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Evaluation of the severity of Black Sigatoka (*Mycosphaerella fijiensis* Morelet) in plantain 'Barraganete' under magnesium fertilization

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Abstract

Black Sigatoka (BS) is a foliar disease that represents the main limiting factor in plantain production worldwide. Therefore, the research aimed to evaluate the severity of Black Sigatoka (*Mycosphaerella fijiensis* Morelet) in 'Barraganete' plantain under magnesium fertilization, in El Carmen, Ecuador. A completely random block design with three repetitions was used; with 288 seeded plants with adensity of 2,222 plants/ha. Basic fertilization of N-P-K (100-40-150 Kg/ha) was conducted with six doses of MgO (0, 25, 50, 75, 100, and 125 Kg/ha), segmented into three parts (12, 18 and 24 leaves). Every week, leaf 3, 4, and 5 were examined with the Fouré scale, these data were analyzed by using the methodology of repeated measures over time. To assess the incidence of BS weekly, leaf 3, 4, and 5 were inspected with the Fouré scale, along with leaf removal and surgery. Ten plants per fertilization treatment were evaluated, and six fungicide applications were performed with contact and systemic products. The highest severity of BS was shown for all the treatments in week 20, on leaf 3, reaching levels higher than severe in treatments of 75 and 125 Kg/ha of MgO. The equations of the polynomial models determined that with the dose of 25 Kg/ha of MgO the lowest severity of BS was observed. Knowing the environmental conditions and supervision allow for better agronomic management.

Keywords: *Musa* sp.; *Mycosphaerella fijiensis*; plantain 'Barraganete'; crop management; fertilization.

Evaluación de la severidad de Sigatoka negra (*Mycosphaerella fijiensis* Morelet) en plátano "Barraganete" bajo fertilización con magnesio

Resumen

Sigatoka negra (SN) es la enfermedad foliar que representa la principal limitante en la producción de plátano a nivel mundial. Por lo que, la presente investigación tuvo como objetivo evaluar la severidad de Sigatoka negra (*Mycosphaerella fijiensis* Morelet) en plátano "Barraganete" bajo fertilización con magnesio, en El Carmen, Ecuador. Se utilizó un diseño de bloques completamente al azar con tres repeticiones; con 288 plantas sembradas a una densidad de 2.222 plantas/ha. Se realizó una fertilización básica de N-P-K (100-40-150 Kg/ha), con seis dosis de MgO (0, 25, 50, 75, 100 y 125 Kg/ha), fraccionada en tres partes (12, 18 y 24 hojas). Semanalmente se inspeccionaron las hojas 3, 4 y 5 con la escala de Fouré, analizando estos datos mediante la metodología de medidas repetidas en el tiempo. Para evaluar la incidencia de SN semanalmente se inspeccionaron las hojas 3, 4 y 5 con la escala de Fouré, junto con deshoje y cirugía. Se evaluaron 10 plantas por tratamiento de fertilización, se realizaron seis aplicaciones de fungicidas con productos de contacto y sistémicos. Durante la semana 20 en la hoja 3 se presentó la mayor severidad de SN, inclusive fue superior al nivel severo en los tratamientos de 75 y 125 Kg/ha de MgO. Las ecuaciones de los modelos polinómicos determinaron que con la dosis de 25 Kg/ha de MgO, se obtuvo la menor severidad de SN. Conocer las condiciones ambientales y supervisión permite realizar un mejor manejo agronómico.

Palabras clave: *Musa* sp.; *Mycosphaerella fijiensis*; plátano "Barraganete"; manejo del cultivo; fertilización.

Introduction

Tropical fruit crops include plantains and bananas, not only because of the volumes produced but also in terms of meeting the caloric needs of millions of people, especially in Africa, Asia and America; in addition to the fruits, it is known that any other part of the plant has commercial or medicinal value [1].

The Black Sigatoka (BS, *Mycosphaerella fijiensis* Morelet), is one of the pathogens with the greater economic, social, and environmental impact on the history of agriculture, and particularly on the world plantain production [2]. It is the main foliar disease in economic terms of plantain production in the world [3] because it can reduce yields by 50% [4], [5]. Disease management costs in commercial plantations range from 27% of total production costs [6].

