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RESEARCH ARTICLE

COMPARATIVE EFFICACY OF FOUR FORMULATIONS BASED ON AROMATIC PLANT EXTRACTS AND A SYNTHETIC FUNGICIDE AGAINST *Mycosphaerella fijiensis* MORELET CAUSAL AGENT OF BLACK LEAF STREAK DISEASE (BLSD), IN INDUSTRIAL DESSERT BANANA PRODUCTION

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Abstract

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Black leaf streak disease (BLSD) caused by *Mycosphaerella fijiensis* an ascomycete fungus is the most important foliar disease ofbananas (*Musa* sp.). Losses due to this pathogen can exceed 50% in case of no resistant cultivars and effective treatments. This study aimed to evaluate the efficacy of four biopesticides on the severity of *Mycosphaerella fijiensis*. It was conducted under natural infestation conditions in the industrial dessert banana plantation of the Agricultural Company KablanJoublin (SAKJ) at Elima (Aboisso). To make it possible some phytopathological, growth and agronomic parameters of banana plants were evaluated. The results showed that banana trees of plots treated with biopesticides had identical characteristics, about all the assessed parameters, with those of plots treated with the chemical fungicide. In addition, applications of biofungicide contributed to protecting banana leaves, slowed down the onset of necrotic first stage and significantly reduced the disease infestation level in the parcels. The use of biofungicides based on aromatic plant extracts could be suggested as an ecological efficient solution to dessert banana and plantain producers against *Mycosphaerella fijiensis* responsible for the black leaf streak disease.

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Introduction:-

Banana (*Musa* spp.) is a food source for millions of people around the world. Its cultivation also generates significant income for these populations (**Teycheney *et al*., 2007**). In Côte d'Ivoire, in addition to the main cash crops of cacao and coffee, bananas takes an important position in the country's agricultural sector. It is grown according to two main cropping systems: intensive monoculture and polyculture (**Traoré *et al*., 2009)**. However, during its cultivation, banana is prone to many pathologies, in particular, foliar fungal diseases. Black Leaf Streak Disease (BLSD) caused by the fungus *Mycosphaerella fijiensis* Morelet is among the most damaging foliar diseases of this crop (**Amari *et al*., 2008**).

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In fact, harvest losses due to pathogenic fungus *M. fijiensis* range from 20% to 50% and can reach 100% from the second crop cycle, in case of no treatment **(Tuo *et al*., 2015**). This pathogen attacks banana leaves and leads to a decrease of the photosynthetic surface that causes a weak filling and an earlier ripening of bananas (**Kassi, 2014**). Therefore, in industrial production of dessert bananas, to better control this disease, producers sometimes make abusive use of synthetic fungicides. Despite the constraints associated with the use of synthetic pesticides (prohibitive cost, risks for environment and human health), chemical fungicides is still the one recommended in management of BLSD (**Tuo *et al*., 2021**). In response to these problems, initiatives are being developed to propose alternative methods to the use of chemical fungicides. Products commonly known as biopesticides and formulated from bacteria, viruses, protozoa, fungi or plants have the advantage of being biodegradable. In addition, they have inhibitory activities against a wide range of pests and no side effects on environment and human health (**Rahbani, 2015**). In the context of sustainable agriculture, these products could be the ecological solution to be promoted instead of the « all chemical ».

This study aims to evaluate the efficacy of four biopesticides based on aromatic plant extracts against the Black Leaf Streak Disease and to determine their effects on the agronomic parameters in production of dessert bananas in Côte d'Ivoire.

Material And Methods:-

Plant Material

Dessert banana vitroplants of Great Dwarf cultivar belonging to the Cavendish subgroup were used as plant material in this study. This cultivar is highly susceptible to the Black Leaf Streak Disease (**Abo, 1994**).

Fungicides

Four biofongicides: NECO 50 EC, PRORALY 50 EC, ASTOUN 50 EC and FERCA 50 EC as well as one chemical product (DITHANE 60 OS) commonly used in banana plantations were evaluated.The biofungicides formulated from aromatic plant extracts were supplied by the Industrial Research Unit (URI) on biopesticides of Félix HOUPHOUËT-BOIGNY University. The characteristics of these fungicides are reported in **Table I**.

