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Evaluation of Sprays in the Management of Black Sigatoka in Banana Crop

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Abstract **Original Research Article**

The main phytosanitary problem of commercial bananas is black Sigatoka, caused by the fungus *Mycosphaerella fijiensis* Morelet. This pathogen causes loss of leaf area, loss of exportable quality and low crop yields. The objective of the research was to evaluate four systemic fungicides applied in mixtures in different combinations and to determine percentages of severity, total leaves, and old leaf free of streaks in the two zones established for data collection. This work was carried out in Rivas, Nicaragua, municipality of Potosí, in the farms El Trapiche, El Espíritu and La Granja. In an area of 5 ha-1 of the cultivar CEMSA ¾, 50 plants were selected in the border zone and 50 in the center, with four treatments: T1 (Triazole + Amine), T2 (Pyrimethanil + Spiroxamine), T3 (Difenoconazole + Amine), T4 (Amine + Pyrimethanil) each with three replications, the frequency of application was 14 days, disease severity was recorded in percentage using the Stover scale on leaves 3, 4 and 5. The experimental design was randomized blocks and the data were analyzed using a two-way ANOVA. It was determined that the percent severity on leaf 4 in the center and border zone was High (> 30 and < 50%) and on leaf 5 in both zones was severe (> 60 to 70%) in all farms. The T4 fungicide mixture (amine + pyrithamethanil) had the lowest percentages of black Sigatoka severity, the best average number of old leaves free of streaks and the highest number of total leaves.

Keywords: Severity, systemic, control, pyrimethanil, amine.

I. INTRODUCTION

Black sigatoka is the most aggressive epiphytotrophic fungus in Musaceae plantations in the world. It causes great damage to plant biomass, reducing production when control strategies are not implemented (Arias, 2003; Marín *et al*., 2003). In the department of Rivas, reductions of up to 60% in bunch weight have been reported in plantations where it is not controlled (Castillo-Arévalo and Martínez (2022).

The most effective curative method to control the pathogen is with systemic pesticides, which causes environmental contamination in established plots (Astorga, 1999; Vindas *et al*., 2004).

At present, the best sanitation technique for the disease is by means of the control method with up to 40 sanitation sprays in the first cycle, which means three quarters of the production price, causing resistance genes of the pathogen to fungal products (Sagder, 1995). These pesticides are manufactured to be applied every seven, fourteen and twenty-one days to break the fungal cycle, which means up to 50 applications in the mother generation (Chica *et al*., 2004).

Cedeño *et al*., (2017) mentioned that the most destructive disease of the banana crop is black Sigatoka, because the pathogen destroys the leaf area by the effect of excreting the phytotoxin "Juglone", by interrupting the electron transport in the chloroplast membranes, causing necrosis and death of leaf tissue in the plant.

Black Sigatoka controls increasingly require the application of more fungicides in mixtures and at low frequencies due to the resistance that this pathogen has developed, which increases production costs by more than 30% (Sepúlveda, 2015). To carry out controls, it is necessary to monitor the phytosanitary status of the crop on a weekly basis; in addition, Maiguashca (2018) emphasized that applications should be made taking into consideration the rotation indicated by FRAC for the different chemical groups (triazoles, amines and anilopyrimidines, protectants).

To control black Sigatoka in banana crops, the use of fungicides is mandatory to obtain an acceptable commercial production; this increases costs and producers' income is affected (Ramírez *et al*., 2014). The use of fungicides applied by spraying with a motor pump is the most used way for the management and control of this disease, systemic products such as: amines (fenpropimorph), triazoles (epoxiconazole), strobilurins, anilinopyrimidines, carboxamides and guanidine's are the most used and the application cycles depend on the degree of infection, the frequency is 7 to 14 days in the rainy season and 28 days in the dry season.

In this sense, Quevedo *et al*., (2018), Cedeño-Zambrano *et al*., (2021) and Sánchez-Urdaneta *et al*., (2021) highlighted those chemical fungicides constitute the main tool to control black Sigatoka, they also recommend monitoring banana plantations weekly and reviewing the rotation schedule of the chemical groups applied.

