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Review Article

Managing Black Sigatoka in Cavendish Bananas: Effects of Pyrimethanil, Spiroxamine, and Mancozeb Using The Single-Leaf Method

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About Article

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ABSTRACT

This study investigates the effects of various fungicidal treatments on banana crops, focusing on crop injury (phytotoxicity) and disease control efficacy against Banana Sigatoka. The treatments under consideration are Pyrimethanil 600 SC, Spiroxamine 500 SC, Mancozeb 600 OS, the mentioned fungicides mixed with oil and emulsifier, and a control received to treatments. The crop injury/phytotoxicity ratings were determined at different times at 13, 15, 17, 19, 21, and 23 days after treatment application. No phytotoxicity symptoms were observed on the plants receiving the different treatments with the average value being 00% injury. The untreated control also did not record any injury. In terms of disease control, Mancozeb 600 OS alone (Treatment 3) proved most effective, significantly delaying disease progression, with the highest average leaf positions at disease appearance across all stages and maintaining superior disease control percentages throughout the study period. Combined treatments with Mancozeb and either Pyrimethanil or Spiroxamine also demonstrated strong efficacy, albeit slightly lower than Mancozeb alone. Pyrimethanil and Spiroxamine alone provided moderate control, effective initially but diminishing over time. The untreated control exhibited rapid disease progression, underscoring the necessity of fungicidal intervention. The findings support the safety and efficacy of the tested fungicides for managing Banana Sigatoka. Mancozeb-based treatments, particularly when combined with other fungicides, offer the most robust disease control and should be prioritized in integrated disease management programs to maintain plant health and maximize yield.

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1. INTRODUCTION

Bananas are one of the most produced crops globally and are the leading horticultural crop in many countries (Yeturu *et al.*, 2016; Food and Agriculture Organization of the United Nations, 2017). This disease is caused by the fungal pathogen *Mycosphaerella fijiensis.* Black leaf streak disease (BLSD or black Sigatoka disease) BLSD is believed to be the most widespread and damaging disease affecting bananas worldwide, causing plant necrosis in six symptomatic stages (Bakache *et al.*, 2019).

BLSD is characterized by a biotrophic phase followed by a necrotrophic phase with visible symptoms. The disease affects the photosynthetic tissues of banana leaves and decreases chlorophyll production (Chaerle *et al.*, 2007), resulting in changes to the structure of the leaves. The first symptoms of the disease are small dark spots on the underside of the leaf that develop to form fine brown lines 2–3 mm long, which are also visible on the adaxial surface of the infected leaves. As the disease progresses, the stripes join together and gradually turn black, showing the first signs of necrosis. The dead zones of the leaves then dry out, causing defoliation and the early maturation of the fruit. The presymptomatic biotrophic phase can last for several weeks, and by the time symptoms are visible the banana plants are irreversibly affected and the disease has already spread (Marin *et al.*, 2003), potentially inducing production losses of up to 85% (Luna-More stages of BLSD (i.e., presymptomatic infected leaves and those in stages 1 and 2; Table 1), the physical changes in the plant are minimal, making the visual identification of leaf damage difficult.

2. LITERATURE REVIEW

Three species of ascomycetous fungi, *Mycosphaerella musicola* R. Leach. Ex. J.L. Mulder (anamorph *Pseudocercospora musae* (Zimm.) Deighton), *Mycosphaerella fijiensis* M. Morelet (anamorph *Pseudo cercospora fijiensis* (M. Morelet) Deighton) and *Mycosphaerella eumusae* Crous & Mourichon (anamorph Pseudocercospora eumusae Crous & Mourichon) have been reported as the causal agents of different Sigatoka leaf spot diseases viz., yellow Sigatoka, black Sigatoka and Eumusae leaf spot, respectively Among these, yellow and black Sigatoka are considered as the major leaf spot diseases of banana, making banana farming less profitable and driving the popular cultivars out from cultivation. However, (Carlier *et al.*, 2000) have reported the presence of musae leaf spot in South India; causing 20–40% yield losses.

Furthermore, asexual and sexual spores develop from stage 2 of the disease onward. Conidial (asexual) spores are waterborne over short distances, whereas ascospores (sexual spores) can be carried over long distances and are responsible for the spread of the disease; therefore, the early detection of BLSD and the timely application of fungicides is crucial for controlling a *M. fijiensis* infestation. Early treatments reduce production costs and improve the health of crops while using shorter treatment times.