Table I:- Characteristics of fungicides experienced.

Trade names	Active ingredients	Chemical families	Formulation types
NECO 50 EC	Thymol, Eugenol	Biofungicide	50 EC
ASTOUN 50 EC	Geranial, Neral, Myrcene	Biofungicide	50 EC
PRORALY 50 EC	Thymol, Eugenol, Citronellol, Citronellal	Biofungicide	50 EC
FERCA 50 EC	Citronellol, Citronellal	Biofungicide	50 EC
DITHANE 60 OS	Mancozeb	Dithiocarbamate	60 OS

Study site

The trials were carried out under a natural infestation condition of *Mycosphaerella fijiensis* for 10 months in the plantation of Elima (Aboisso) owned by the Agricultural Company Kablan Joublin (SAKJ). The experimental plot was a 3-year follow located at 05°26'52'' latitude North and 003°10'52'' longitude West (**Figure 1**). Aboisso is characterized by a humid tropical climate with four seasons: one half rainy and the other dry (**Koua, 2007**). The daily temperature range is low, with an average ranging 23 and 29 °C (**Essis *et al*., 2016**). Air humidity at midday ranging 60 to 85 % (**Kouassi *et al*., 2005**).

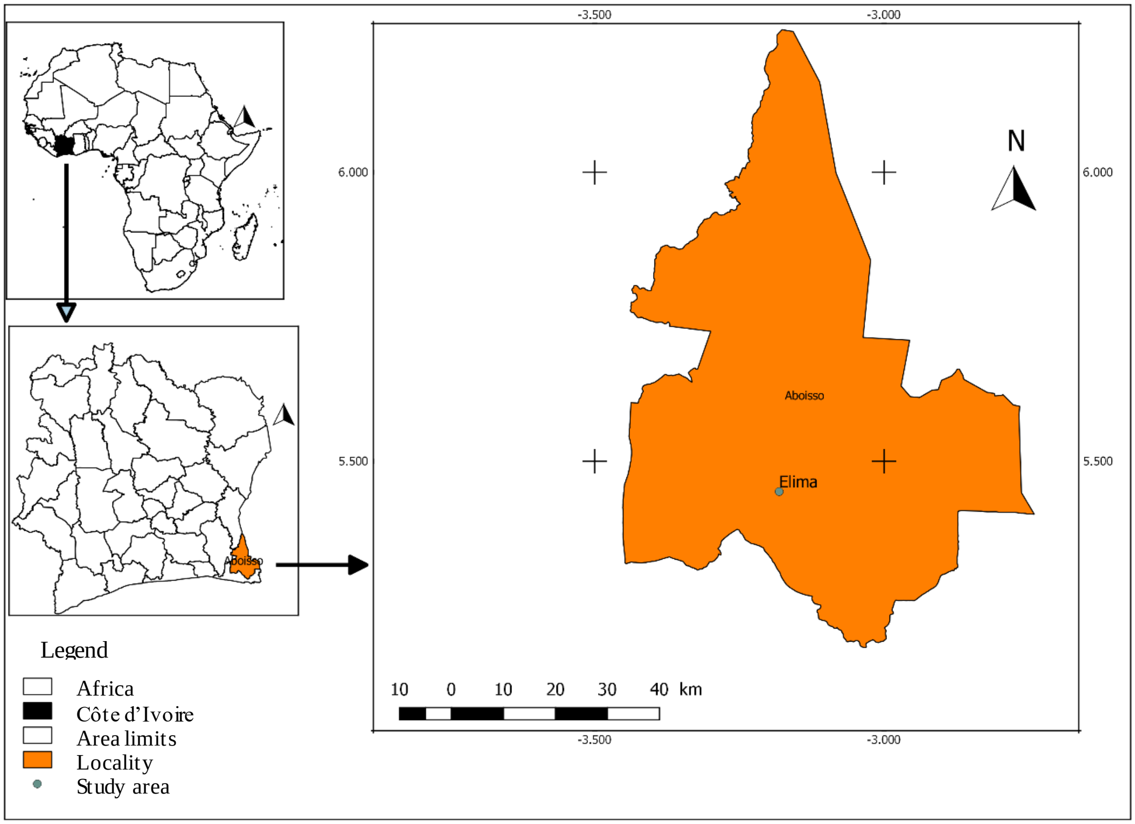

Figure 1:-Localizationof the study site.