The main effect of the disease is the extension of the flowering to harvest period and the acceleration of the ripening process of the fruit in the plant. After harvest, under poor control conditions, the largest losses related to the disease are the elimination of clusters in the field from plants with a low number of leaves (less than 4 healthy leaves), due to the risk of premature ripening of the fruit; therefore, a minimum of eight functional leaves should be maintained at the time of flowering, indicating the importance of agronomic management to reach flowering, with at least eight leaves with a low severity degree of Black Sigatoka [7], [8].

Magnesium (Mg) is the second most abundant cation in plants, is involved in various physiological and biochemical processes (photosynthesis, enzymatic activation, and synthesis of nucleic acids and proteins). Its deficiency not only affects crops productivity and quality, but also behaves in the soil as a K and Ca antagonistic element [9, 10].

Excessive application of fertilizers such as K and NH_4^+ antagonistically interferes with the uptake of Mg in the plant, which increases the risk of Mg deficiency [10]. Long-term Mg deficiency causes excessive starch accumulation and chlorosis in several plant species. Further reducing the rate of photosynthesis; therefore, plant growth is affected [11].

Magnesium acts significantly in the growth and development of plants, as it involves 1) the structure of chlorophyll and chloroplasts stabilization , by accepting and retransferring luminous energy, promoting photosynthesis, and metabolic carbon fixation; 2) the sugar load in the phloem, as well as other nutrients, and their transport; 3) regulates the cation-anion equilibrium, and turgor along with K in the vacuole, and 4) maintains stability and macromolecules synthesis. The imbalance of Mg homeostasis in cells affects these processes [12].

Currently, agronomic practices are carried out, aiming to a decrease in the number of applications of agrochemicals (surgery, leaf removal, fertilization, management of the waste removed from the plant, among others). Due to the aforementioned, the severity of Black Sigatoka (*Mycosphaerella fijiensis* Morelet) in 'Barraganete' plantain under magnesium fertilization was evaluated.

Experimental

The research was conducted at the Río Suma Experimental Farm, Universidad Laica 'Eloy Alfaro de Manabí', Extension in El Carmen, located in the Province of Manabí, Canton El Carmen, Ecuador. Coordinates DMS 0°15'34.2" S, 79°25'39.2" W, humid tropical type climate, altitude 263 masl, average temperature 24.15 °C. An average rainfall of 2,806 mm/year, 86% relative humidity, heliophane of 1,026 daylight hours/year and evaporation of 1,064 mm/year [13]. Soil analysis showed low levels of NH_4^+ (11.61 ppm), P (4.56 ppm) and Mg (0.90 meq/100 g), and high levels of K (0.50 meq/100 g). With sandy loam texture (62% sand, 28% silt and 10% clay) [14].

A 'Barraganete' plantain (*Musa* sp. AAB) second-cycle field was evaluated, with a planting distance of 2.5 m between rows, and 1.8 m between plants (4.5 m^2), for a total of 2,222 plants·ha^{-1} (high density). The total number of plants was 288 distributed in three blocks. Fractionated fertilizer applications were made in three parts (N-P-K and MgO). The fractionation of P was considered because increase in fertilization efficiency, as pointed out by Avellán-Vásquez [14]. And since it is an element with little soil mobility, the absorption at the roots will occur at the close to them. When added to the soil it is soluble and available, although it is quickly fixed and no longer usable for the plant. This low mobility causes it to remain in the upper layer of the soil, being lost mainly through surface runoff and erosion.

The treatments were arranged in a completely random blocks experimental design, with three repetitions. The variation in severity during the study period was analyzed with the Statistical Analysis System package (SAS v.9.1.3, 2020) [15], using the methodology of repeated measurements over time through the mixed linear model procedure (MIXED), to study the longitudinal behavior of the six MgO treatments, selecting fourth-degree polynomial models that best explained the behavior of this variable over time. Environmental temperature (measured with a digital thermometer), relative humidity (digital hygrometer), and the temperature of the evaluated leaves (measured with an infrared thermometer) were weekly quantified during the evaluations, to observe the influence of these climatic variables over the disease severity level.