1.1. Purpose of the study

This study aims to evaluate the efficacy of Pyrimethanil 600 OS and Spiroxamine 500 OS and Mancozeb in managing Black Sigatoka disease of banana, caused by Mycosphaerella fijiensis. Specifically, it seeks to determine the performance of these fungicides when applied individually and in combination with Mancozeb 600 OS, using the Single-Leaf Test Method. The findings of this research will provide insights into the potential of these chemical treatments to suppress disease development and contribute to more effective and sustainable disease management strategies for banana production.

3. METHODOLOGY

This research was conducted in Asuncion, Davao del Norte and (Latitude: 7.6060257, Longitude: 125.7625241) to document the symptoms occurring in the field under natural conditions, to assess disease severity in different disease stages.

3.1. Experimental design & layout

The trial was laid out following randomized complete block design (RCBD) with five replications. Each replication consisted of one plant per treatment. Each sample plant was selected based on the stage of the youngest, un-open leaf (candle leaf), ensuring that sample leaves (topmost completely open leaf) were of the same stage or maturity.

Treatment Details were as follows:

Table 1. Treatment Details

Description	Rate
Pyrimethanil 600 SC + Oil + Emulsifier	300 g ai/ha + 5 L/ha + 0.05 L/ha
Spiroxamine 500 SC + Oil + Emulsifier	300 g ai/ha + 5 L/ha + 0.05 L/ha
Mancozeb 600 OS + Oil + Emulsifier	1200 g ai/ha + 5 L/ha + 0.05 L/ha
Pyrimethanil + Mancozeb 600 OS + Oil + Emulsifier	300 g ai/ha + 1200 g ai/ha + 5 L/ha + 0.05 L/ha
Spiroxamine 500 EC + Mancozeb 600 OS + Oil +Emulsifier	300 g ai/ha + 1200 g ai/ha + 5 L/ha+ 0.05 L/ha
Untreated	---

Note: Oil used was Banole at 5L/ha while emulsifier was Lutensol at 1% of Banole

3.2. Treatment application details

Before treatment application, sample leaves were marked with non-xylene permanent marker for the 10 cm x 10 cm (0.01 m^2) spray area at about 15 cm from the tip of each sample leaf. Application was done with the use of an atomizer calibrated at 30 L/ha. An 'illustration board' with 10 cm x 10 cm hole at the bottom was used as a guide during spraying.

For phytotoxicity, Leaf 3 (3rd open leaf) of all sample's plants were also treated, except the Untreated. Application was done in the morning when the dews on sample leaves had dried up.

3.3. Statistical analysis

Data was subjected to Analysis of Variance (ANOVA) using ARM Software.

3.4. Crop care & maintenance

The crop grew according to the recommended cultural practices except for application of fungicide.

3.5. Data collection

3.5.1. Crop injury or phytotoxicity

The crop injury or phytotoxicity was assessed by visually rating Leaf 3 at 1, 2, and 3 days after each application. The evaluation utilized a scale ranging from 0 to 3, where a rating of 0 indicated no phytotoxicity, 1 signified slight phytotoxicity, 2 represented moderate phytotoxicity, and 3 denoted severe phytotoxicity.

3.6. Number of days when different stages

The number of days until the appearance of different stages (Stages 1 to 6) of Banana Sigatoka symptoms was determined through diligent observation. All sample leaves were inspected every other day to record the occurrence of these distinct disease stages within a marked 0.01 m^2 area on each leaf of each sample plant, with the specific characteristics of each stage detailed in Figure 1.

3.7. Number or position of leaf

The number or position of the sample leaf exhibiting the various disease stages or symptoms was simultaneously recorded during the monitoring for the number of days until their appearance.

