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Comparison of Two Defoliation Methods in the Control of Black Sigatoka Disease (*Mycosphaerella fijiensis* Morelet) in Industrial Banana Plantations in Côte d'Ivoire

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Abstract – **In order to assess different methods of health-purpose defoliation on the severity of black leaf streak disease under conditions of intensive cultivation in Côte d'Ivoire, this study was conducted in the Agro-industrial farms of Banacomoé, located in the Mé region. The treatments consisted in carrying out surgery (removal of portion of leaves at stage 6) and sanitation (removal of 25% of leaves if stages 4-5-6 were noticed on the tip of the leaf, 50 % of leaves if stages 4-5-6 were noticed on half of the leaf, and the entire leaf, if stages 4-5-6 were noticed on more than half of the leaf). Both treatments were carried out on two plots forming a compact block. On the plot where defoliation was done using the sanitation method, the weekly assessments of symptomatological parameters of BLSD (SE, YLS, YLN) made on 10 banana trees during the assessment period (January 2012-July 2012) revealed a very significant reduction in the amount of inoculum. On the other hand, the daily yield was estimated at 3.6 ha for sanitation, while it was 2.2 ha for surgery. There was no significant difference between the numbers of functional leaves at flowering whatever the treatment, while this difference could be noticed at harvest.**

Keywords – **Banana Tree, Defoliation, *Mycosphaerella fijiensis*, Severity, Côte d'Ivoire.**

I. Introduction

In Côte d'Ivoire, banana occupies an important place in people's diet. Its cultivation is also a substantial source of income for these populations. Two large banana tree cropping systems are distinguished: the dessert banana tree, mainly grown in intensive systems for the export of fruits, while the plantain tree can be found in extensive systems, intercropping, without inputs and is grown for local consumption [1].

Banana trees are faced with various diseases including black Sigatoka or black leaf streak disease (BLSD) [2]. Most of banana productions intended for exploitation are from the Cavendish subgroup, and especially, from the (Grand naine) cultivar very sensitive to this disease.

In Côte d'Ivoire, BLSD was detected in 1985 in the region of Aboisso[3]. It causes leaf necrosis leading to yield losses but above all, a premature ripening of bananas, not enabling to provide an acceptable product for export [4]. It can thus lead to a yield loss of 25 to 90% when not controlled [5]. Moreover, it is estimated that the means of Sigatoka control, especially black Sigatoka represent 15 to 25% of the total production costs of banana [6].

The disease is spread mainly by ascospores and conidia. Unlike conidia, ascospores are formed in pseudothecia present on the old banana leaves or on dead leaves lying on the ground [7].

The methods of black Sigatoka control are implemented around management systems that integrate health-purpose defoliation and the use of fungicides. The intensive use of fungicides namely, systemic single-site fungicides, caused the appearance of resistance of pathogenic strains [8] and brought about the formation of strains more virulent than local strains, in addition to environmental pollution [9];[10]. In areas where resistance to fungicides is established, the disease control requires weekly systematic application of contact fungicides, which increases the number of treatments per year [11].

These methods of control are efficient if and only if the health-purpose defoliation is not limited to the removal of necrotic leaf tissues. One should include the stages that cannot be blocked by fungicide treatments. It is at these stages that occurs most of the inoculum present in plantations and which are the cause of the formation of conidia and ascospores[12] cited by [13].

The conditions of control become then increasingly difficult which is why one must develop population management systems that implement all appropriate techniques for maintaining these populations below levels in order to limit the dispersion of the inoculum and cause damage.

For this reason, in the experiments carried out in farms, a health-purpose defoliation method sanitation was assessed so as to propose less costly and less environment-contaminating options in the control of black leaf streak disease.

II. Materials and Methods

The study was conducted in the Agro-industrial farm of Banacomoé property of the S.C.B, located in the department of Akoupé, Mé region, in the center-east of Côte d'Ivoire. The experimental site was located at 6°38' north latitude and 3°42' west longitude. It took place during the period from January to July 2012. The accumulated rainfall during that period were 947 mm. The maximum temperature in that area was 32.91°C, the minimum temperature was 22.09°C, which gave an average temperature equal to 27.5°C. In that zone, the amount of rainfall varies between 1200 and 1400 mm

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annually [14]. The relative humidity is of the order of 80%. These are good conditions for the development of banana tree cultivation, but also for *Mycosphaerella fijiensis.*

1) Plant material

The plant material consisted of dessert banana tree plants (Musa AAA.)