Experimental design

A Fisher block design randomized with 5 treatments and 3 replications was adopted. Each elementary plot surface was 1,000 m^2. Banana plantation density was 1,820 plants/ha. Plants were staggered on following two double lines. Banana plant had a spacing of 2.2 m × 1.7 m.

Tests set-up and follow-up

The agronomic management of the experimental plot consisted of fertilization, weeding and irrigation. Organic and chemical fertilizers were brought according to a well-established protocol. As soon as bananas were planted, 50 g of Diammonium phosphate (DAP) per plant was added, followed by 15 g of urea (46%) each week. From the 6th week after planting 15 g of urea and 75 g of NPK 12.5-04-28 were applied in alternation weekly. Concerning the organic amendment (coffee parch), it was applied in a single dose of 1 kg per banana plant, 8 weeks after their planting, around each banana tree in a radius of 30 cm.

Chemical weeding with Glufosinate was performed from transplanting until the 4th month. After, Glyphosate was used. Banana plots were watering with a sprinkling system every 3 days for 3 hours. The fungicides were applied on banana leaves using STIHL brand backpack sprayers with an individual capacity of 15 litres up to 3 months and then with a CIFARELLI brand motor atomizer from the 3rd month until the fruit harvest. The biofungicides had a 14-day application frequency while the synthetic product had a 7-day application frequency. Applications were made according to the manufacturer's recommendations. Treatments, doses and application frequencies are reported in **Table II**.

Table II:- Application doses and frequencies of experienced treatments.

Fungicide treatments	Application doses	Application frequencies
NECO 50 EC	1,2 L/ha	14 days
ASTOUN 50 EC	1,2 L/ha	14 days
PRORALY 50 EC	1,2 L/ha	14 days
FERCA 50 EC	1,2 L/ha	14 days
DITHANE 60 OS	2,5 L/ha	7 days

Evaluation of agrophysiological and phytopathological parameters
Observation stations including 10 bananas randomly selected have been installed in the elementary plots.

Growth parameters
The growth of bananas was assessed from the Leaf Emission Rate (LER), the Height (PH) and Circumference (PC) of the Pseudo-stem. The LER representing the average number of leaves emitted by bananas was determined each week. The Pseudo-stem Height (PH) was measured from the collar to the last two functional leaves. The Circumference of the Pseudo-stem (PC) was measured to 10 cm from the ground. These parameters were expressed in cm and recorded monthly from the 3rd month after transplantation to the flowering of bananas.

Banana phenology and yield parameters
Concerning the phenology, observations focused on the Intervals,expressed in days, between Planting and Flowering (IPF), Flowering and Harvest (IFH) and finally Planting and Harvest (IPH). At harvest, the agronomic characteristics determined were the Numbers of Hands per Bunch **(**NHB), of Fingers per Bunch (NFB) and the Mass in kilograms of each Banana Bunch (MB).

Phytopathological parameters
The determined parameters during the vegetative phase of the bananas were the Youngest Leaves Affected (YLA), Spotted (YLS), bearing Stage 3 (YL3) or Completely Spotted (YFCS) and Disease Progression Status (DPS). At flowering and harvest, the descriptors evaluated were the Numbers of Functional Leaves at Flowering (NFLF) and at Harvest (NFLH), respectively.

Vegetative phase
- The Youngest Leaf Affected (YLA), by counting from top to bottom, is the youngest leaf bearing the early symptoms of BLSD with at least 10 streaks of stage 1 of its evolution (**Fouré, 1983**).
- The Youngest Leaf Spotted (YLS) is the rank of the youngest leaf showing 10 necrosis of BLSD at stage 5 or 6 (**Fouré, 1983**).
- The Youngest Leaf bearing Stage 3 (YL3), reported by **Meredith and Lawrence** (**1970**), is the youngest leaf having blackish-brown spotting of 2 to 3 cm on the upper and lower side of the blade.
- The Youngest Leaf Completely Spotted (YLCS) which enables to compare the severity of the disease by the loss of the functional activity of the leaves (**Koné, 1998**).
- Disease Progression Status (DPS) is used to quantify the development of BLSD on the experimental site. The determination of the DPS or the rate of progression of the disease according to the time characterized the basic index that represents the pair (leaf rank - cercospora stage). DPS is a decision-making tool for the fungicide treatments in banana plantations (**Fouré and Ganry, 2008**). Each week, leaves were evaluated from top to down on each banana selected for observations. It consisted in noting: the progression stages of the disease and the most advanced stage of the disease on the leaves whose rank will be determined. Then the DPS was determined by the following formula: DPS = LER x (GT–EC). Where LER = Leaf Emission Rate; GT = Gross Total characterizing the evolution of the disease without taking into account the rate of foliar emission; EC = Evolution Coefficient calculated by multiplying the cigar stage value by the number of leaves having the different stages of the disease; and GS–EC corresponding to the Corrected Total noted SEV.