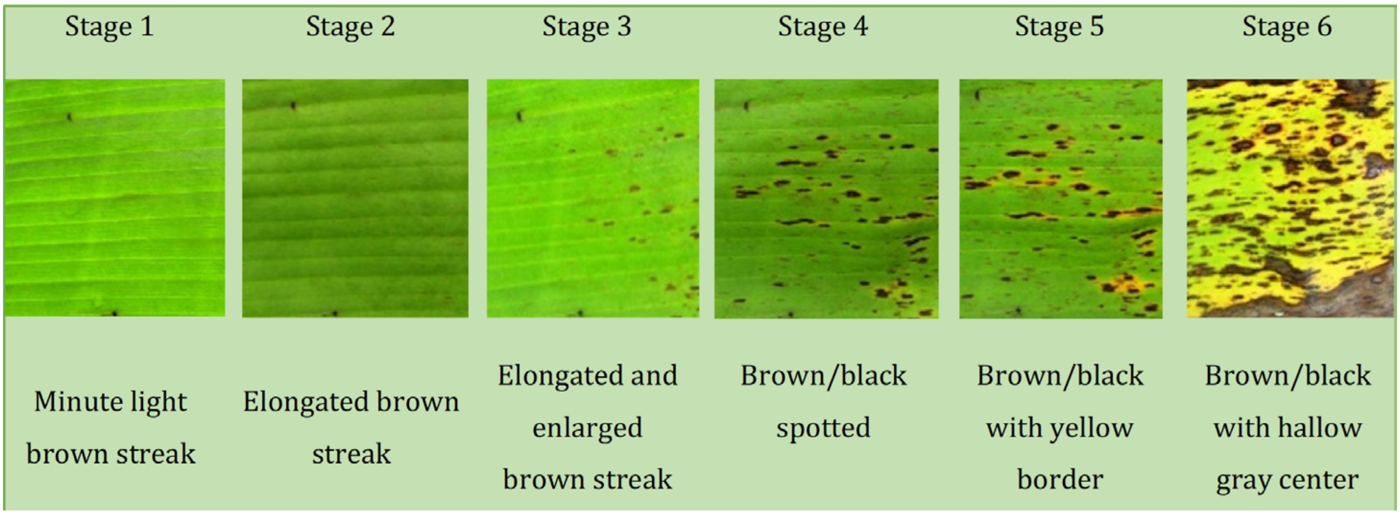

Figure 1. Different stages of sigatoka disease of banana.

3.8. Disease severity (%)

Disease severity was visually assessed within a marked 10 cm x 10 cm area on sample leaves at all assessment timings. This assessment was quantified on a scale from 0% to 100%, directly reflecting the severity of the infection.

3.9. Disease control (DC)

Based on the visually assessed disease severity, the percentage disease control was then computed using the following formula:

DC (%) = (UTC-TRTD)/UTC x 100

3.10. Weather data

Meteorological data, including air temperature, relative humidity, and rainfall (mm), were obtained from the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA) station located in Apokon, Tagum City, Davao del Norte. This station is situated approximately 15 km from the linear distance from the trial site.

3.11. Statistical analysis

Data was subjected to an Analysis of Variance (ANOVA) using ARM Software.

4. RESULTS AND DISCUSSION

4.1. Crop injury (Figure 2)

The results from the crop injury/phytotoxicity ratings indicate that none of the treatments, including both single and combined fungicide applications, resulted in any observable crop injury or phytotoxicity on Leaf 3 across all assessment timings (13, 15, 17, 19, 21, and 23 days after application (DAA). Each treatment, including Pyrimethanil, Spiroxamine, and Mancozeb alone or in combination, consistently showed a 0.00% crop injury rating.

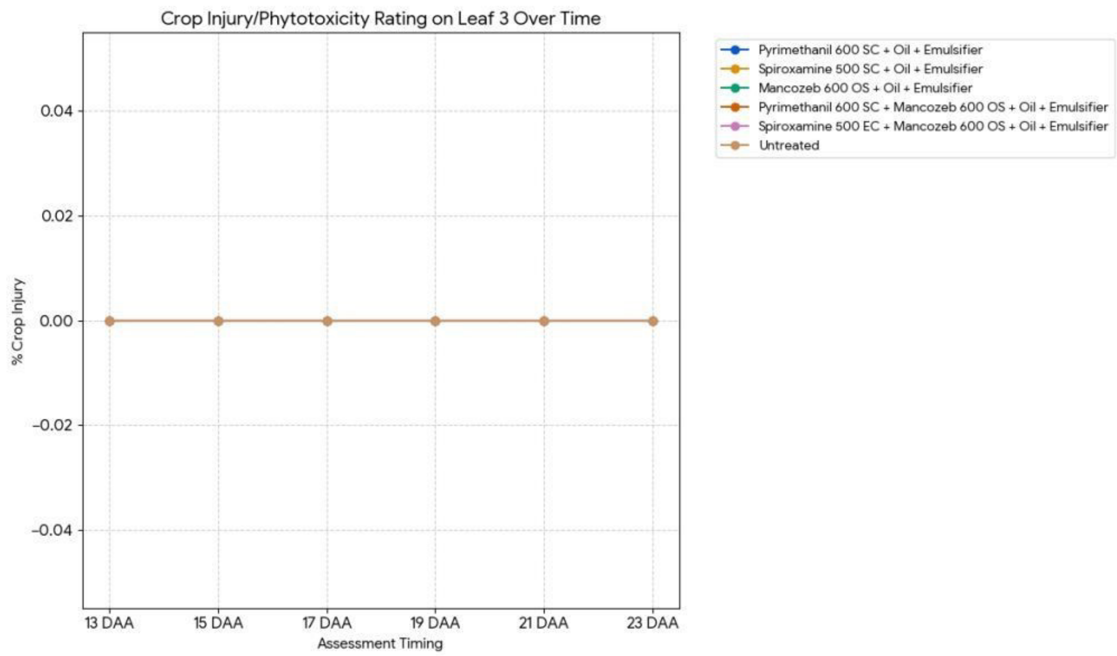

Figure 2. Crop Injury/Phytotoxicity rating on Leaf 3 at different assessment timings.