2) Treatments

The treatments assessed were:

a) Surgery: it consisted in removing portions of leaves necrosed by black Sigatoka (stage 6) and broken leaves.

b) Sanitation: it consisted in removing 25% of the leaf if stages 4, 5, 6 were noticed by transparency on the tip of the sheet, in removing 50% of the leaf if stages 4, 5, 6 were noticed only on half of the leaf, and to remove 100% of the leaf (entire leaf), if stages 4, 5, 6 were noticed on more than half of the leaf.

The different stages of the disease were identified according to the scale ofFouré[15] (Table I).

Table I: Different stages of black leaf streak disease

Stages	Fouré (1982)
Stage I	Yellowish specks, invisible under 500 µm length, 200µm width transmitted light
Stage II	4mm length over 0.5mm width streaks, visible on both sides, brown on the underside and black on the upper side the coalescence is visible in case of strong attack.
Stage III	Extended streaks with irregular dimensions clearly visible on the upper side face.
Stage IV	Brown spots, circular or elliptical, light brown, presence of a light halo, elliptical depressed-center spot, black, surrounded by a yellow halo.
Stage V	The center startsdepressing
Stage VI	Dried-center spot, grey with a narrow border and an edge

Experimentation

Two plots with a density 1850 plants/ha were used, with respectively 2.5m and 2.16 m between plants and rows. A cable-way line was used to divide the two plots. Each plot was delineated so as to have 100 m wide and 150 m long (15 000 m^2). The quantity of plant per plot was approximately 2700.

Chemical control of black Sigatoka was performed homogeneously and under the same conditions on the two plots during the production cycle, the program being made up of 16 Mancozeb cycles (Dithane at 1.75 l/ha), 8 Chlorothalonil cycles (Balear at 2 l/ha), 3 Triazole cycles (Difenoconazole at 0.4 l/ha) in mixture with Morpholine (Fenpropimorph at 0.5 l/ha). The spreading were made in a range of 7 to 8 days. The fertilization route consisted of N, P_2O_5, $K_2O$of respectively 210g, 31g, and 60g per plant. The management of the other agronomic practices such as drainage, nematodes, weevils and weeds were similar on the two plots.

Every week, the different treatments were carried out on all plants according to the plot. 10 non-bloomed plants were chosen and the same plants were observed every week until flowering in order to follow the development of the disease.

Every week 10 plants at flowering stage and 10 plants at harvesting stage were selected and identified in order to track the number of functional leaves.

Parameters Assessed

For each experimental plot, the following parameters of the disease were assessed, the State of Evolution (SE), the Youngest Leaf Spotted (YLS), the Youngest Leaf Necrosed (YLN), basing on the calculation method described by Fouré [5].

The Number of Leaves at Flowering (NLF), the Number of Leaves at Harvest (NLH) and the achieved yield for each treatment were also assessed.

The statistical analyses of the data were performed with the STATISTICAT 7.1 software. Analyses of variance were carried out in order to assess the effect of treatments. The Newman Keuls test was used to compare the average values of SE, YLS, YLN, NLF, the NLH with the α risk of 5 p.c. and classify the treatments

III. Results

The sanitation caused a drop in the SE of the disease compared with the surgery. In figure 1, we could estimate the behavior of SEs in accordance with the treatments. These results showed a significant difference between the values of the corresponding SEs ($p > 0.05$) for each treatment (fig.2).

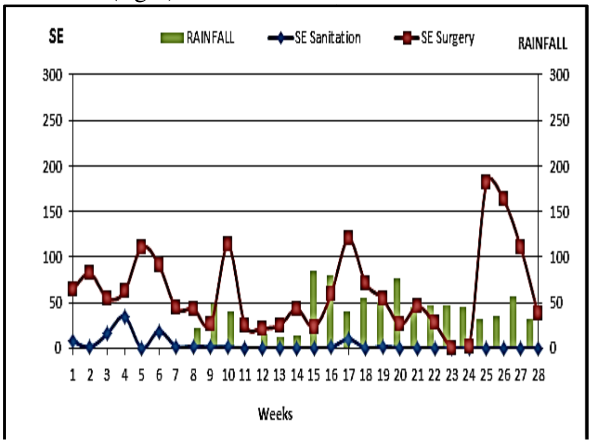

Fig.1. Weekly evolution of the state of BLSD in accordance with treatments

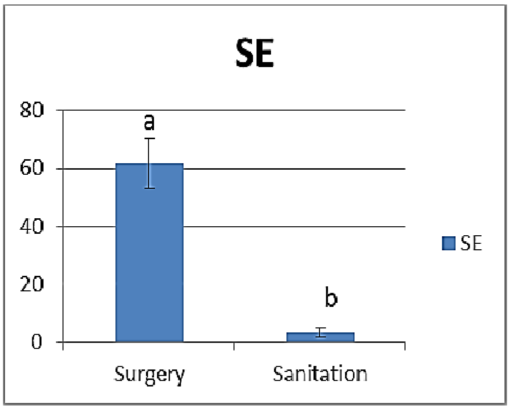

Fig.2. Effect of the type of treatment on the state of evolution of the disease

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Significant differences (p> 0.05) were noticed in the YLS and also at the YLN, revealing that reduction in disease severity was better noticed with sanitation.

