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Management of Banana Black Sigatoka in Industrial Dessert Banana Cultivation through the Reasoned Use of Synthetic Fungicide VONDOZEB 62 OD

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Abstract **Original Research Article**

Black Sigatoka, caused by the fungus *Mycosphaerella fijiensis*, is the main devastating banana (*Musa* sp.) leaf disease. The environmental and health constraints linked to the misuse of chemicals against this disease imply efficient methods aimed at reducing these products. This study, conducted on the Akressi site of Société Agricole Kablan Joublin (SAKJ), an industrial company of dessert banana, assessed the reduction in the dose of contact fungicide associated with adjuvants on black Sigatoka prevalence in Ivorian industrial banana tree plantations. This study made it possible to assess certain phytopathological (YLA, YNL and SI), growth (NEL and LER) and toxicity parameters of treatments every week over two months. Banana trees treated with reduced doses of VONDOZEB 62 OD associated with adjuvants induced statistically identical performance to the reference control. Thus, the use of reduced doses of fungicides associated with adjuvants appears to be an ideal strategy for reducing *M. fijiensis* severity and the use of chemical fungicides in the control of this disease.

Keywords: Banana tree, Sigatoka, adjuvant, fungicide, prevalence, Côte d'Ivoire.

INTRODUCTION

Banana is the fruit or berry that grows from banana tree (*Musa* sp.) inflorescence. It is a real source of nutrition due to its high fiber, mineral element and carbohydrate contents [1]. In developing countries in the tropics and subtropics, this fruit constitutes an important source of employment, income and food security for populations [2; 3]. Dessert banana, mainly intended for export, is number one, ahead of grapes and citrus fruits, in fruit production worldwide [4].

In Côte d'Ivoire, the banana sector generates nearly 10 000 direct and 35 000 indirect jobs, and the European Union market absorbs 80% of its yield [5]. Since 2016, the country has been the leading African producer and exporter of dessert banana in this said market [6]. Dessert banana yield increased by 20% in 2018, allowing the country to reach around 400 000 tons [7]. Regarding plantain, which also plays an important role in the diet of Ivorian populations, the production in the same year was 1 883 063 tons with a yield of 3.66 t/ha because its cultivation occupies a surface area of 514 836 ha [7]. The banana sector contributes 8% to agricultural GDP and 3% to national GDP [8], generating a turnover of 145 billion CFA francs (221 million euros).

However, this crop is prone to many diseases, especially those of fungal types. Among these diseases, yellow Sigatoka or Sigatoka disease and black Sigatoka or black leaf streak disease (BLSD) caused by *Mycosphaerella musicola* and *Mycosphaeraella fijiensis* respectively are the ones which cause much yield losses among the leaf diseases of this crop. The action of these diseases, which result in considerable leaf photosynthetic surface area reduction, leads to poor and early fruit ripening [3]. Regarding black Sigatoka, which is the most damaging of these diseases, yield losses due to this pathogen vary between 20 and 50% and can reach 100% from the second crop cycle for lack of treatment [9; 10].

Chemical control through the use of synthetic pesticides remains the main method used by producers against Sigatoka. Nevertheless, despite the proven effectiveness of these products, their use is the source of many constraints including, among others, the appearance of strains resistant to fungicides, non-compliance with the environmental balance and threats to the health of users as well as consumers. Likewise, operators face new sustainability policies, and increasingly demand from importing countries in terms of biopesticide residues.

Thus, the sector is resorting to alternative, sustainable and ecological solutions that limit the use of these synthetic products.

This trial that was carried out aimed at making a lasting contribution to Sigatoka control in dessert banana cultivation by using the fungicide VONDOZEB 62 OD mixed with an adjuvant in order to reduce the conventional dose used.

MATERIAL AND METHODS

MATERIAL

The plant material consisted of micropropagated plants from dessert banana (*Musa acuminata*) cultivar Grande Naine from the Cavendish group. These plants, which had spent 11 weeks in nursery, were 3 months old at the time of planting.