Reproductive phase
The observed parameters during the reproduction phase of bananas concerned the Number of Functional Leaves at Flowering (NFLF) and the Number of Functional Leaves at Flowering (NFLH).

- The NFLF is the average number of functional leaves present on bananas at the time of flowering. In order to obtain properly filled fruits, it is necessary to have at least 8 functional leaves on the banana at flowering (**Lassourdière, 1978**).
- The NFLH represents the number of leaves remaining on the bananas at the harvest of bunches. Subsequently, the ratio (NFLH/NFLF) between the numbers of functional leaves at harvest (H) and flowering (F) was determined. This ratio provides information on the effectiveness of treatments. Indeed, a treatment is more effective when this ratio is higher (**Amari, 2012**).

Statistical analyses of data

The collected data were submitted to analysis of variances (ANOVA) using the Statistica 7.1 software. In case of significant difference between the treatments experienced, the Student Newman-Keuls multiple comparison test, at the 5% threshold was performed to classify the averages into homogeneous groups.

Results:-

Effects of treatments on growth parameters

The different fungicide applications (biological and synthetic) performed had the same effect on the bananas Leaf Emission Rate (LER) (**Table III**). In fact, the statistical analyses of this parameter did not reveal any statistical difference (P = 0.53) between the different treatments at the 5% threshold. The overall average of the LER for all the treatments was 1.62 leaves. For pseudo-stem height (PH) and circumference (PC) also grouped in **Table III,** variance analysis also showed no significant differences between treatments (P = 0.89 and P = 0.91, respectively). The overall average induced for all the treatments were 221.74 cm for the height and 74.84 cm for the circumference.

Table III:- Banana growth parameters according to the fungicide treatments.

Fungicide treatments	LER	PH (cm)	PC (cm)
PRORALY 50 EC	1.64 ± 0.18 **a**	223.50 ± 9.14 **a**	75.20 ± 6.52 **a**
FERCA 50 EC	1.58 ± 0.16 **a**	222.20 ± 10.22 **a**	74.30 ± 4.27 **a**
NECO 50 EC	1.60 ± 0.12 **a**	222.80 ± 5.84 **a**	75.40 ± 5.66 **a**
ASTOUN 50 EC	1.61 ± 0.18 **a**	220.50 ± 13.95 **a**	75.60 ± 5.27 **a**
DITHANE 60 OS	1.68 ± 0.17 **a**	219.70 ± 6.00 **a**	73.70 ± 3.81 **a**
Overall average	1.62 ± 0.16	221.74 ± 9.23	74.84 ± 5.04
C.V. (%)	9.87	4.16	6.73
P-value	0.53	0.89	0.91

LER = Leaf Emission Rate, **PH** = Pseudo-stem Height, **PC** = Pseudo-stem Circumference, **C.V.** = Coefficient of Variation. In a same column, numbers followed by the same letter are not significantly different at the threshold α = 5% according to the Student Newman-Keuls test.

Effects of fungicide treatments on dessert banana phenology and yield parameters

Banana production cycle

The time interval between Planting and Flowering (IPF) of bananas ranged 154 to 158.90 days with an overall average of 155.75 days (**Table IV**). However, no significant differences were observed for IPF (P = 0.07). The time interval between Flowering and Harvest (IFH) fluctuated between 82.95 and 91.70 days. The overall average of IFH was 88.13 days. In addition, analyses of variance did not show significant difference between the tested treatments (P = 0.08). As with the previous two parameters, the time interval between Planting and Harvest (IPH) was not significantly different for all the fungicide treatments, with P = 0.15 (**Table IV**).