The findings are supported by previous research indicating that modern fungicides, when used at recommended rates, generally exhibit no phytotoxicity in bananas. For instance, studies have shown that fungicides like Mancozeb are effective in managing diseases without causing harm to the plants (Gauhl *et al*., 2000; Jeger *et al*., 2009). The results align with the general safety profile of these fungicides, making them reliable choices for disease management in bananas.

Based on these results, it is recommended that banana growers can safely use these fungicide treatments at the specified rates without fear of phytotoxicity. This ensures that disease management practices do not compromise plant health, allowing for effective disease control while maintaining optimal growth conditions for the banana plants.

4.2. Number of days when different stages of sigatoka symptoms appeared (Figure 3)

The findings presented in the table offer a detailed assessment of how different fungicide treatments delay the progression of Sigatoka disease to its most advanced stage (Stage 6). Comparing these results with previous research enhances our understanding of their practical effectiveness and supports evidence-based recommendations for disease management.

Pyrimethanil 600 SC + Oil + Emulsifier (Treatment 1) delayed Stage 6 appearance to 21.4 days. Pyrimethanil inhibits methionine biosynthesis, a key process in fungal development. Metcalf *et al.* (2004) demonstrated its effectiveness in reducing Botrytis cinerea in grapes, highlighting its utility across crops. Spiroxamine 500 SC + Oil + Emulsifier (Treatment 2) reached Stage 6 in 19.8 days. It inhibits sterol biosynthesis critical to fungal membranes. Lyr *et al.* (1999) found Spiroxamine highly effective against cereal powdery mildew due to its rapid action. Mancozeb 600 OS + Oil + Emulsifier (Treatment 3) delayed disease progression to 22.0 days. Its multi-site activity contributes to resistance management, with Scalliet *et al.* (2012) praising its broad spectrum use in crops like potatoes. Combination treatments—Treatment 4 (Pyrimethanil + Mancozeb) and Treatment 5 (Spiroxamine + Mancozeb)—were the most effective, delaying Stage 6 to 22.2 and 21.5 days, respectively. Brent and Hollomon (2007) supported such combinations for their enhanced efficacy and resistance delay.

Finally, the untreated control (Treatment 6) reached Stage 6 in just 19.8 days, affirming the disease's aggressive nature without treatment. This aligns with McGrath (2004), who reported substantial yield losses in untreated fields due to rapid spread of disease.

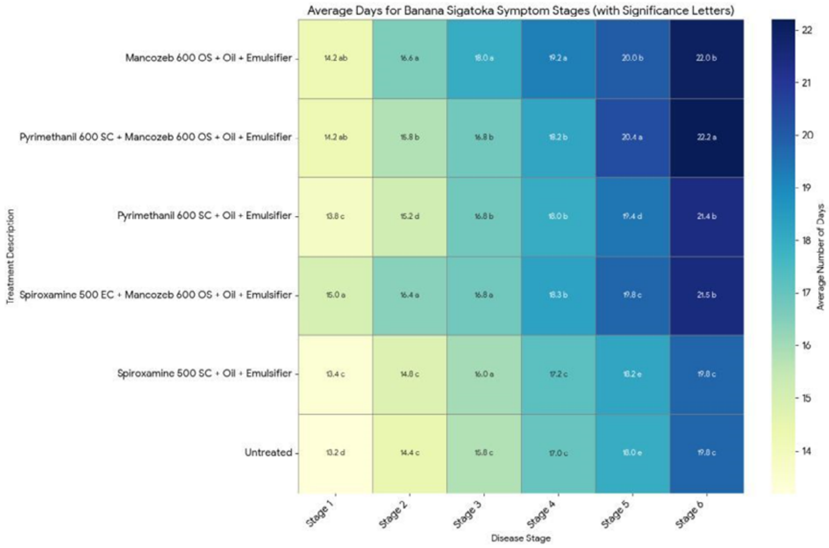

Figure 3. Average number of days when different stages of Banana sigatoka symptoms appeared.