As regards the fungicidal material of this study, it was made up of: VONDOZEB 62 OD, offered by the company CALLIVOIRE, whose active ingredient is Mancozeb 620 g/L, fungicide PERSIST 60 OS whose active ingredient is Mancozeb 600 g/L marketed by SODIA and SILWET Stick and SILWET 408 adjuvants supplied by SODIA.

METHODS

Experimental site

The study was carried out in the village of Akressi, in the town of Ayamé, in the region of Aboisso, within the industrial banana tree plantation of the Société Agricole Kablan Joublin (SAKJ) with the following geographical coordinates: 5°37'100" N, 03°05'31" W and 87 m altitude. The region of Aboisso is an area of very high parasite pressure from *Mycosphaerella fijiensis*. It is characterized by a humid tropical climate with four seasons, including two rainy and two dry ones [11].

Experimental design

The trial was carried out under natural infestation conditions by *Mycosphaerella fijiensis* over 8 weeks of the period going from week 37 to 45 of the year 2020. The experimental design adopted was Fischer blocks made up of 9 treatments (T1, T2, T3, T4, T5, T6, T7, T8 and T9) with 4 repetitions each. VONDOZEB 62 OD was applied at 2 different rates: 1.5 L/ha and 2 L/ha. Each of VONDOZEB 62 OD doses were added with adjuvants SILWET 408 0.1%, SILWET STIK 0.1% and SILWET STIK 0.4% respectively thus constituting for VONDOZEB at 1.5 L/ha treatments T2, T3 and T4 and for VONDOZEB at 2 L/ha treatments T6, T7 and T8. Treatments T1 and T5 were VONDOZEB 62 OD at 1.5 L/ha and VONDOZEB 62 OD at 2 L/ha respectively without adding adjuvants. The effect of each dose of VONDOZED 62 OD with or without adjuvant was compared to a synthetic fungicide PERSIST 60 OS at a rate of 1.75 L/ha (T9). The trial consisted of 36 experimental plots spread over a total surface area of 18 000 m^2 (1.8 ha). Within the plots, the banana trees arranged in quincunx on two double rows, on 1000-m^2 beds, were planted at a density of 1820 plants per hectare. The banana trees were spaced 2.2 m apart on the same row and 1.7 m with those of the double row in quincunx. Each elementary plot consisted of 90 banana trees, for a total of 3240 for the entire trial.

Preparation and application of treatments

On the basis of a 60 L/ha slurry, the mixture was made as follows:

- 50% of the volume of water + fungicide, stir for 3 min;
- Add the adjuvant and stir for 3 min;
- Add water up to the final volume and stir for 3 min

Applications were made weekly for the 8-week trial using an "OSATU" type backpack sprayer. During this period, maintenance work consisting of mechanical stripping of necrotic leaves and portion of leaves was carried out every week.

Parameters to be measured

- The measurements were carried out on a weekly basis and concerned 5 banana trees selected from the different elementary plots.

Assessment of epidemiological descriptors

The epidemiological parameters of black Sigatoka assessed were:

- The youngest leaf affected (YLA), that is to say, by counting the leaves from top to bottom, the youngest leaf bearing the first symptoms of Sigatoka with at least 10 streaks of stage 1 of its evolution [12].
- He youngest necrotic leaf (YNL), which corresponds to the rank of the youngest leaf showing at least 10 necroses at stage 5 or 6 of Sigatoka [12, 13].
- the severity index (SI) of the disease, calculated for each treatment by the modified Stover formula [14]:

$$\mathbf{SI} = \frac{\sum \boldsymbol{nb} \times 100}{(\boldsymbol{N}-1)\boldsymbol{T}}$$

Where

n = number of leaves of each degree;
b = degree (0 = no symptom;
1 = less than 1% of leaf blade showing symptoms
2 = 1 to 5% of leaf blade with symptoms;
3 = 6 to 15% of leaf blade with symptoms;
4 = 16-33% of leaf blade with symptoms;
5 = 34 to 50% leaf blade with symptoms
6 = 51-100% of leaf blade with symptoms);
N = number of degrees used in the scale (7)

T = total number of leaves assessed.
Severity rating scale:
0: less than 1% necrotic tissue / less than 10 spots per leaf,
1: 1 to 5% necrotic tissue,
2: 6 to 15% necrotic tissue,
3: 16 to 33% necrotic tissue,
4: 34 to 50% necrotic tissue,
5: 51 to 100% necrotic tissue.