Table IV:- Characteristics of banana development cycle according to the fungicide treatments.

Fungicide treatments	Time intervals (in days)		
	Planting-Flowering	**Flowering-Harvest**	**Planting-Harvest**
PRORALY 50 EC	158.90 ± 6.46 **a**	86.80 ± 10.98 **a**	245.70 ± 15.04 **a**
FERCA 50 EC	155.05 ± 5.68 **a**	91.70 ± 12.20 **a**	246.16 ± 16.35 **a**
NECO 50 EC	156.10 ± 6.85 **a**	91.35 ± 10.52 **a**	247.45 ± 13.67 **a**
ASTOUN 50 EC	154.00 ± 4.54 **a**	82.95 ± 10.95 **a**	236.95 ± 14.41 **a**
DITHANE 60 OS	154.70 ± 5.02 **a**	87.85 ± 10.02 a	242.55 ± 14.05 **a**
Overall average	155.75 ± 5.91	88.13 ± 11.21	243.88 ± 14.94

C.V. (%)	3.79	12.71	6.12
P-value	0.07	0.08	0.15

C.V. = Coefficient of Variation. In a same column, numbers followed by the same letter are not significantly different at the threshold α = 5% according to the Student Newman-Keuls test.

Effects of fungicide treatments on the characteristics of banana bunch

Statistical analyses of data about the effect of fungicides on the agronomic characteristics of bananas did not show any significant difference between treatments expected for the number of fingers (Table V). The highest number of fingers was obtained in case of applications of the biofungicide FERCA 50 EC, with an average of 129.00 fruits per bunch. The lowest values of numbers of fruits per bunch were reported in plots treated with the biofungicide PRORALY 50 EC (117.77 fingers) and synthetic fungicide (117.80 fingers). Concerning the number of hands and the mass of bunches, the global averages for all the treatments were respectively 6.71 hands and 22.01 kg.

Table V:- Characteristics of banana bunches at harvest according to the fungicide treatments.

Fungicide treatments	NHB	NFB	MB (kg)
PRORALY 50 EC	6.44 ± 0.52 **a**	117.77 ± 7.00 **b**	21.70 ± 1.71 **a**
FERCA 50 EC	7.20 ± 0.83 **a**	129.00 ± 14.21 **a**	23.20 ± 3.33 **a**
NECO 50 EC	6.50 ± 0.70 **a**	120.85 ± 15.45 **ab**	21.95 ± 1.76 **a**
ASTOUN 50 EC	7.00 ± 1.05 **a**	128.30 ± 16.89 **ab**	21.80 ± 2.82 **a**
DITHANE 60 OS	6.60 ± 0.54 **a**	117.77 ± 7.00 **b**	21.40 ± 3.34 **a**
Overall average	6.71 ± 0.79	122.84 ± 13.31	22.01 ± 2.71
C.V. (%)	11.80	10.83	12.32
P-value	0.29	0.01	0.26

NHB= Numbers of Hands per Bunch; **NFB** = Number of Fingers per Bunch; **MB** = Mass of Bunch; **C.V.** = Coefficient of Variation. In a same column, numbers followed by the same letter are not significantly different at the threshold α = 5% according to the Student Newman-Keuls test.

Effects of fungicide treatments on phytopathological parameters

The study of the phytopathological parameters during the vegetative phase of bananas (Table VI) consisted to report the ranks of the youngest leaves affected by the first spots of disease (YLA), bearing the stage 3 (YL3), spotted (YLS), completely spotted (YLCS) and finally, to assess the disease progression status (DPS). Analyses of variance between biofungicide treatments and synthetic fungicide did not reveal any statistical difference. The onset of the first symptoms of the black leaf streak disease (BLSD) was identical for all the treatments (P = 0.19). The first symptoms of the disease (YLA) were observed on average on leaves 4. For the youngest leaf bearing the stage 3 of disease (YL3), the rank of affected leaves averaged 6.39. Statistical analyses did not show significant difference between treatments, with P = 0.60. In the case of the youngest leaf spotted (YLS), as with the previous two parameters, no significant differences were also reported between the treatments (P = 0.08). It was the same effect for the youngest leaf completely spotted (YLCS), with P = 0.69. However, the average value of YLCS ranged from 10.43 to 10.86. The DPS, shown in Figure 2, was similar to all the plots treated whatever the fungicide (DPS less than 2000).

