundiali ; **F:** Ferkéssédougou ; **S:** Sinématiali ; **K:** Korhogo ; **Ram:** Twig ; **Fe:** Leaf ; **Fr:** Fruit ; **IS:** Severity Index

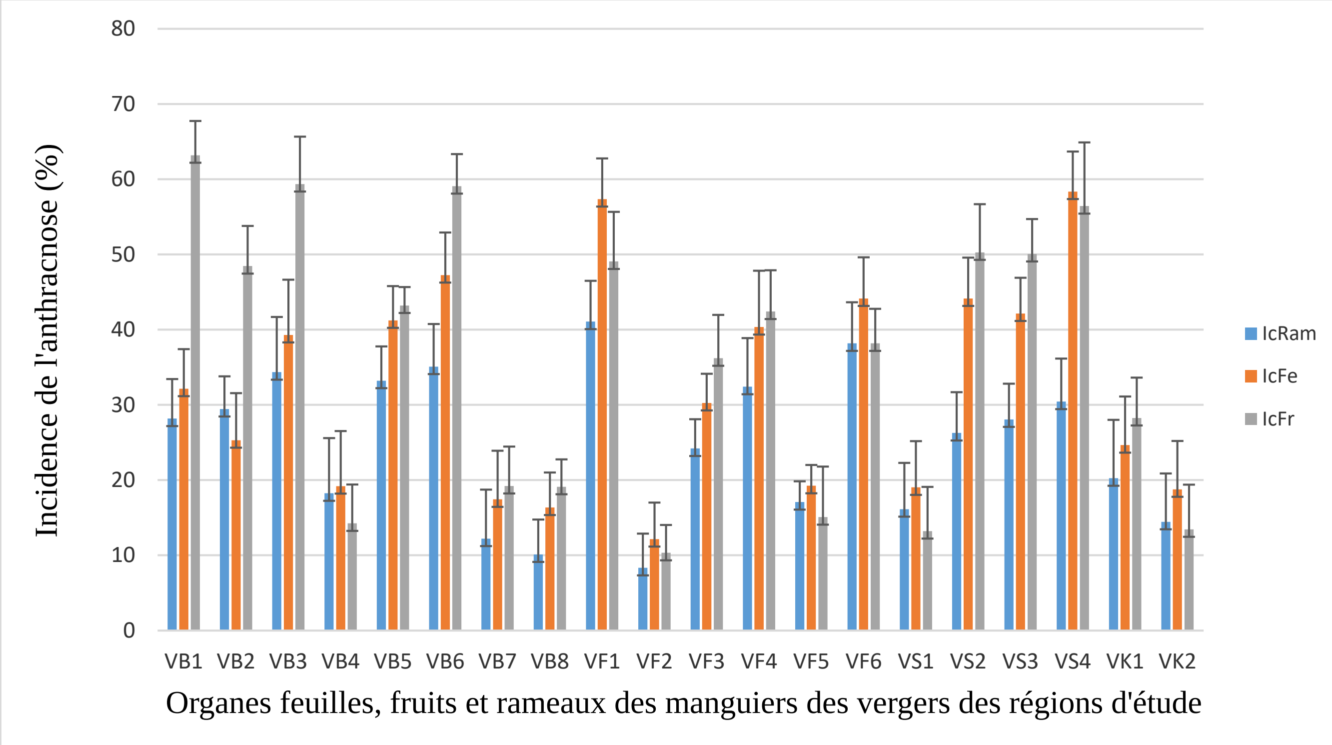

Figure 2 : Comparative profile of the incidence of anthracnose according to the organs

V: Orchards ; B: Boundiali ; **F:** Ferkéssédougou ; **S:** Sinématiali ; **K:** Korhogo ; **Ram:** Twig ; **Fe:** Leaf ; **Fr:** Fruit ; **Ic:** Incidence

2-2-Average incidence and severity index of anthracnose according to mango orchards