Assessment of agromorphological parameters

Agromorphological descriptors studied during this trial were:

- Number of living leaves (NFV), the leaves were counted from top to bottom and only leaves capable of carrying out photosynthetic activities were taken into account [15];
- Leaf emergence rate (LER), this parameter made it possible to establish a relationship between the plant growth and disease development. It corresponded to the number of emerged leaves per week. It had to be calculated regularly for each plant assessed and each reference plant, from three months after the date of planting until the bunch emergence, inflorescence emergence [16]. During the experiment, cigar stage was indicated by numbers 0, 2, 4, 6, 8 or letters A, B, C, D, E which were the 5 reference stages. The number of days between two observations was N = 7.

Correction by LER (LERi): For the banana trees observed, LERi = LER/N
We use LERc for correction and LERc=LER previous week + LER1/2.

Assessment of treatment phytotoxicity

The toxicity of the different treatments in the study on aerial organs, in particular leaves, of banana trees was determined using the following rating scale:
0 = neither leaf burning nor discoloration;
3 = leaf discoloration or stunted growth without necrosis (burns);
5 = yellowing accompanied by necroses;
7 = plant destruction and death;
10 = total destruction of the plot.

Rainfall

It consisted in the quantitative assessment of rainfall, its nature and distribution. This evolution will be superimposed on the evolution of fungal attacks so as to see the correlation.

Statistical analyses of data

Xlstata software was used for data analysis. A one-way ANOVA was performed, followed by a test comparing the means of the different treatments according to disease status in the event of a significant treatment effect at 5% threshold.

RESULTS

Assessment of epidemiological parameters

- **Rank of the youngest leaf affected (YLA)**

Table 1 shows the weekly evolution of the rank of the youngest leaf (YLA) affected by black Sigatoka in the plots treated with the different doses of VONDOZEB 62 OD and the reference control PERSIST 60. The analyses of variance of this parameter, whose assessment started in week 41, showed no significant differences (P > 0.05) between the treatments. Overall, the different fungicide applications made it possible to induce mean YLA ranks between 5.5 and 5.7 leaves (Figure 1).

- **Rank of the youngest necrotic leaf (YNL)**

For the rank of the youngest necrotic leaf (YNL), no significant differences were observed between the treatments. Observations showed an increase in the rank of the youngest necrotic leaf (YNL) from the first weeks of the trial (37 to 41), in all VONDOZEB 62 OD preparations as well as in the reference control PERSIST 60 (Figure 2).

- **Severity index (SI)**

The severity index measures the rate of leaf area destroyed by *M. fijiensis* on banana trees at a given time. The results shown in Figure 3 indicate that there were no statistically significant differences between treatments from one month to another. However, during the 2 months of trial, with the exception of treatments T5 (VONDOZEB at 2 L/ha) and T6 (VONDOZEB 2L/ha + SILWET 0.1%), it was noted in the other treatments applied an increase in severity index (SI) from month 1 to month 2 of the trials.

Table-1: Weekly evolution of the rank of the youngest leaf affected by black Sigatoka in bananas depending on treatments

Treatments	Rank of the youngest leaf affected (YLA)					After 8 weeks
	W41	**W42**	**W43**	**W44**	**W45**	
T1	7.20	5.55	5.50	5.40	4.85	5.70 ± 1.07 **a**
T2	6.75	5.50	5.55	5.35	5.15	5.70 ± 0.95 **a**
T3	6.40	5.85	5.90	5.25	5.00	5.70 ± 0.72 **a**
T4	6.60	5.35	5.35	5.25	5.00	5.50 ± 0.85 **a**
T5	6.60	5.40	5.70	5.55	4.95	5.60 ± 0.83 **a**
T6	6.70	5.50	5.70	5.75	5.05	5.70 ± 0.90 **a**
T7	6.55	5.25	5.55	5.40	5.00	5.60 ± 0.77 **a**
T8	6.35	5.50	5.70	5.40	4.95	5.60 ± 0.80 **a**
T9	6.60	5.50	5.40	5.30	5.05	5.60 ± 0.80 **a**
Mean						5.62
Probability						P = 0.61>0.05

N.B: The numbers assigned the same letter do not differ significantly at 5% threshold of the Newman-Keuls test.