Table VI:- Characteristics of foliar phytopathological parameters during the vegetative phase of bananas according to the fungicide treatments.

Fungicide treatments	Foliar phytopathological parameters			
	YLA	**YL3**	**YLS**	**YLCS**
PRORALY 50 EC	3.78 ± 0.18 **a**	6.56 ± 0.78 **a**	7.76 ± 0.51 **a**	10.86 ± 0.76 **a**
FERCA 50 EC	3.62 ± 0.11 **a**	6.17 ± 0.53 **a**	7.26 ± 0.38 **a**	10.43 ± 0.82 **a**
NECO 50 EC	3.67 ± 0.17 **a**	6.34 ± 0.73 **a**	7.45 ± 0.63 **a**	10.74 ± 0.65 **a**
ASTOUN 50 EC	3.70 ± 0.23 **a**	6.38 ± 0.68 **a**	7.50 ± 0.54 **a**	10.82 ± 0.85 **a**
DITHANE 60 OS	3.70 ± 0.22 **a**	6.50 ± 0.77 **a**	7.71± 0.55 **a**	10.70 ± 1.08 **a**
Overall average	3.69 ± 0.18	6.39 ± 0.70	7.54 ± 0.55	10.71 ± 0.83
C.V. (%)	4.87	10.95	7.29	7.74
P-value	0.19	0.60	0.08	0.67

YLA = Youngest Leaf Affected, **YL3** = Youngest Leaf bearing the Stade 3, **YLS** = Youngest Leaf Spotted, **YLCS**= Youngest Leaf Completely Spotted, **C.V.** = Coefficient of Variation. In a same column, numbers followed by the same letter are not significantly different at the threshold α = 5% according to the Student Newman-Keuls test.