In the present investigation, two evaluation sites were considered: a first zone subjected to normal frequency cycles called "center" that received a chemical load of fungicides respecting the FRAC guidelines and a second "border" zone that received a higher chemical load due to the drift of adjacent applications. Pérez (2006) pointed out that the systemic action of fungicides allows them to enter at the level of the waxy layers and cuticle in the leaf, highlighting that the chemical groups presented different solubility values: spiroketalamines and pyrimethanil (2.8); epoxiconazole (3.4); tridemorph (4.2); difenoconazole (4.3) and fenpropimorph (4.7) products that were used in the evaluated treatments.

The above coincided with what was reported by Murillo (2015) who pointed out that the absorption and translocation of systemic fungicides depends on their lipophilicity (a characteristic that allows penetration at the level of the waxy layers and cuticle of the leaf) and solubility in water, factors that substantially affect their systemicity. Fungicide mixture applications should be applied preventively at short (low) frequency during the period of greatest disease pressure (rainy season) (Guzmán *et al*., 2013).

Therefore, the objective was to evaluate four systemic fungicides applied in mixtures in different combinations and to determine percentages of severity, total leaves, and old leaf free of streaks in the two zones established for data collection.

II. MATERIALS AND METHODS

This research was carried out in the southern region of Nicaragua, in the municipality of Potosí, Department of Rivas in the banana farms: El Trapiche, El Espíritu, La Granja, and a farm of fourth generation children, which has no economic value. The study area has a tropical climate, with average temperatures of 27 °C, with an annual rainfall of 2500 mL and an average relative humidity of up to 85.5% (Castillo-Arévalo, 2022).

The plantations corresponded to the CEMSA ¾ cultivar and have more than 20 years in production. For data collection, 50 ready plants of more than 3 m in height were evaluated in an area of 5 ha-1 in each farm, the treatments were established in two sampling zones called "border" and "center", registering data every 7 days after each application. The severity of black Sigatoka was evaluated weekly in 10 plants randomly, cutting the top of the apex towards the base 40 cm from leaves 3, 4 and 5, using a pruning shear. The percentage of severity was evaluated according to the Stover scale modified by Gauhl (1989) and the levels of evolutionary stages of each farm were evaluated following the methodology that expresses the levels of severity cited by Sánchez-Urdaneta *et al*., (2021). The values for the variable streak-free old leaf (HVLE) were taken according to the last streaked leaf whose percentages were less than 5% in plants with the presence of inflorescences (newly emerged acorn) in both zones within the trial area, the data for the number of total leaves (HT) were calculated by counting the first leaf counting from the top, in the 10 selected plants. The units of study were banana plants cultivar Williams, the treatments were the four mixtures of systemic fungicides. The applications were in water-oil emulsion (2 g·L-1·ha-1) and the dosage of the fungicides was as indicated on the label by the manufacturer and the rotation frequency was 14 calendar days.

III. RESULTS

In the estimation of the severity of black Sigatoka, considering the border zone and the central zone of the plantation, the results obtained were different, in leaf 3 there were no significant differences between treatments, while for leaf 4 and 5 there were significant differences between the treatments studied by application zone; However, when the three subsets that were formed separately in each of the farms evaluated (El Trapiche, El Espíritu, La Granja and the control) were analyzed in the border (L) and center (C) respectively, in some of the variables studied, the subsets showed up to 5 levels, which indicated that the molecule and the application zone showed significant statistical differences as shown in Table 2. All systemic fungicides applied at a frequency of 14 calendar days exerted a satisfactory control of the disease on leaf 4 in general, showing that the different fungicide treatments acted independently in the different farms.

Table 1: Effect on the severity of black Sigatoka on leaves 4 and 5

Farm	Severity (%)	
	Leaf 4	Leaf 5
El Trapiche L	37, 5a	55, 0a
El Trapiche C	38, 0a	55, 5a
El Espíritu L	42,5b	60,0b
El Espíritu C	43,0b	62,7c
La Granja L	45,0c	72,5d
La Granja C	45,0c	73,0d
Testigo L	81d	86d
Testigo C	83d	89d
F	140,9	552,16
Significance	0	0

Note: Values with the same letter indicate that the means are not significantly different. Abbreviations: L=Boundary; C=Center.