The results presented in FIG. 3 revealed severity indices and incidences which oscillate between light values which are between 11 and 25% (marginal type) and severe values (major type) between 26 and 50%. The results (Figure 3) showed that the types of severity and incidence indices (marginal and major) of mango anthracnose are distributed in the three regions where the orchards surveyed are located. Thus, orchards VB4 (Is = 16.05 ± 5.29; Ic = 17.23 ± 4.73), VB7 (Is = 16.42 ± 5.33; Ic = 16.29 ± 3.65), VB8 (Is18.21 ± 5.47 =; Ic = 15.19 ± 4.25), VF2 (Is = 12.44 ± 6.26; Ic = 10.27 ± 7.45), VF5 (Is = 16.22 ± 7.67; Ic = 17.14 ± 6.85), VS1 (Is = 19.7 ± 8.75; Ic = 16.13 ± 5.33), VK2 (Is = 21.68 ± 6.45; Ic = 15.56 ± 7.83) expressed severity index (IS) and incidence (Ic) values while the orchards VB1 (Is = 26.44 ± 8.57; Ic = 41.17 ± 7.63), VB2 (Is = 31.63 ± 7.33; Ic = 34.40 ± 8.25), VB3 (Is = 49.47 ± 5.69; Ic = 44.33 ± 7.45), VB5 (Is = 36.35 ± 6.64; Ic = 39.21 ± 7.44), VB6 (Is = 31.42 ± 8.42 ; Ic = 47.14 ± 7.55), VF1 (Is = 42.47 ± 7.35; Ic = 49.16 ± 8.44), VF3 (Is = 36.35 ± 7.44; Ic = 30.22 ± 6.55), VF4 (Is = 42.37 ± 6.63; Ic = 38.39 ± 7.33), VF6 (Is = 43.41 ± 9.85; Ic = 40.37 ± 6.47), VS2 (Is = 37.39 ± 7.25; Ic = 40.23 ± 5.33), VS3 (Is = 39.18 ± 6.48; Ic =

40.09 ± 5.63), VS4 (Is = 38.35 ± 7.44; Ic = 48.40 ± 5.67) and VK1 (Is = 32.11 ± 7.52; Ic = 24.38 ± 3.54) all presented signs of severity and severe or major type incidences. Or 35% of the orchards presented a slight or marginal impact of mango anthracnose disease and a predominance of the major type with 65% of the orchards which presented a severe level of aggression. The mango orchards of the three regions presented similar values of incidence and severity index of anthracnose disease (Figures 3); Bagoué (Is = 28.26 ± 4.57; Ic = 33.60 ± 5.78), Poro (Is = 31.40 ± 6.48; Ic = 30.80 ± 5.29) and Tchologo (Is = 32.21 ± 2.89; Ic = 30.89 ± 7.55).