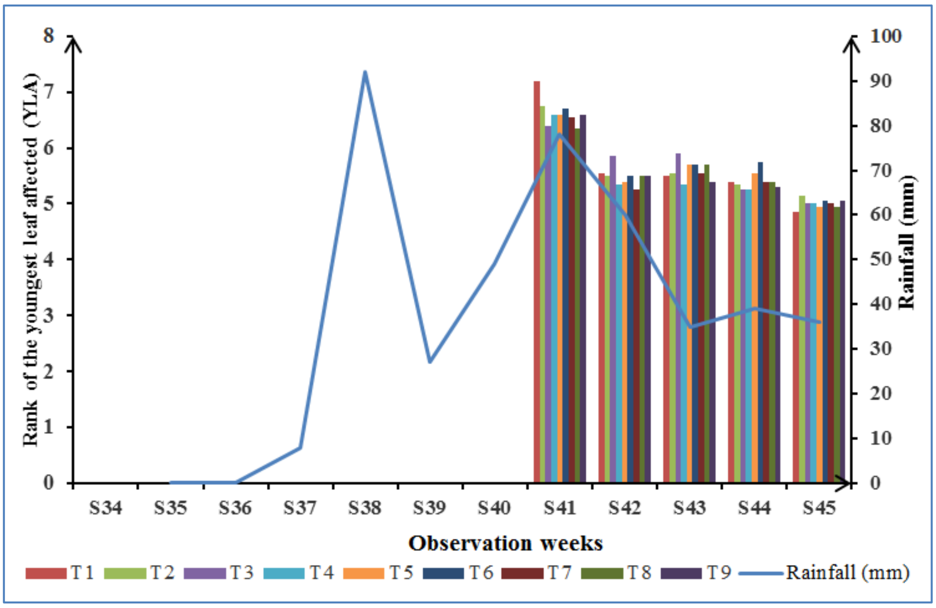

Fig-1: Effect of rainfall on the weekly evolution of the rank of the youngest leaf affected (YLA) by Sigatoka of the different treatments

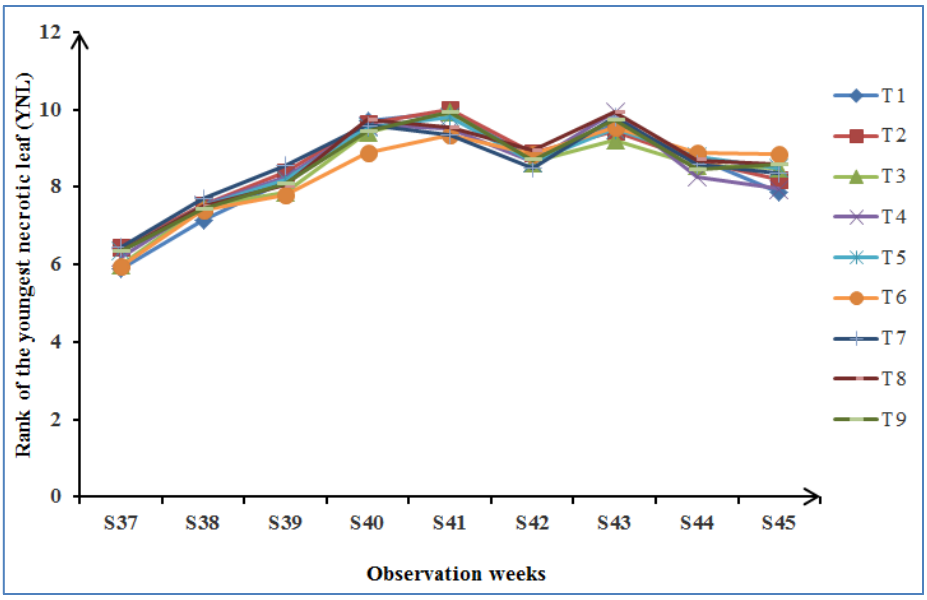

Fig-2: Effect of treatments on the evolution of the rank of the youngest necrotic leaf (YNL)