Fertilization consisted in the application for all plants of a standard dose of 100, 40 and 150 kg/ha ºf N, P_2O_5 and K_2O respectibily, complemented with fertilization treatments with MgO at six levels (0, 25, 50, 75, 100 and 125 kg/ha of MgO), divided into three equal parts and applied to the soil when the plants issued leaves 12, 18 and 24. Commercial fertilizers used were urea (46% N), diammonium phosphate (DAP; 18% N and 46% P_2O_5), Potassium Chloride (commonly referred to as Muriate of Potash or MOP) (60% K_2O) and magnesium oxide (30% MgO).

Field supervision, surgery, and leaf removal wereweekly done; in addition to using the Fouré scale [16] modified, to establish the severity of the disease, the symptoms of BS were recognized across seven stages (figure 1). Degrees of infection: 1A. Pinch. Small depigmented yellowish-white to brown spot (dot), visible only on the lower surface of leaves (less than five pinches); 1B. Pinch. Small depigmented spot (dot) visible only on the lower surface of leaves (greater than five pinches); 2C. Stria. Long, widened dark brown to almost black stripe visible on the upper surface of leaves; 3C. Stain. Elliptical, dark brown on the lower surface and black on the upper surface of leaves; 4C. Burn up. Black spot on the upper and lower surfaces of leaves, the center is depressed and surrounded by a yellowish halo; 5C. 1/3 of the burned leaf blade. Similar to the previous one, occupying one-third of the leaf surface; and 6C. More than 50% of the leaf blade burned. The center of the stain dries and necrotizes, becoming greyish [16].

To evaluate the degree of severity of the disease in growing plants (evolutionary status), under fertilization treatment, a sample of 10 plants was taken at random, in which leaves 3, 4 and 5 were placed from top to bottom, even and odd (figure 2), and some of the symptoms according to the Fouré scale [16] were determined (figure 1). Later on, the mathematical calculation of de infestation degree in this type of plant was carried out,which allowed their classification as mild, high, or severe.

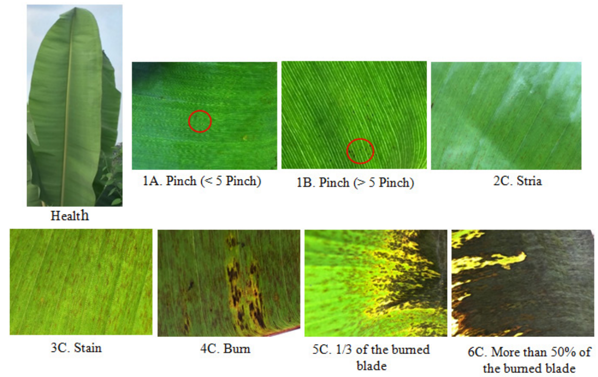

Figure 1. Infestation degree or disease progression status caused by Black Sigatoka (*Mycosphaerella fijiensis* Morelet), 'Barraganete' plantain, cultivated at the Río Suma Experimental Farm, Universidad Laica "Eloy Alfaro de Manabí", Extension in El Carmen Ecuador.

The values of leaves 3, 4 and 5 were added for each one according to the infestation degree (1A, 1B, 2C, 3C, 4C, 5C, and 6C), obtained from the weekly crop inspection and the value was averaged for each leaf number (ALN) (n=10), the letters are equal to the values of A=1, B=2, and C=3, these were added and divided by 10 to obtain their average (ALL).

Subsequently, ALN x ALL was multiplied from leaves 3, 4, and 5. The result of the previous multiplication was multiplied once more by a constant, which varied according to the number of the leaf, for leaf 3= 120, for leaf 4= 100 and leaf 5= 80. The constants were obtained from the arbitrary severity coefficients according to the infection density in leaves 3, 4 and 5, as described by Orozco-Santos *et al*. (17).

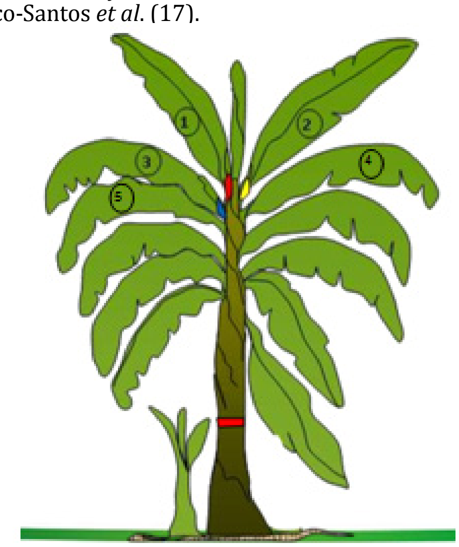

Figure 2. Diagram of position and marking of leaves 1 to 5, of a plant in an evolutionary state, for incidence or severity level evaluation of Black Sigatoka (*Mycosphaerella fijiensis* Morelet). Modified from Calle y Yangali [18].