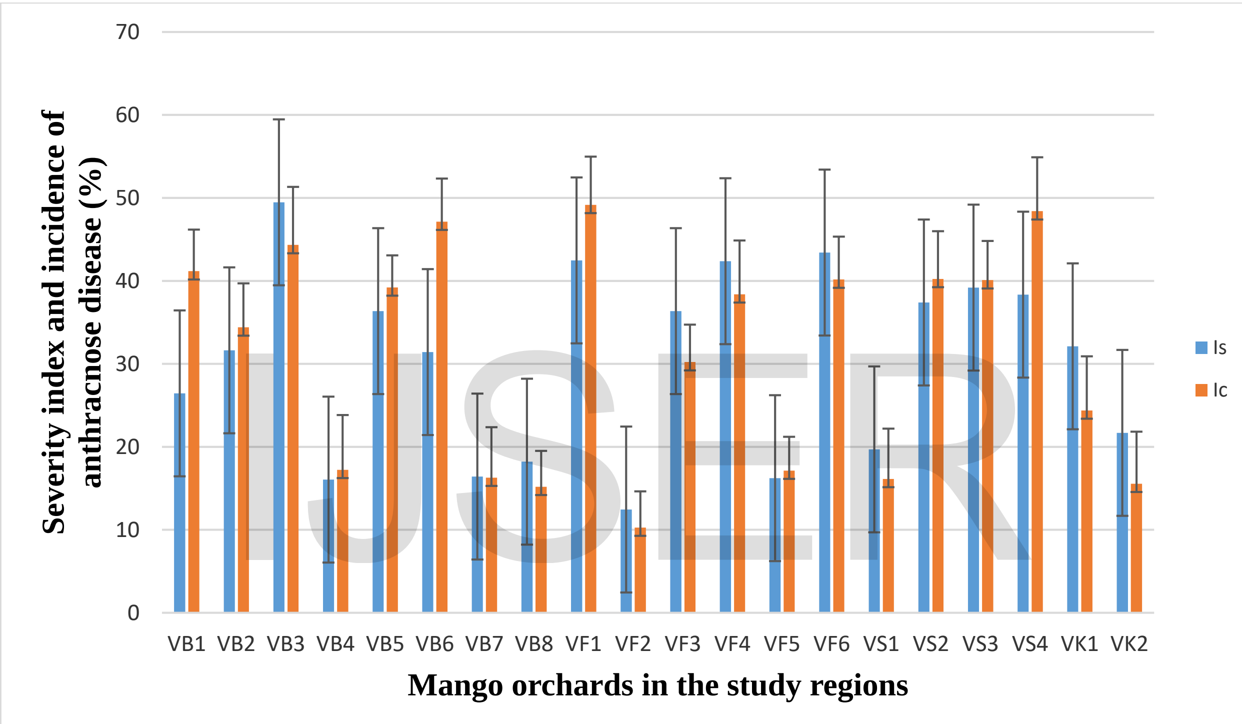

Figure 3 : Comparative profile of the severity index and the incidence of anthracnose according to orchards

V: Orchards ; B: Boundiali ; **F:** Ferkéssédougou ; **S:** Sinématiali ; **K:** Korhogo ; **Ic:** Incidence ; **IS:** Severity Index

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2-3- Analyse en Composante Principale (ACP) de la distribution de l'anthracnose

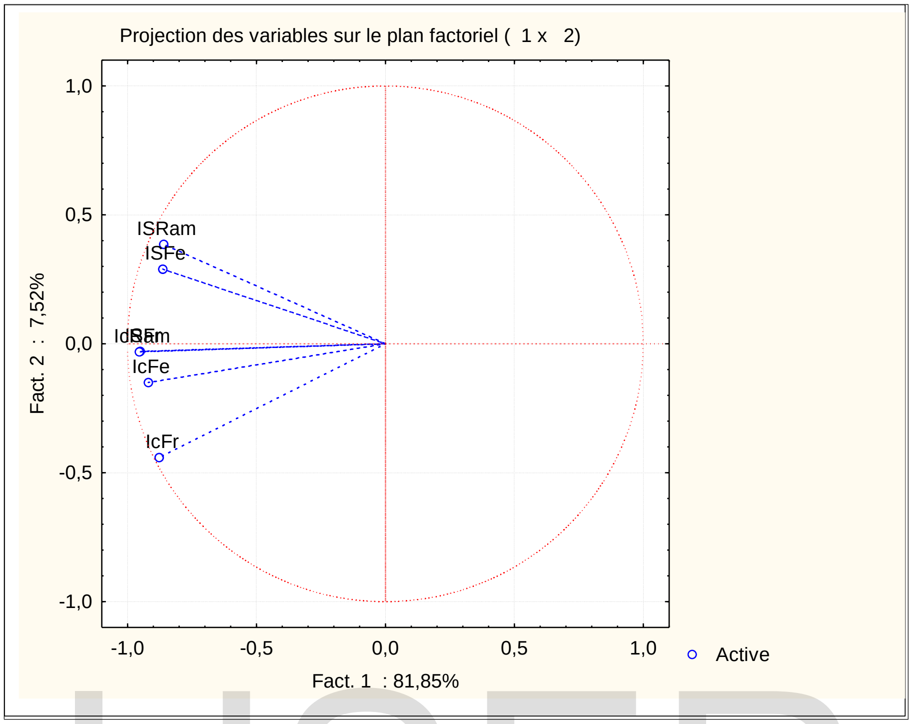

Figure 4 : Projection of the incidence and severity index variables along axes 1 and 2

Principal component analysis ACP was defined by the first two axes which explained 89.37% of the total variability observed. The observed variability is on the one hand negatively expressed by IcFr, InFe, InRam and ISFr with in particular the mango trees of VS4, VB6, VS2, and VS3. On the other hand, this variability is positively expressed in ISFe and ISRam with in particular the mango trees of VB3, VB5, VF1, VF4 and VF6. The SI and Ic for anthracnose of mango trees in the orchards VK1, VK2, VS1, VB4, VF5, VB8, VF2 and VB7 do not contribute to this observed variability.