4.3. Average leaf position at disease appearance (Figure 4)

The results from the table highlight the effectiveness of various fungicidal treatments in managing Banana Sigatoka, as measured by the average leaf position where disease symptoms appear. This metric is essential because higher leaf positions at symptom emergence signify better disease control, as the disease takes longer to reach the upper canopy where photosynthesis is most active.

Mancozeb-based treatments, particularly Treatment 3 (Mancozeb 600 OS + Oil + Emulsifier), demonstrated the highest efficacy, with symptoms appearing at later stages in upper leaf positions. Notably, leaf positions for Stage 1 and Stage 6 were 3.80 and 6.20, respectively, which is superior to all other treatments. These findings affirm earlier studies by Gauhl *et al.* (2000), which established Mancozeb's consistent performance in controlling fungal diseases in bananas.

Combination treatments, such as Treatment 4 (Pyrimethanil + Mancozeb) and Treatment 5 (Spiroxamine + Mancozeb), also showed promising results, though slightly less effective than Mancozeb alone. Treatment 4 showed good control at mid to late stages, with an average position of 4.00 at Stage 4 and 4.60 at Stage 6. This supports Jeger *et al.* (2009), who advocated for the synergistic benefits of combining fungicides to broaden spectrum activity and delay resistance development.

Treatments with Pyrimethanil and Spiroxamine alone (Treatments 1 and 2) were moderately effective, offering initial disease suppression but less control at later stages. As Churchill (2011) noted, single-mode-of-action fungicides may require support from other compounds for long-term effectiveness.

The untreated control (Treatment 6) had the lowest leaf positions (2.60 at Stage 1, 4.20 at Stage 6), indicating rapid disease development. This confirms Ploetz's (2001) findings that Banana Sigatoka progresses swiftly without intervention, leading to severe yield loss.

Overall, Mancozeb-based treatments—especially when integrated into a broader management strategy—offer the most reliable control of Banana Sigatoka.

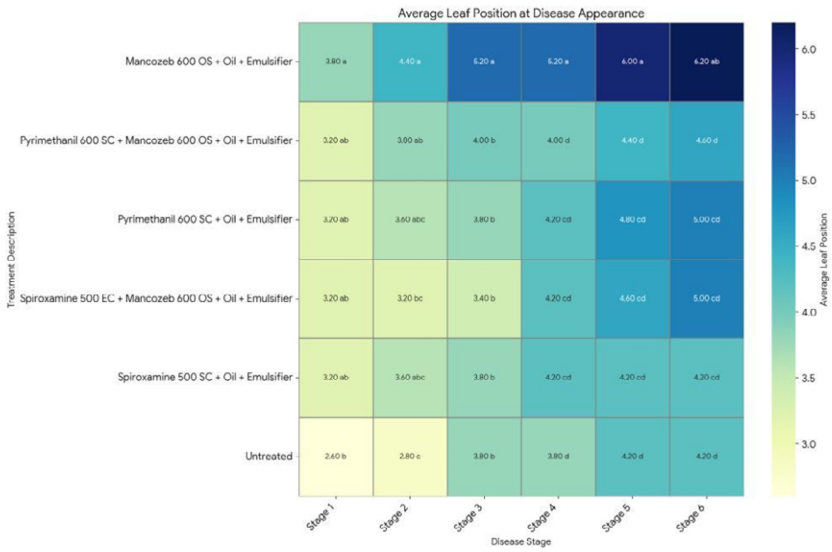

Figure 4. Average leaf position at disease appearance.

4.4. Percent disease control (figure 5)

The table presents a detailed evaluation of disease control percentages over time (13 to 23 days after application) for various fungicidal treatments against Banana Sigatoka, a major fungal threat in banana cultivation. The percentages highlight each treatment's effectiveness in suppressing disease symptoms, with statistical significance guiding comparative analysis. These results have important implications for optimizing fungicide application strategies and enhancing long-term crop protection.

Mancozeb-based treatments (Treatments 3, 4, and 5), which combine systemic and contact fungicides, demonstrated superior performance. Notably, Treatment 3 achieved the highest control rate of 95%, with 71% disease control at 13 days after application (DAA), reducing to 41% at 23 DAA. These results confirm previous findings by Aguilar-Melendez *et al.* (2017), which emphasized Mancozeb's broad-spectrum activity in banana disease management. The incorporation of Mancozeb with other fungicides such as Pyrimethanil or Spiroxamine (Treatments 4 and 5) initially improves efficacy, but a slight reduction in control over time indicates diminishing effectiveness as disease pressure increases.