The average severity was in a range of 37.5 to 45% on leaf 4 (Table 2) in the border zone (L), on the farms El Trapiche, El Espiritu, La Granja, and the control, considered high for all treatments. When analyzed in the subsets between the border and center zones in each farm, there were no significant differences between them. However, El Trapiche boundary (37.5%) and Centro (38%) had a lower risk of burning (slight). La Granja (45%) and El Espíritu (42.5%) had severity percentages within the range considered high, which implied a higher risk of burning.

The lowest percentage of severity of the disease on leaf 5 was presented by the El Trapiche farm, both for the center and border zone with 55.0 and 55.5% respectively, but considered as severe damage, the El Espíritu farm showed an average of 60.0 and 62.7% (severe) for border and center respectively, while El Trapiche had a higher percentage of severity of 72.5 and 73.0% (severe) for border and center respectively (Table 1).

The results showed that the selection of systemic fungicides in winter was important to avoid the presence of the disease. The phytosanitary leaf removal management of each plantation also played an important role in the control of black Sigatoka, coinciding with what was reported by Hernández *et al*., (2016) who indicated that *M. fijiensis* was responsible for causing this endemic disease of Musaceae and with recurrence in dry and rainy seasons, when the phytosanitary programs are not reinforced with good leaf removal management and application frequencies.

The banana plantations El Trapiche, El Espíritu, La Granja and the experiment were areas planted with the CENSA ¾ clone and the treatments were applied according to the fungicide mixtures most used in the banana-growing area of the municipality of Potosí; triazole + amine, amine + anilinopyrimidines and spiroxamine + anilinopyrimidines were fungicides that efficiently controlled the disease in the fourth leaf during the rainy season.

Black Sigatoka has been the most destructive disease of the banana crop, and that the CENSA ¾ cultivar has been pointed out as one of the most susceptible to damage caused by this fungus, given the magnitude of the damage it generates in plantations of Musaceae (Cedeño *et al*., 2017). The fungicide mixture where the highest averages of streak-free old leaves (HVLE) were quantified was the one corresponding to T4= fenpropimorph (amine) + pyrimethanil (anilinopyrimidine) (Figure 1), with an average of 7.20 to 7.30 healthy leaves for the three farms, with the highest value (7.30) found at La Granja farm. For T1= epoxiconazole + tridemorph and T3 (difenoconazole + tridemorph), which corresponded to the physical mixture of triazole with an amine, the HVLE averages were equal in the three farms, but in T2 (spiroxamine + pyrimethanil) the lowest HVLE averages were obtained.

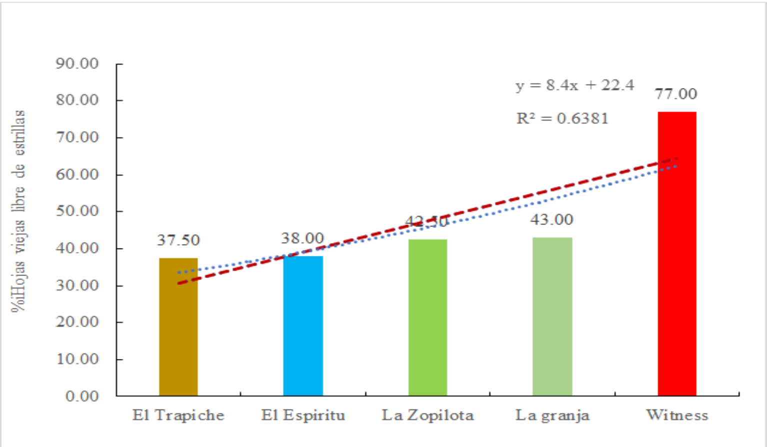

Fig 1: % Old leaves free of streaks (average) by fungicide treatment applied on El Trapiche, El Espiritu and La Granja farms. Abbreviations: T1 = epoxiconazole + tridemorph fungicide, T2 = spiroxamine + pyrimethanil, T3 = difenoconazole + tridemorph and T4 = fenpropimorph + pyrimethanil