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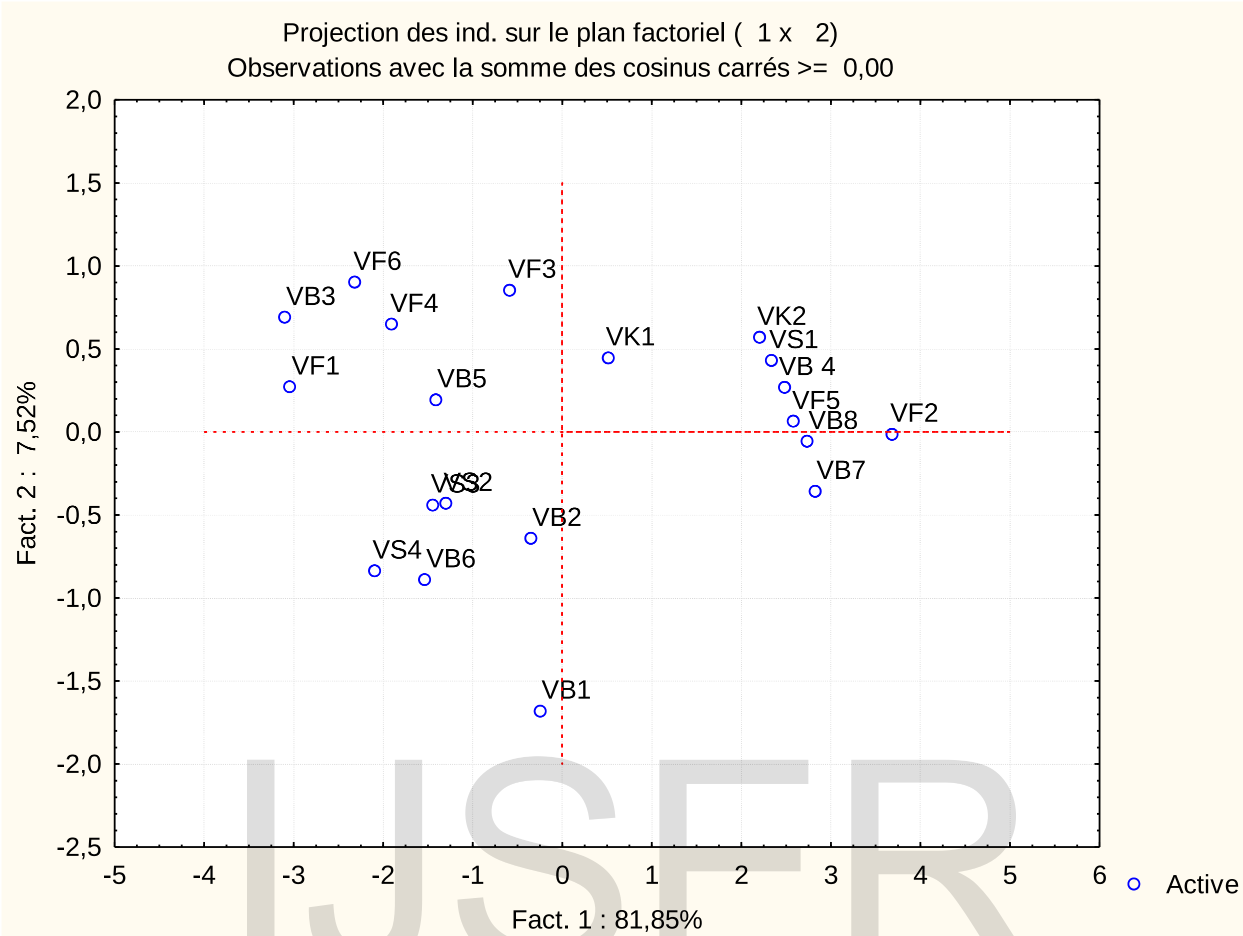

Figure 5 : Distribution of orchards in factorial plan 1 and 2

2.4- Structuring of orchards according to the distribution of anthracnose in the three regions by Ascending Hierarchical Classification (AHC)