At flowering, the number of functional leaves (NFL) was not significantly different (p> 0.05) between the treatments. However at harvest, a difference was noticed in the number of functional leaves (NLH), the sanitation indicated the highest average value (Figure 3).

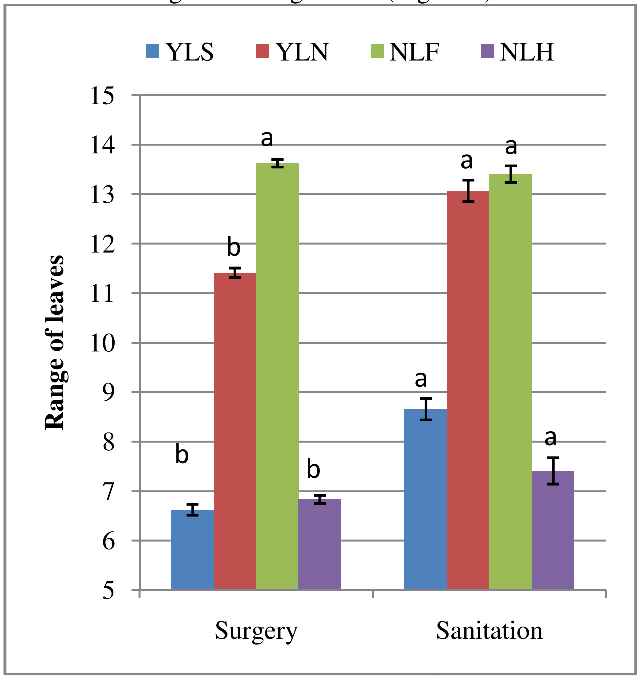

Fig.3: Effect of the type of treatment on the parameters of YLS, YLN, NLF and NLH

The evolution of the NLH for the sanitation treatment, during the first 4 weeks (Wk1, Wk2, Wk3, Wk4) after implementation of the study, showed the loss of 1 leaf per week (Figure 4). From week 5, a rise in the NLH started, the optimal values were reached from week 8

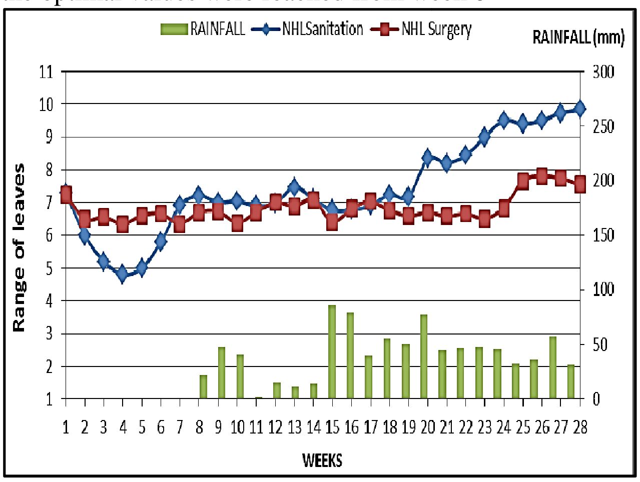

Fig.4. Weekly evolution of the NLH in accordance with the treatments.

The duration for completion of sanitation was significantly better (P> 0.05) (Figure 5). It took an average 3.6 hours to carry out a sanitation tour on a surface of 1.5 ha against 5.5 hours for the same surface concerning surgery.