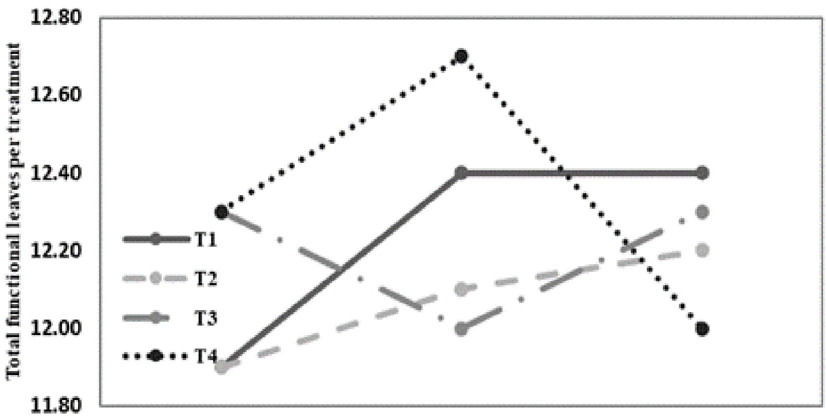

Fig 2: Old leaves free of streaks (average) by application zones and by fungicide treatment applied at El Trapiche, El Espiritu and La Granja farms. Abbreviations: T1 = fungicide epoxiconazole + tridemorph, T2 = spiroxamine + pyremethanil, T3 = difenoconazole + tridemorph and T4 = fenpropimorph + pyrimethanil

For the variable HVLE ($P<0.05$) there was interaction between the application site and the fungicides applied independently of the evaluated farm (Figure 2), the mixture of T4 (fenpropimorph + pyremethanil) interacted with T3 (difenoconazole + tridemorph), in the center zone and with the mixture of T2 (spiroxamine + pyremethanil) in the border zone. It should also be noted that in the mixtures of T2 (spiroxamine + pyremethanil) and T4 (fenpropimorph + pyremethanil), the average HVLE was lower when they were applied in the center zone, with values of 6.95 and 7.2 leaves, respectively; On the contrary, with the applications of T1 (epoxiconazole + tridemorph) and T3 (difenoconazole + tridemorph), the lowest number of HVLE was found when the applications were made in the border zone, with values of 7.05 and 7.15 leaves, respectively.

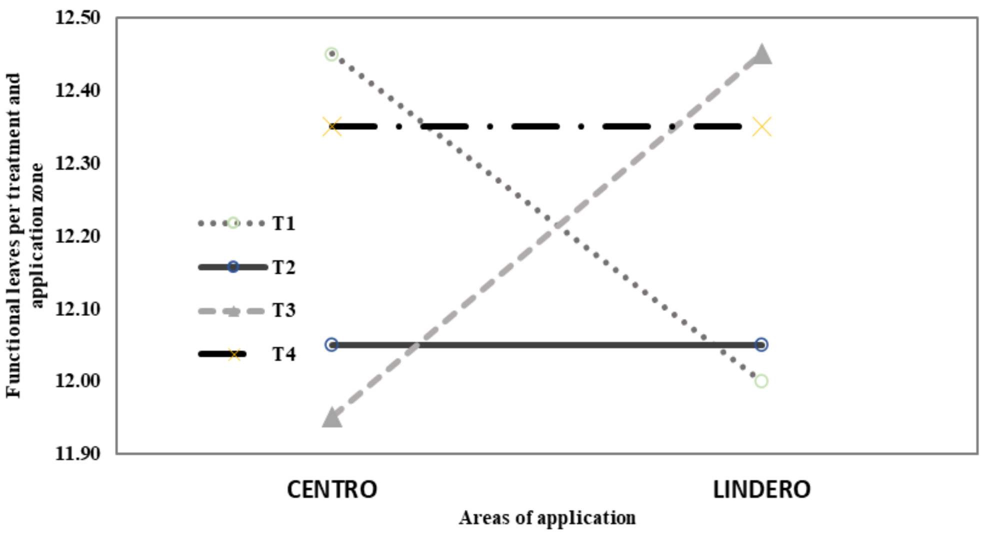

Fig 3: Total functional leaves (average) by application zones and by fungicide treatment applied on El Trapiche, El Espiritu and La Granja farms. Abbreviations: T1 = fungicide epoxiconazole + tridemorph, T2 = spiroxamine + pyrethamethanil, T3 = difenoconazole + tridemorph and T4 = fenpropimorph + pyrethamethanil