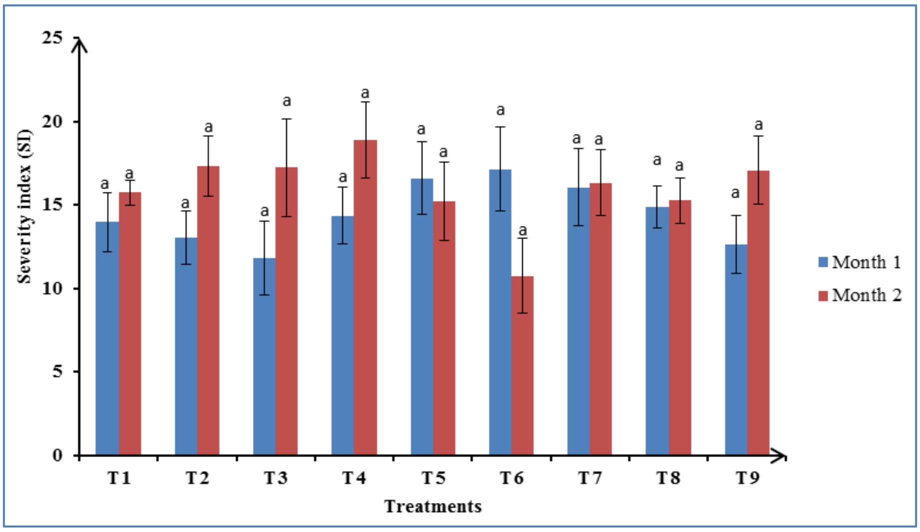

Fig-3: Monthly variation in black Sigatoka severity index in banana trees treated with the different fungicidal formulations

Assessment of agromorphological parameters

- **Number of emerged leaves (NEL)**

Plant growth was good throughout the trial. Significant numbers of leaves were obtained in all the fungicidal preparations tested (Table 2). This parameter changed very little from one preparation to another. The lowest NEL was obtained with preparation T1 (Vondozeb 62 OD at a dose of 1.5 l/ha without adjuvant) and the highest NELs were obtained with preparations T2 (Vondozeb 62 OD 1.5 / ha + Silwet 408 0.1%) and T8 (Vondozeb 62 OD 2 l / ha + Silwet stik 0.4%).

- **Leaf emergence rate (LER)**

Leaf emergence rate (LER) varied very little between the different treatments over the weeks. It varied between 1.5 and 1.6 leaves on average for all fungicide preparations. There were no significant differences between LERs of the different treatments compared. Banana trees had similar growth with all treatments throughout the trial. Leaf emergence was not significantly influenced by the treatments made (Figure 4).

Assessment of treatment phytotoxicity

The phytotoxicity of treatments with respect to the aerial parts of banana trees is presented in Table 3. Observations revealed phytotoxicities on the leaves of all preparations. However, no statistical differences were recorded between the treatments as a result of the analyses of variance performed (P > 0.05). Over the entire trial, the phytototoxicities of the different preparations varied between 0.43 and 0.80.

Table-2: Number of emerged leaves in banana trees during the trial depending on treatments

Treatment	Number of emerged leaves									After 8 weeks
	W37	W38	W39	W40	W41	W42	W43	W44	W45	
T1	4.9	6.35	7.8	9.4	11.2	12.7	14.25	15.8	17.15	11.06±1.42 a
T2	5.45	6.6	8.45	10	11.85	13.36	15	16.7	18.1	11.72±1.48 a
T3	5	6.5	7.95	9.73	11.67	13.3	14.95	16.5	17.95	11.50±1.51 a
T4	5.2	6.65	8.34	9.9	11.6	12.95	14.6	16.25	17.35	11.42±1.41 a
T5	5.43	6.6	8.45	10	11.85	13.41	15.11	16.6	18	11.71±1.47 a
T6	5.05	6.65	8.35	9.9	11.6	12.62	14.85	16.44	17.8	11.47±1.46 a
T7	5.45	6.85	8.65	10.35	11.95	13.4	15.05	16.55	17.9	11.79±1.44 a
T8	5.35	6.7	8.5	10.3	11.9	13.4	15.15	16.5	18.1	11.76±1.47 a
T9	5.35	6.8	8.5	10.15	11.8	13.65	14.95	16.45	17.9	11.72±1.45 a
Means										11,57
Probability										P = 0,99>0,05