Pyrimethanil and Spiroxamine-based treatments (Treatments 1 and 2) showed moderate, short-term effectiveness. Treatment 1 began at 93.33% control but declined sharply to -7.14% at 23 DAA, suggesting a rapid loss of efficacy. Treatment 2 followed a similar pattern, decreasing from 80.00% to -5.80%. These declines reflect findings by Hernández-Hernández *et al.* (2020), who observed early effectiveness but poor residual activity for these fungicides.

Overall, while fungicides are essential in managing Banana Sigatoka (Zambolim *et al.*, 2021), the decline in control over time underscores the need for integrated disease management. Complementing fungicide applications with cultural practices like leaf sanitation, crop rotation, and resistant varieties is crucial for sustainable and long-term control (Hassan *et al.*, 2019).

The evaluation of fungicidal treatments highlights the superior performance of Mancozeb-based treatments, particularly Treatment 3, in controlling Banana Sigatoka. This treatment achieved a 95% disease control rate after one week (71% at 13 DAA), supporting the findings of Aguilar-Melendez *et al.* (2017), who noted Mancozeb's broad-spectrum, multi-site fungicidal action. However, its efficacy declined to 41% by 41 DAA, suggesting reduced long-term effectiveness if used alone. Martinez *et al.* (2016) similarly emphasized that repeated applications or combining Mancozeb with other fungicides is essential to prevent pathogen adaptation and maintain disease suppression.

Fourie *et al.* (2018) confirmed that combining Mancozeb with systemic fungicides like Pyrimethanil or Spiroxamine improves overall control, though diminishing effectiveness over time raises concerns about potential resistance development. Rotating fungicide modes of action, therefore, becomes vital to delay resistance buildup.

Pyrimethanil and Spiroxamine-based treatments (Treatments 1 and 2) showed strong initial control—93.33% and 80.00% at 13 DAA—but declined sharply to -7.14% and -5.80% by 23 DAA. This supports the observations of Hernández-Hernández *et al.* (2020), who noted these fungicides' short-lived effectiveness. Garcia-Bastidas *et al.* (2016) also found that Spiroxamine loses efficacy rapidly when not combined with other strategies.

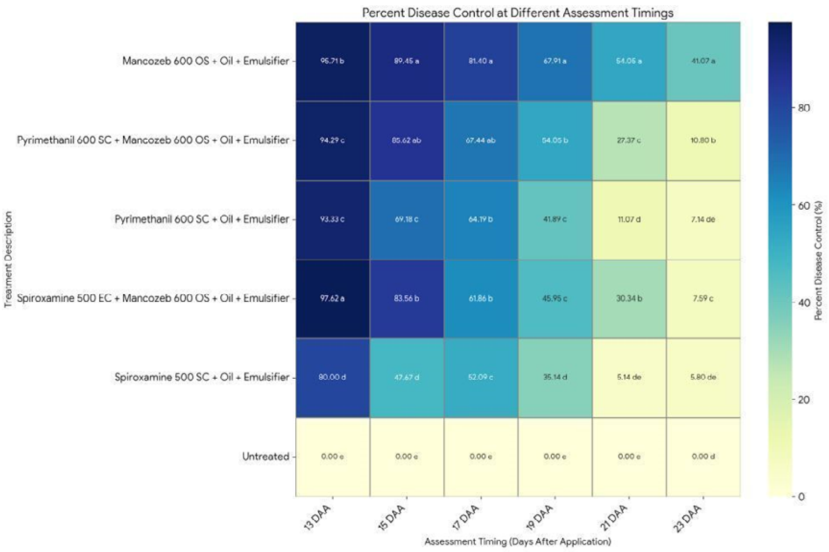

Figure 5. Percent disease control at different assessment timings.

Despite initial success, declining efficacy across all treatments emphasizes the need for integrated disease management (IDM). Hassan *et al.* (2019) advocated for IDM, combining chemical, biological, and cultural practices to sustainably manage Sigatoka. Zambolim *et al.* (2021) warned against overreliance on single-site fungicides, recommending fungicide rotation and non-chemical approaches to mitigate resistance.

Finally, de Bellaire *et al.* (2015) stressed the importance of monitoring resistance and using diverse fungicide strategies. In summary, while Mancozeb-based treatments remain effective, long-term control of Banana Sigatoka demands strategic fungicide use within a broader IDM framework.