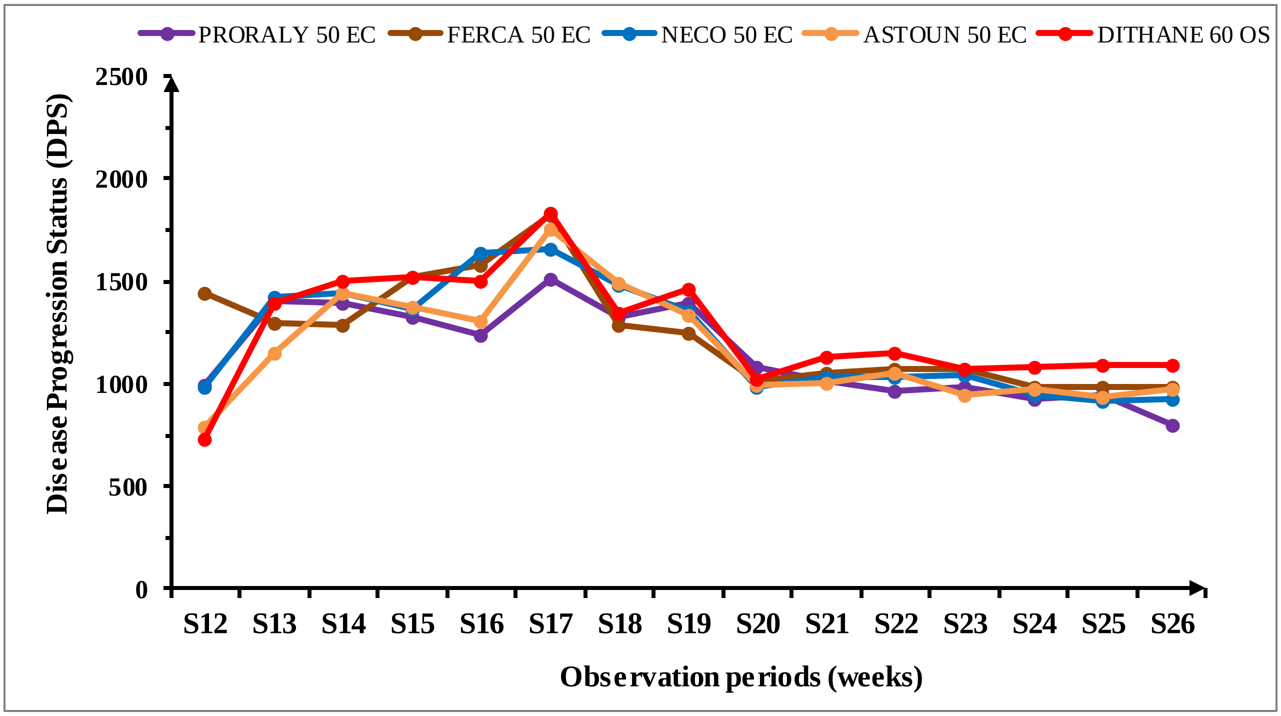

Figure 2:- Weekly evolution of the DPS according to the applied fungicide treatments.

At flowering, the average number of functional leaves on bananas (NFLF) from all treatments tested was 9.87 (**Table VII**). Variance analyses revealed significant differences between treatments performed. Thus, the highest NFLF was induced by the biopesticide PRORALY that recorded an average of 10.01 leaves. On the other hand, the lowest NFLF were obtained with ASTOUN 50 EC, FERCA 50 EC and NECO 50 EC. They generated respectively 9.56; 9.55 and 9.46 leaves. The application of DITHANE 60 OS, made it possible to get 9.86 functional leaves at flowering, an intermediate value. At harvest, the number of functional leaves on bananas (NFLH) was not statistically different between all treated plots. In addition, all these treatments allowed the maintain about 4 functional leaves from the flowering of bananas to the harvest of their bunches. For the ratio NFLH/NFLF, treatments allowed to preserve on average 40 % of leaves of bananas from their flowering to their harvest. In addition, no significant difference (P = 0.41) was reported between the treatments for the latter two parameters.

Table VII:- Characteristics of foliar phytopathological parameters at flowering and harvest of bananas according to the fungicide treatments.

Fungicide treatments	Foliar phytopathological parameters		
	NFLF	**NFLH**	**NFLH/NFLF**
PRORALY 50 EC	10.01 ± 0.98 **a**	4.00 ± 0.98 **a**	0.40 ± 0.14 **a**
FERCA 50 EC	9.55 ± 0.92 **b**	3.61 ± 1.16 **a**	0.38 ± 0.12 **a**
NECO 50 EC	9.46 ± 0.75 **b**	3.93 ± 0.99 **a**	0.42 ± 0.11 **a**
ASTOUN 50 EC	9.56 ± 0.87 **b**	3.94 ± 0.82 **a**	0.41 ± 0.10 **a**
DITHANE 60 OS	9.86 ± 0.87 **ab**	3.87 ± 1.22 **a**	0.39 ± 0.13 **a**
Overall average	9.69 ± 0.93	3.87 ± 1.12	0.40 ± 0.12
C.V. (%)	9.61	28.93	30.75
P-value	0.00	0.35	0.41

NFLF = Number of Functional Leaves at Flowering, **NFLH** = Number of Functional Leaves at Harvest; **NFLH/NFLF** = Ratio of the number of functional leaves at harvest to the number of functional leaves at flowering.

In a same column, numbers followed by the same letter are not significantly different at the threshold α = 5% according to the Student Newman-Keuls test.

Discussion:-

Evaluation of the effect of fungicide treatments (biological and synthetic) on the growth parameters of bananas showed that they were not statistically different between the treatments. These results agree with those of studies of **Sadia *et al*.** (**2017**) on the use of chemical fungicides for the management of banana black leaf streak disease. They showed in a negligible effect of these treatments on growth parameters. According to **Hoarau and Huet** (**2002**), growth is stable over time whatever fungicide treatments applied on bananas. For **Bekunda** (**1999**), soil fertility management is the starting point for the improvement of plantain productivity. Thus, the nutrient state of the soil is the parameter that most significantly influences growth and development of plants (**Nassy *et al*., 2020**). Soil fertility is therefore a limiting factor for better growth of bananas during the vegetative phase (**Tuo *et al*., 2015**). In this study, the similarity of biopesticides and synthetic fungicides on banana growth parameters would be due to cropping practices including identical soil fertilization on the experimental plots.