The El Trapiche farm in the border zone presented the lowest number of functional leaves with 11.95 and in the center zone 12.25 (Figure 3); similar behavior was found in El Espíritu with 12.05 in the border zone and 12.55 in the center zone, with an average difference of 0.50 functional leaves (Figure 4). At La Granja farm, this variable in the border and center zones was 12.25 and 12.20, respectively. For the variable functional leaves, significant statistical differences were found in the interaction between the farms with the fungicide treatments applied ($P<0.05$).

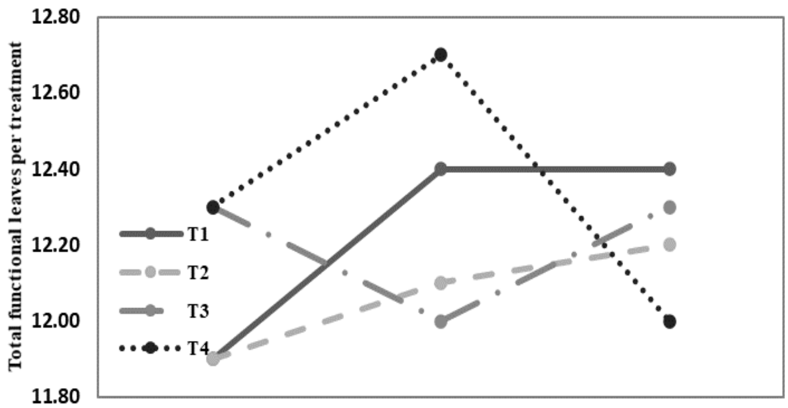

Fig 4: % Total functional leaves (average) per fungicide treatment applied on El Trapiche, El Espiritu and La Granja farms. Abbreviations: 1= epoxiconazole + tridemorph fungicide, T2 = spiroxamine + pyremethanil, T3 = difenoconazole + tridemorph and T4 = fenpropimorph + pyremethanil

Figure 4 showed that on the El Trapiche farm for the treatments (T3 and T4) 12.3 functional leaves were quantified, while for T3 and T4 on the El Espiritu farm there were 12 and 12.7 total functional leaves on average, respectively, showing a difference of 0.7 leaves for this mixture. At Lolita farm, 12.3 and 12 total functional leaves were reported for T3 and T4, respectively. Similarly, T1 (epoxiconazole + tridemorph) and T2 (spiroxamine + pyremethanil) had similar behavior, only in greater magnitude in T1. In both treatments, the lowest number of functional leaves (11.9) was found on the El Trapiche farm. In Espiritu it was 12.4 and 12.1 functional leaves, increasing in La Granja farm, for T1 it was 12.4 and for T2 12.2 total functional leaves.

Significant differences were found for the interaction by fungicide application program and application zone (P<0.05) for the variable total functional leaves (number). Treatments 1 and 3 and T2 and T4 had similar behavior. In Figure 5, with the application of spiroxamine + pyremethanil (T2) the average of total leaves was 12.05 in both the center and border application zone; With the use of fenpropimorph + pyremethanil (T4) the average was 12.35 HF, which was 0.35 times higher in T4 with respect to T2, which assures that the fenpropimorph + pyremethanil mixture acts in a preventive and curative way, guaranteeing 35% more leaf area.