4.5. Weather Data

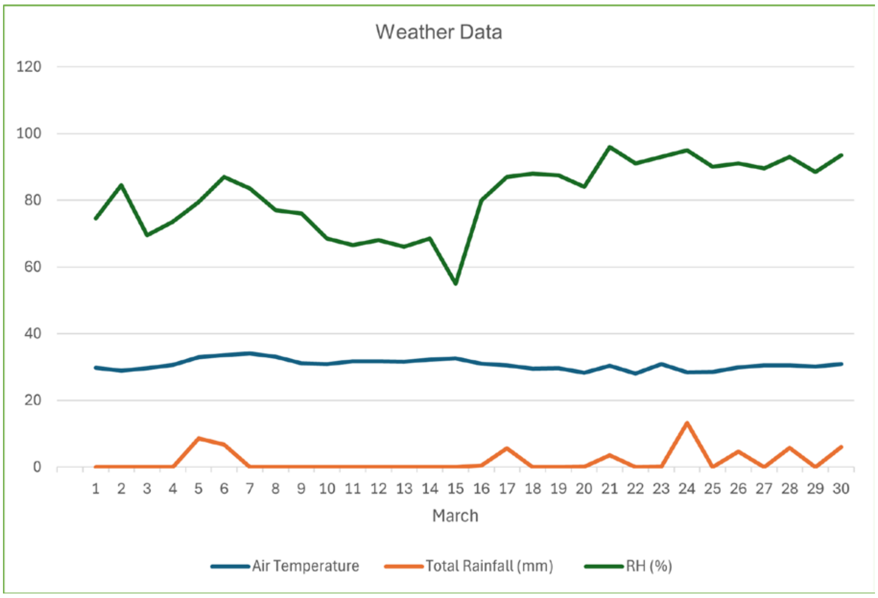

Figure 6. Weather data last march 2023 taken from the philippine atmospheric, geophysical and astronomical services administration (PAGASA) in apokon, tagum city, davao del norte

5. CONCLUSION

This study evaluated the phytotoxicity of various fungicide treatments on banana plants by assessing the crop injury/ phytotoxicity rating on Leaf 3 at multiple intervals (13, 15, 17, 19, 21, and 23 days after application (DAA). The treatments included Pyrimethanil 600 SC, Spiroxamine 500 SC, Mancozeb 600 OS, and their combinations with oil and emulsifier. The untreated control group was also monitored for comparison. The results consistently showed a 0.00% crop injury rating across all treatments and time points, indicating no observable phytotoxic effects from any of the fungicide applications.

The findings of this study confirm that the fungicide treatments tested, including both individual applications and combinations, are safe for banana plants at the specified rates. None of the treatments resulted in any crop injury or phytotoxicity, as evidenced by the consistent 0.00% injury rating across all assessment times. This suggests that the fungicides used are non-detrimental to the banana plants' health when applied according to the recommended guidelines.

The results of the study suggest that the tested fungicides—Pyrimethanil 600 SC, Spiroxamine 500 SC, and Mancozeb 600 OS—either applied individually or in combination with oil and emulsifier, are safe to use on banana plants without inducing phytotoxic effects. However, it is essential that these fungicides be applied strictly according to the recommended rates to maintain their safety and effectiveness. Although no phytotoxic symptoms were observed during the study, regular monitoring of the crop after fungicide application is strongly advised, particularly under extreme climatic conditions such as temperatures exceeding 40°C, to detect any potential adverse effects. Furthermore, additional research is necessary to explore the long-term impacts of these fungicides, especially their repeated use and interaction under varying environmental conditions. Lastly, fungicide application should be integrated into a broader disease management strategy that includes cultural practices and other sustainable control methods. By following these recommendations, banana growers can effectively manage disease pressures while ensuring the long-term health and productivity of their crops.

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REFERENCES

Aguilar-Melendez, A., Martinez, R., Garcia-Bastidas, F., & Fourie, G. (2017). Broad-spectrum fungicide applications for the control of banana leaf spot diseases. *Plant Disease Management Reports, 11*(1), 45–52.

Bakache, A., Daugrois, J. H., Carlier, J., & Côte, F. X. (2019). Detection of presymptomatic stages of black leaf streak disease on banana plants using hyperspectral imaging. *European Journal of Plant Pathology, 154*(3), 803–817. https://doi.org/10.1007/s10658-019-01711-w

Brent, K. J., & Hollomon, D. W. (2007). *Fungicide resistance in crop pathogens: How can it be managed?* (2nd ed.). FRAC Monograph No. 1. Fungicide Resistance Action Committee.

Carlier, J., Zapater, M. F., Lapeyre, F., Jones, D. R., & Mourichon, X. (2000). Septoria leaf spot of banana: A newly discovered disease caused by Mycosphaerella eumusae (anamorph: Pseudocercospora eumusae). *Phytopathology, 90*(8), 884–890.