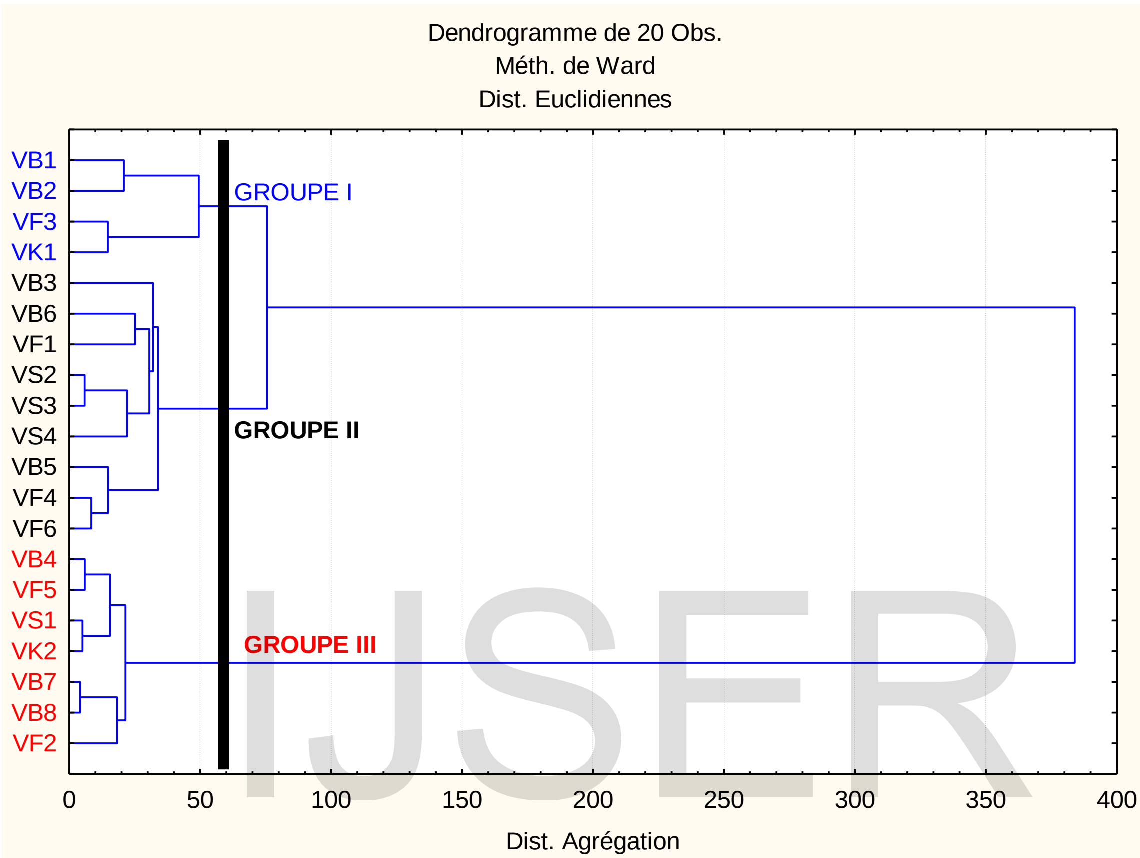

Figure 6 : Structure of orchards according to the distribution of anthracnose

The Ascending Hierarchical Classification (CAH) made it possible to structure the orchards studied into 3 groups (Figure 6) according to the method of Ward (1963).

Group 1 was made up of four orchards (VB1, VB2, VF3 et VK1). Group 2 also contained nine vergers namelyVB3, VB6, VF1, VS2, VS3, VS4, VB5, VF4, and VF6.

The third group with 7 orchards comprised the vergers VB4, VF5, VS1, VK2, VB7, VB8 and VF2. The mango trees of group 1 and 2 orchards showed a level of severity and incidence index of the major type anthracnose disease. However, the mango trees in group 1 orchards expressed severity and incidence indices between 26 and 50% and those in group 2 showed severity and incidence indices between 25 and 35%. The mango trees of group 3 orchards presented severity and incidence indices of marginal type with light values between 10 and 25%.