N.B: The numbers assigned the same letter do not differ significantly at 5% threshold of the Newman-Keuls test

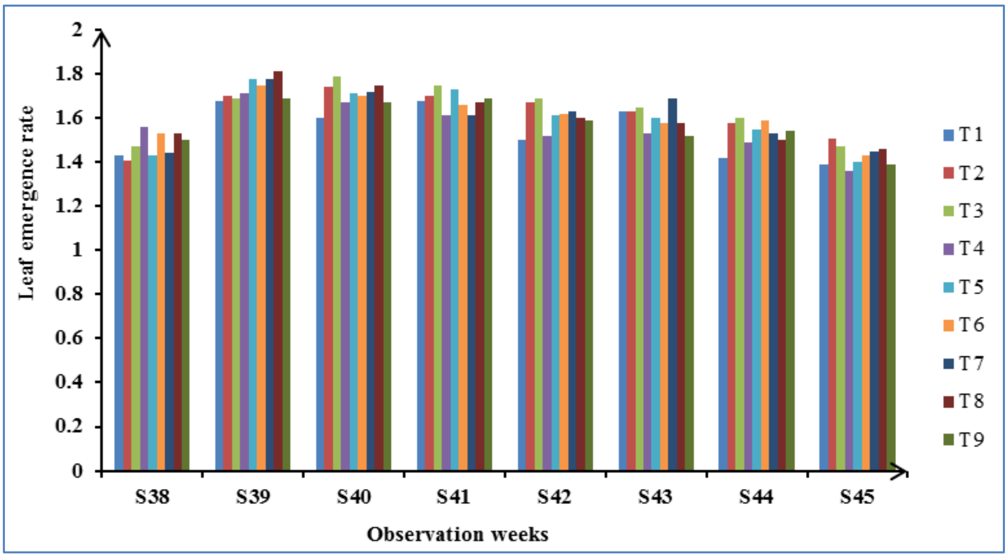

Fig-4: Leaf emergence rate of banana trees after application of fungicidal preparations

Table-3: Assessment of the phytotoxicity of the different fungicide preparations on banana trees

Treatments	Treatment phytotoxicity after 8 weeks
T1	0.43 ± 1.12 a
T2	0.70 ± 1.32 a
T3	0.61 ± 1.31 a
T4	0.45 ± 1.07 a
T5	0.62 ± 1.27 a
T6	0.80 ± 1.42 a
T7	0.43 ± 1.12 a
T8	0.56 ± 1.17 a
T9	0.52 ± 1.14 a
Means	0.57
Probability	P = 0.56 > 0.05

N.B: The numbers assigned the same letter do not differ significantly at 5% threshold of the Newman-Keuls test