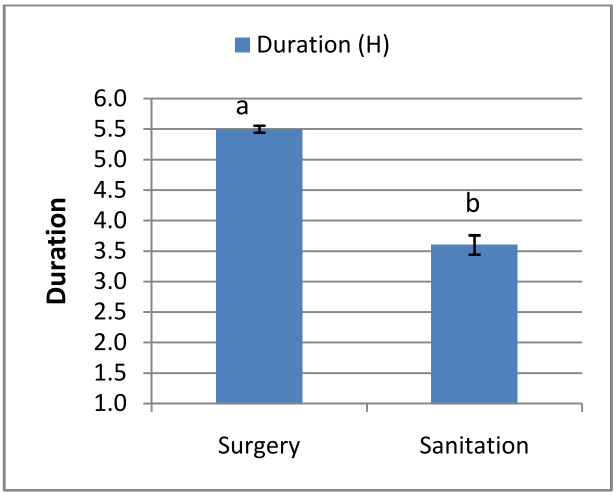

Fig.5. Duration (H) for completion of each type of treatment

The yield (Ha/day) was expressed (Table 2), basing on duration data, and showed per type of treatment the daily amount of defoliated surface. Thus, it resulted from this estimate that 3.6 Ha were defoliated per day for sanitation, while a surface of 2.21 Ha per day were concerned for surgery.

Table II: Average daily yield estimate in accordancewith treatments performed

Treatments	Yield (Ha/day)*
Surgery	2.21[a]
Sanitation	3.64[b]

* The different letters indicate significant differences at the threshold of 5 p.c. (Newman-Keuls test) between the average yields of each treatment.

IV. Discussion

The trials carried out in the farm have shown for all parameters characterizing the foliar symptoms of BLSD (SE, YLS, YLN) lower levels of black Sigatoka infection in plots where the practice of sanitation was performed. Indeed, the gradual removal of leaves or portions of leaves attacked as early as the appearance of stage 4, did not help achieve the development of necrotic stages. It is during these stages that occur the fungal reproductive structures. This form of defoliation significantly reduces the presence of the inoculum, fungicide spreading have thus better efficiency on the development of BLSD. The works of [16] on another method of gradual defoliation confirmed and promoted the decrease in disease severity.

As for surgery it was implemented when there appeared necrotic tissue (stage 6), but the sexual stage of the reproductive cycle is ensured by ascospores, the first ones of which are produced between stages 5 and 6 [17]. This will obviously facilitate the emergence of a considerable amount of damage with development stages 5 and 6, and therefore increase the presence of inoculum in the plot. The infectious cycle will be complete and the ascospores will be dispersed by the wind and projected violently following the drying up of perithecia[18]. Furthermore, [19] reports that on necrotic areas or completely necrotic

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leaves excised, lying on the ground and even hanging, there is still some release of ascospore over several weeks. This situation caused a cycle of black leaf streak disease which did not favor the reduction of its severity.

Regarding the number of leaves at flowering, the lack of difference between the two treatments may be explained by the fact that according to [20], 15 to 25 functional leaves are produced with a rate of emission of one leaf per week during the vegetative period. This does not enable a fungus lesion accumulation, due to a dilution factor, which favors the maintaining, over the longest period possible, of leaves on the banana tree without quickly reaching the stages necessary for their removal. Similar results were observed by [21] who did not notice significant difference on the amount of leaves produced with also two defoliation methods.

When the banana tree reaches the flowering stage, there is more leaf emission; the number of leaves at harvest will be thus conditioned by the health status of the plot at the time of flowering. In the surgery plot, dissemination of ascospores by the wind will increase the risk of contamination on existing leaves and a rapid accumulation of inoculum. Leaf removal stages will quickly be reached for this treatment, thus enabling to notice a significant difference in the number of leaves at harvest in accordance with treatments. Moreover, [19] argues that leaf phyllotaxy at that time and the pressure of inoculum does not favor the efficiency of fungicide treatments mainly contact fungicides. Indeed contact fungicides are used in a preventive way and to protect the newly emitted leaves at the rate of one treatment every 7 to 10days, which caused therefore the quick removal of more leaves.

In order to perform the surgery, one needs much more time therefore low yield, compared to sanitation. Indeed, the surgery is performed by removing only the points and necrotic areas without affecting the healthy portions of the leaf, which required much more attention and thus much more time from the worker. And so re-contamination is caused by the presence of ascospores, pest pressure is still present and requires much more time. Unlike sanitation, the gradual decline of inoculum has led to a better health status and the evolution of stages was slow, one needs less time to complete this treatment.

V. Conclusion

Under intensive exploitation conditions of dessert banana, the practice of sanitation has caused a greater impact on the black leaf streak disease than surgery, helping thus to limit the spread of inoculum and also the sources of re-infestation. These results are very important because they will enable producers to carry out sanitation so as to lower the pressure of BLSD inoculum in their farms without jeopardizing the banana trees which will have at least 7 healthy functional leaves at harvest. Also, one needs less time to achieve sanitation, which involves less staff and therefore will generate economic gains for planting.

The use of sanitation as health-purpose defoliation is therefore recommended in the integrated control of the black leaf streak disease.

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