3- Discussion

The evaluation of the incidence and the severity index of anthracnose revealed a predominance of the severe or major type of severity index and incidences of anthracnose disease in the orchards of the mango production basin in Côte ivory. Indeed, the result presented in figure 3 revealed severity index and incidences which oscillate between light values which are between 11 and 25% (marginal type) and severe values (major type) between 26 and 50%. The results (Figure 3) showed that the types of severity index and incidence (marginal and major) of mango anthracnose are distributed in the three regions where the orchards surveyed are located. Thus, orchards VB4, VB7, VB8, VF2, VF5, VS1, VK2 expressed values of severity index (IS) and incidence (Ic) light while orchards VB1, VB2, VB3, VB5, VB6, VF1, VF3, VF4, VF6, VS2, VS3 and VK1 all presented severity index and severe or major type incidences. Or 35% of orchards presented a slight or marginal impact of mango anthracnose disease and 65% of orchards presented a severe or major type. This predominance of major or severe type of anthracnose disease symptoms suggests that it represents one of the main threats to mango production and marketing in Côte d'Ivoire. Indeed, according to the work of Yah et al. (2013), Colletotrichum gloeosporioides is believed to be the causative agent of anthracnose in mango trees and would represent one of the main biotic constraints in the production and marketing of mango in Côte d'Ivoire. The mango orchards of the three regions presented similar values of incidence and severity index of anthracnose (Bagoué (Is=28.26±4.57; Ic=33.60±5.78), Poro (Is=31.40±6.48; Ic=30.80±5.29) et Tchologo (Is=32.21±2.89; Ic=30.89±7.55)). This distribution or harmonious spatial distribution of mango anthracnose disease within the three regions would show that this disease is common to these three regions. In addition, the Poro region, through the departments of Korhogo and Sinématiali, has always been the spearhead of mango production in the Ivory Coast. Thus, this harmonious spatial distribution of anthracnose disease could result from an exponential dispersion of this disease that may have occurred over time from the Poro region as the center of dispersion. These results are in agreement with those of Chrys (2006) who affirms that this pathology is the most damaging and the most widespread in all production areas. The rapid dispersal of mango anthracnose could be justified by the fact that the pathogen, Colletotrichum gloeosporioides, is very present in tropical areas because the environment (temperature, relative humidity, rainfall and climate) of its areas would be favorable to its proliferation. In addition, the work of Yah (2015) has shown that the period of harvest and transport of fruits (mango) coincides with the rainy season which develops a climate favorable to the infection and proliferation of anthracnose. These arguments would explain the strong predominance of the major type of severity index and disease incidence on fruits in these regions. Moreover, this predominance of severe type infections according to the Cardoso et al. (2004) would explain that the Kent variety is more sensitive to the causative agent of anthracnose and that the fruits evaluated were at the stage of physiological maturity. Indeed, Djeugap et al. (2009) have shown that the sensitivity of mango to anthracnose depends on the variety of the mango or the phenological stage of the mango tree which is under the influence of certain external and internal factors. Thus, varieties Tommy, atkins and Keitt are less susceptible than varieties, Irwin, Kent, Haden and Edward to anthracnose (Campell, 1992). In addition, immature mangoes unlike ripe or physiologically mature mangoes, are said to contain high concentrations of natural antimicrobial compounds. These compounds made up of mixtures of 5-substituted resorcinols such as resorcinol-5- (12-heptadecadienyl) and resornol-5- (pentadecyl) accumulate in the pericarp (Cissé, 2012). Faced with such an environment that is chemically unfavorable for pathogenic action, the fungus remains latent until the concentration of antimicrobial compounds decreases in the pericarp of the fruit. In addition, the predominance of the major type of infection of the disease would result in the trilogy of a sensitivity of the genotypes to anthracnose, a large quantity of spores produced and accumulated over time and climatic conditions favorable to the expression of the disease. In fact, in order for the pathogen to penetrate, colonize the tissues of the plant and reproduce, it must have all the genetic information and all the biochemical tools necessary to overcome, suppress or avoid all of these means of defense of the plant. where plant-pathogen compatibility (Chevaugeon, 1985). The leaves and, to a lesser extent, the twigs would behave as organs for preserving the inoculum of the causative agent of anthracnose disease. The severity index and 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 agrees with that of the ascending hierarchical classification (CAH) which structured the mango trees of these orchards in group 3. Which group presented slight or marginal type values of anthracnose severity index and incidence. These orchards would have a method of maintenance or agronomic management, including a good application of prophylaxis measures, unfavorable to the proliferation of the causative agent of anthracnose disease.

4-conclusion

The present study found a similar spatial distribution of anthracnose 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 of the severity and incidence index level of anthracnose disease to the detriment of the marginal type. In addition, the vegetative organs of leaves and twigs appear to be organs for preserving the inoculum of the causative agent of anthracnose disease. Thus, fruits are the preferred target organs with a predominance of the major type of severity indices and the incidence of anthracnose disease in all orchards in the mango production area in Côte d'Ivoire. However, these orchards were structured into three (3) groups according to the distribution of anthracnose disease. Group three (3) orchards, with severity index values and marginal type incidences pave the way for an objective agroecological management of anthracnose disease.

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