The present study showed almost no significant difference between the treatments for the studied phytopathological parameters. However, treatments favoured the appearance of BLSD first symptoms (YLA) on leaves 3 to 4. These observations are similar to those of **Kassi *et al*.** (**2014**) that found that bananas treated with NECO biofungicide were less prone to *M. fijiensis* infections than those in control plots (untreated). These authors observed YLAon leaves 2 in the first case and on leaves 3 in the control plots, respectively. The identical efficacy of biofungicide and synthetic fungicide treatments against the BSLD revealed by this experimentation agrees with many previous studies that have also confirmed the efficacy of biofungicides in comparison to chemical fungicides. For example, **Silué *et al*.** (**2018**) reported that cashew treated with NECO 50 EC remained at very low levels of anthracnose severity in comparison with other treated with Propiconazole and Prochloraze fungicides. In the same order, the works of **Fofana *et al*.** (**2020**) reported that the biofungicides NECO 50 EC and ASTOUN 50 EC have a very significant inhibition rate in greenhouse on cocoa brown pod rot compared to the synthetic fungicide CALLOMIL SUPER. The capacity of biofungicide treatments to mitigate the spread of pathogens would be due to their organic components such as phenolics, terpenes and aldehydes. These compounds would act directly to pathogens and their propagating organs (**Silué *et al*., 2018**) by alteration of membrane permeability, denaturation and precipitation of micro-organism proteins (**Kassi *et al*., 2014**). In the same way, **Yoshimura *et al*.** (**2010**) have shown that essential oils dense in oxygenated monoterpenes are toxic on mitochondrial membranes of microorganisms thus causing cellular physiological and biochemical disturbances. **Soumanou and Adjou** (**2016**) argue that the antimicrobial activity of essential oils is the result of a synergy action between their majority and minority compounds. The efficacy observed with the synthetic fungicide DITHANE 60 OS would be due to Mancozeb (**Tonon *et al*., 2017**). The biofungicides with lower application doses and frequencies than DITHANE 60 OS have induced similar results, This situation would indicate that biofungicide applications would have effects that extend over 7 days. In addition, this study reveals similar results to those of **Kassi *et al*. (2014)**, which showed that foliar applications of the biofungicide NECO 50 EC on bananas would be effective against *M.fijiensis* over 5 weeks after application, with environmental and health benefits. The fungicide treatments have reduced the infestation due to *M. fijiensis* and allowed bananas to reach flowering with more than 8 functional leaves that would involve obtaining bunches of very good quality at harvest. In fact, the good development of bunches and quality of fruit are correlated positively with a high number of functional leaves (more than 8 leaves) during the flowering of bananas (**Cohan *et al*., 2003**). Similarly, **Anno** (**1981**) showed that the vegetative growth of banana stops at the time of the inflorescence emission, so at this stage the leaf area available to the banana is a limiting parameter to the productivity of plants (**Tuo *et al*., 2015**). In addition, the treatments tested allowed bananas to reach the harvest with an average of 4 functional leaves. For **Sadom *et al*.** (**2010**), a large number of functional leaves on plants between flowering and harvest allows better fruitsfilling, heavier bunches and increased yield.

Conclusion:-

The objective of this study was to evaluate the effect of aromatic plant essential oils-based biofongicides on *Mycosphaerella fijiensis* responsible of the black leaf streak disease (BLSD) in intensive dessert banana cultivation in Côte d'Ivoire. The biopesticides NECO 50 EC, ASTOUN 50 EC, PRORALY 50 EC and FERCA 50 EC were effective in the same way as the chemical fungicide DITHANE 60 OS. In addition to the proven effectiveness, these biopesticides ensure better protection of environment and human health and would also provide a financial income to operators and producers through the reduction of application frequencies. Thus, these products could be a better alternative to the chemical fungicides use which has more disadvantages than advantages.

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Conflict of interests:
The authors declare no conflict of interest for this manuscript.

Contributions of the authors:
This work was carried out in collaboration among all authors. TS handling experimental, analyses data and drafting of this paper. The other co-authors, particularly ALDGE and KKFJM, took part in the analysis of data and the correction of paper according to journal requirements. All the authors read and approved the final manuscript.

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