The final result indicated the severity level of BS, considering the following levels, when on leaf 3 the values were <300, received the category of mild; on leaf 4 when they reached values > 300 up to 500 received the category of high and when on leaf 5 they reached values > 500 the received category is severe.

Six fungicide applications were made with contact and systemic products, the active ingredients of the applied products were mancozeb (100 g) + tebuconazole + triadimenol (20 mL) + a mixture of alkylaryl and polyglycol 12.5% (two applications, eight day interval); difenoconazole (20 mL) + propineb (100 g) + a mixture of alkylaryl and polyglycol 12.5% (two applications, 15 days interval) and carbendazim (20 mL) + mancozeb (100 g) + a mixture of alkylaryl and polyglycol12.5% (two applications, 15 days interval).

Results and discussion

The implementation of efficient management programs requires three types of basic information: 1) climate: particularly amount and frequency of rain and duration of moisture on the leaves, this allows to assess the future epidemiological evolution of the disease [19], [20]; 2) biological: speed or rate of leaves emission, presence of necrotic symptoms and spots in younger leaves; severe level of BS in blossoms within 7 to 9 weeks after sprout of bunches [8] and speed of disease evolution [6] and; 3) sensitivity of populations to the main fungicides used [21].

Given these requirements, environmental variables were quantified at the beginning and end of the assessments period of field inspections, to know the environmental conditions at the time of the sampling. The average relative humidity was 85.6% and 85.4%, respectively. The average ambient temperature was 24.62 and 25.32°C, respectively. The temperature was 23.98 °C for leaf 3;23.88 °C for leaf 4, and 23.84 °C for leaf 5. The thermal difference between leaf 3 and leaf 4 was 0.1 °C; between leaf 3 and leaf 5 was 0.14 °C and between leaf 4 and leaf 5 was 0.04 °C.

The average rainfall for the period evaluated was 40.14 mm/week and 160.55 mm/month, with a minimum rainfall of 0.00 mm and a maximum of 279.10 mm; however, during the evaluation period (four months) the total rainfall was 642.2 mm. Having all these environmental factors relative importance in the incidence, severity, and dissemination of BS.

Álvarez *et al.* [22] noted that heavy and frequent rainfall, as well as temperatures around 26 to 28 °C had a marked effect on the processes of infection, germination, penetration of the pathogen and release of the inoculum, while Calle and Yangali [18] indicated that the wind favored dissemination. Likewise humans are part of the pathosystem when making decisions about the use of a certain cultivar, production system, host management and BS control methods, among others [18].

Calle and Yangali [18] reported that the fungus develops under the conditions of high humidity and temperature that occur in Ecuador during the rainy season (December-May) and the reproductive structures of the fungus are activated at 21 °C, for which the presence of some moisture and/or film of water on the leaf is required. In turn, the maturation of the reproductive structures causes the detachment of ascospores and conidia that spread the disease, then the spores can be carried by winds or spread to the neighboring leaves, settling on the new foliar tissue, to start a new period of infection.

Number of leaves

The number of leaves per plant according to the fertilization treatments did not show a particular trend, their behavior was very variable during the evaluation time; however, the treatments of 75 and 100 kg/ha of MgO were those that maintained a tendency to increase the number of leaves per plant from the 25 th week of onward, as can be seen in figure 3. For week 29, T5 (100 kg/ha) shown an average of 7.36 leaves/plant. In this sense, the number of leaves present in a plant at the time of the bloom and development of the bunch is important to guarantee the productivity and quality of the fruits.