DISCUSSION

This study demonstrated the comparative effect of contact fungicide Vondozeb 62 OD mixed with an adjuvant at different doses to that of PERSIST (reference fungicide). At the end of the 8 weeks of the trial, the treatments seemed to have no significant different effects on the phytopathological (YLA, YNL and SI), growth (NEL and LER) and phytotoxicity parameters observed. However, the good performances observed in the study of phytopathological parameters, namely the high ranks of youngest leaf affected (YLA), youngest necrotic leaf (YNL) and the low severity index, with regard to the first weeks of the study might result from the effectiveness of the active ingredient of the fungicides (Mancozeb) found in all the preparations, although at reduced doses for some, against the fungus *Mycosphaerella fijiensis*, causal agent of banana black Sigatoka. Several studies have shown the effectiveness of this active ingredient on species of fungi. The work of Sirikou *et al*. [17] showed that Mancozeb reduced the development of Sigatoka caused by *Cercospora beticola* and that of amaranth canker caused by *Phytophthora* sp. on lettuce. Tonon *et al*. [18] showed that the application of Mancozeb to cashew tree foliage reduces the severity of anthracnose caused by *Colletotrichum gloeosporioides* by more than 97%. Milidou in potatoes is significantly reduced by Mancozeb at a dose of 3 kg/ha [19]. The good sanitary condition of the plots treated with low-dose active ingredient formulations might result from the beneficial effect of adding adjuvant to the different mixtures. This beneficial effect has been demonstrated in the course of numerous works. Polar adjuvants have the ability to form hydrogen bonds with water, leading to changes in the appearance and physical form of the formulation in the spray tank. This character is that of surface active agents such as silwet, the most effective adjuvants in improving the effectiveness of pesticides [20]. The addition of a polymeric adjuvant to a formulation can influence the active ingredient. Combined with a herbicide, polymers carrying active hydrogen in their chemical structure can provide controlled release of the active ingredient and reduce phytotoxicity and antagonism [21]. Likewise, the combination with anionic and cationic polymers can reduce the antagonism between the incompatible ingredients while leading to an increase in phytosanitary effectiveness [22]. Also, the formation of specific complexes between the polymer and the pesticide can provide controlled release without forming an encapsulating shell around the active ingredient [23]. Certain polymer-type adjuvants form a shell around the active ingredient (herbicide) in order to control its release [24]. The adjuvant Silwet 408 used as a wetting agent during this work is a surface active agent, nonionic organosilicone.

The good sanitary condition of the treated plots could also be explained by the fact that the practices of cutting diseased leaves have been associated with the applications of fungicides [25]. Indeed, according to Lassoudière [26], a well cut of leaves or fragments of leaves showing symptoms of stage 4 and above of Sigatoka allows a considerable reduction of the latter. However, from the second month of the wetter trial, the addition of adjuvants to VONDOZEB 62 OD formulations did not improve disease control during periods of heavy rains which would have enabled more favorable conditions to disease development. Our observations are corroborated by those of Essis *et al*. [11] who showed that infestation of banana tree foliage by black Sigatoka is linked to climatic factors (relative humidity, temperature and rainfall) of the plantations. The work of Martinez [27] also revealed that the regions most affected by black leaf streak disease are those which receive rainfall of more than 1400 mm/year with a relative humidity of the air above 80% on average. The studies by Tonon *et al*. [18] also showed a slight increase in the severity and incidence of cashew tree anthracnose, which would be linked to rainfall. Regarding leaf emergence rate (LER) and number of emerged leaves (growth parameters), the results showed that the banana trees had good growth in all preparations throughout the trial. Our results are in agreement with those of Hoarau and Huet [28] who observed that the LER is stable over time regardless of the treatment applied to the different banana plants. Also the number of emerged leaves in banana trees of the different treatments was then 30 on average. These similarities between the banana trees of the different treatments could be explained by the adequate and homogeneous supply of organic and mineral fertilizers on all the experimental plots [10].

Regarding phytotoxicity, our results are confirmed by the work of Kassi *et al*. [3] who showed the presence of orange discoloration (phytotoxicity) on banana tree leaves after treatment of the latter with biofungicide NECO mixed with Banole mineral oil. Others have also shown that the defense activator, Acibenzolar associated with vaporized oil induces phytotoxicity on the oldest leaves of banana plants for dosages of 3.6 L/ha [29or greater than 5 L/ha [3], which may affect the leaves.

CONCLUSION

Applications of VONDOZEB 62 OD with or without adjuvant did not slow down plant growth and leaf emergence for all of the trial preparations compared to the reference control. VONDOZEB 62 OD can be used at the first cycle of dessert banana production on 3-week old plants. All preparations of VONDOZEB 62 OD with or without adjuvants showed effectiveness similar to that of the reference control PERSIST 60. VONDOZEB 62 OD is as effective as PERSIST 60 in controlling banana black Sigatoka.

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