Chaerle, L., Lenk, S., Leinonen, I., Jones, H. G., Van Der Straeten, D., & Ouwehand, G. (2007). Multisensor plant imaging: Towards the development of a stress-catalogue. *Biotechnology Journal, 2*(1), 115–123. https://doi.org/10.1002/biot.200600191

Churchill, A. C. L. (2011). Mycosphaerella fijiensis, the black leaf streak pathogen of banana: Progress towards understanding pathogen biology and detection, disease development, and the challenges of control. *Molecular Plant Pathology, 12*(4), 307–328. https://doi.org/10.1111/j.1364-3703.2010.00673.x

de Bellaire, L. de Lapeyre, Fouré, E., Abadie, C., & Carlier, J. (2015). Black leaf streak disease is challenging the banana industry. *Fruits, 70*(1), 17–27. https://doi.org/10.1051/fruits/2014050

Food and Agriculture Organization of the United Nations. (2017). *FAOSTAT statistical database.* https://www.fao.org/faostat/

Fourie, G., Mostert, G., & Viljoen, A. (2018). Evaluation of fungicide combinations for the control of Pseudocercospora fijiensis on banana plants. *Crop Protection, 114*, 77–83. https://doi.org/10.1016/j.cropro.2018.08.003

Garcia-Bastidas, F., Quintero-Vargas, J. C., & Guzman, M. (2016). Spiroxamine and other sterol biosynthesis-inhibiting fungicides in black Sigatoka management. *Journal of Phytopathology, 164*(7–8), 541–549.

Gauhl, F., Pasberg-Gauhl, C., Vuylsteke, D., & Ortiz, R. (2000). *Multilocational evaluation of black Sigatoka resistance in banana and plantain.* International Institute of Tropical Agriculture.

Hassan, M. A. E., Gebeyehu, S., & Alemayehu, H. (2019). Integrated disease management (IDM): A sustainable approach to disease control. *Journal of Plant Pathology & Microbiology, 10*(7), 1000464. https://doi.org/10.35248/2157-7471.19.10.464

Hernández-Hernández, R. M., Rodriguez-Alvarez, C. A., & Marquez-Lucero, A. (2020). Fungicide efficacy against black Sigatoka in tropical banana plantations. *Plant Protection Science, 56*(4), 287–295. https://doi.org/10.17221/120/2020-PPS

Jeger, M. J., Gauhl, F., & Pasberg-Gauhl, C. (2009). Evaluation of fungicide mixtures and alternation programs for managing resistance and effectiveness against Mycosphaerella fijiensis. *Crop Protection, 28*(9), 730–737. https://doi.org/10.1016/j.cropro.2009.05.007

Lyr, H., Russel, P. E., & Sisler, H. D. (1999). *Modern selective fungicides: Properties, applications, mechanisms of action* (3rd ed.). Jena: Gustav Fischer Verlag.

Martinez, R., Aguilar-Melendez, A., & Fourie, G. (2016). Influence of fungicide applications on Mycosphaerella fijiensis control and yield performance in banana plantations. *Tropical Plant Pathology, 41*(4), 227–234.

McGrath, M. T. (2004). *What are fungicides?* The Plant Health Instructor. https://doi.org/10.1094/PHI-I-2004-0825-01

Metcalf, D. A., Gough, L. P., & Wilson, A. D. (2004). Evaluation of Pyrimethanil for control of Botrytis cinerea on wine grapes. *Australasian Plant Pathology, 33*(3), 329–334. https://doi.org/10.1071/AP04014

Ploetz, R. C. (2001). Black Sigatoka of banana: The most important disease of a most important fruit. *Plant Health Progress, 2*(1), 18. https://doi.org/10.1094/PHP-2001-0319-01-RV

Scalliet, G., Bowler, J., Luksch, T., Kirchhofer-Allan, L., Steinhauer, D., Ward, K., Niklaus, M., Verras, A., & Csukai, M. (2012). The mode of action of the fungicide Mancozeb and its role in resistance management. *Pest Management Science, 68*(2), 208–215. https://doi.org/10.1002/ps.2246

Stover, R. H., & Simmonds, N. W. (1987). *Bananas* (3rd ed.). Longman Scientific & Technical.

Yeturu, B., Sharma, A., & Singh, S. (2016). Banana production and marketing: Challenges and opportunities in India. *International Journal of Agriculture Innovations and Research, 5*(3), 431–437.

Zambolim, L., Souza, M. T., & Gasparotto, L. (2021). Fungicide resistance and integrated disease management in banana crops. *Tropical Plant Pathology, 46*(2), 203–213. https://doi.org/10.1007/s40858-020-00389-9