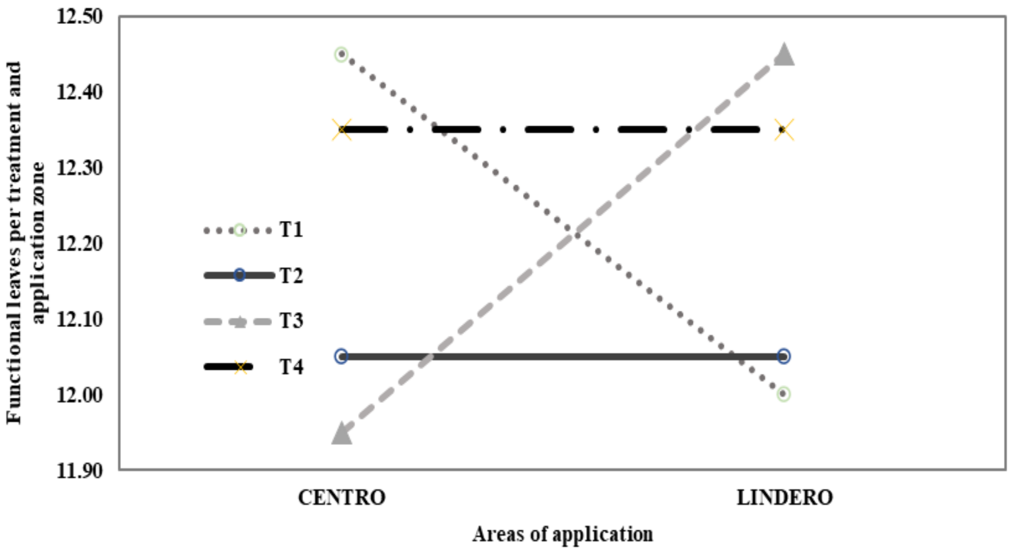

Figure 5: Total functional leaves (average) by application zones and by fungicide treatment applied on El Trapiche, El Espiritu and La Granja farms. Abbreviations: T1 = fungicide epoxiconazole + tridemorph, T2 = spiroxamine + pyrethamethanil, T3 = difenoconazole + tridemorph and T4 = fenpropimorph + pyrethamethanil.

On the other hand, in the center application zone when epoxiconazole + tridemorph (T1) was used, it was 12.45 leaves and in the border zone it was 12 total functional leaves, which represented 0.45 times more in T1 being an important option also to control black Sigatoka; On the contrary, with T3 (difenoconazole + tridemorph) in the border application zone, 12.45 total functional leaves were found, while in the center zone it was 11.95 total functional leaves, which represented 0.5 times more in the border zone, which ratifies the importance of the rotation of the molecules at the beginning of the winter season with a systemic fungicide program.

IV. DISCUSSION

M. fijiensis, the most used fungicides have been systemic fungicides such as triazoles, strobirulins and aminopyrimidines, which coincided with those reported by Martínez-Bolaños *et al*., (2012). Mena-Espino and Couoh-Uicab (2015) reported that 10 to 45 fungicide applications per year were required for the chemical management of black Sigatoka, which coincided with the results of this study. It should be noted that authors such as Guzmán *et al*., (2013) indicated that mixed applications of fungicides during the period of greatest disease pressure should be preventive and short frequency, which allows efficient management of the disease; this was also confirmed in the results obtained

V. CONCLUSION

The percentage of severity in leaf 4 in the center and border zone is high and in leaf 5 both zones are severe in all farms, when applying the mixtures T4= fenpropimorph (amine) + pyrethanil (anilinopyrimidine) there are the best results in the control of black Sigatoka, followed by T1 (epoxiconazole (triazole) + tridemorph (amine), and T3 (difeconazole + tridemorph). The lowest control was presented by the chemical mixture of fungicides of T2 (spiroxamine + pyremethanil).

The application of chemical fungicides can reduce the damage caused by black Sigatoka, but their use must be justified and supervised to avoid cost overruns and damage to health and the environment.

The best results were obtained in the plots where the practice of leaf removal and surgery was carried out, it was demonstrated that the intercalation of the mode of action of the fungicides (Systemic-Contact) prevented the appearance of new populations of the fungus, and it was proven that the use of chemical fungicides in the plots where the practice of leaf removal and surgery was carried out prevented the appearance of new populations of the fungus.

It was proved that the pesticides obtained a better mode of action on the pathogen when applied in the morning or in the afternoon.

VI. STATISTICAL ANALYSIS

The experimental design was randomized blocks and data were analyzed by two-way ANOVA.

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Conflict of Interest: The author declares that he has no conflict of interest.

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