It is also noted that in treatments of 25, 50, and 75 kg/ha of MgO in weeks 21 and 22 the greatest number of leaves was recorded on average 7.17 leaves/plant and in week 29 was 7.11 leaves/plant. On the other hand, in week 16 all treatments had the least number of leaves. Later on, in week 24 the treatments of 0, 25 and 50 kg/ha of MgO showed a decrease in the number of leaves (5.73 leaves/plant on average); perhaps the decrease in the number of leaves in those two weeks was the result of having performed leaf removal and severe surgery as a result of the heavy rainfall that occurred in week 15 and the high severity of the disease in leaves 4 and 5 in week 24.

On the other hand, there were statistical differences (P<0.01) for the samples carried out in weeks 21, 22, and 29. In weeks 21 and 22 there were differences between treatments 50 (with 7.31 leaves/plant), 25, and 75 kg/ha of MgO when compared with treatments 125, 100 and 0 kg/ha of MgO (with 6.08 leaves/plant). Similarly, in week 29, differences were found between treatments of 25 (with 7.42 leaves/plant), 50, 100, and 125 kg/ha of MgO when compared with treatments of 75 and 0 kg/ha of MgO (with 6.08 leaves/plant).

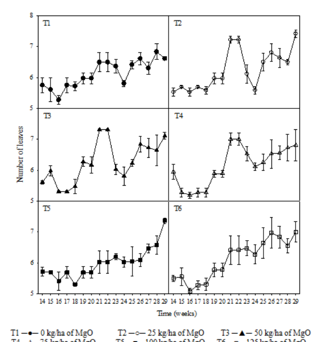

Figure 3. Number of leaves in plants of 'Barraganete' plantain, fertilized with different MgO doses, grown at the Río Suma Experimental Farm, Universidad Laica "Eloy Alfaro de Manabí", Extension in El Carmen, Ecuador.

In Urabá, Colombia, during the vegetative phase, the plant sprout between 35 and 36 leaves, with a frequency of one leaf/week in the rainy season and between 0.4 and 0.6 leaf/week in drought conditions [23]. This leaf production rate allowed the plant to replace leaves that have completed their cycle or that have been affected by diseases such as BS or mechanical damage. Overall, according to Turner *et al.* [24] the plant generated 30 to 50 or more leaves in the growing cycle but at the same time only kept 10 to 14 photosynthetically active leaves, thus ensuring high yields.

In plantain of the type False Horn cv. 'Dominíco Hartón', cultivated between 1,300 and 1,600 masl, the floral transition took place around five or six months after the beginning of the leaf production process with the emission of 50% of the total leaves, around the 19 leaves in number [25].

Aristizábal and Jaramillo [25] indicated that for the same cultivar planted at 1,050 masl, this stage occurred when the plant had sprouted 27 leaves. Meanwhile, Hernández *et al.* [26] in Venezuela, placed the floral transition in plantains (cv. 'Hartón Enano') of the same type (False Horn) on leaf 25 (33% of plants), on leaf 27 (60% of plants) and leaf 30 (80-100% of plants).

Severity level of the disease

Figure 4 shows the evolution of BS during the evaluation time, whose behavior followed a fourth-degree polynomial model (Y= a + bx + cx2 + dx3 + ex4). It shows that in weeks 14 and 15 the heaviest rainfall occurred (168.9 and 279.1 mm, respectively), coinciding with high levels of incidence (100% during the entire evaluation period) and severity for the six MgO fertilization treatments. However, the treatments of 50, 75 and 125 and kg/ha of MgO at the beginning of the trial (week 14) showed the least severity in leaf 3 with values close to or below 300; the control treatments (0), 25 and 50 kg/ha showed a severity of the disease higher than the mild level (300). This led to applications of contact fungicides (protective) and curative (systemic), in addition to the performance of leaf removal and surgery (figure 4).

In week 20, the highest severity values of the disease were shown in leaf 3 for all fertilization treatments, surpassing even the severe level (>500) of BS. This was due to difficulties of performing surgery and leaf removal during week 19, joined with that in week 20 rainfall accumulated 44 mm, and the presence of high temperatures. Similarly, in week 26, treatments of 75 and 100 kg/ha of MgO reached a high level of severity (figure 4).

With leaf removal and surgery, at weekly intervals, the severity level of the disease was reduced. Other practices, additional to sanitary leaf removal could also help in the management of the disease, such as the stacking or cordoning off of diseased tissue in the soil and the application of 10% urea as a sporulation inhibitor [27].

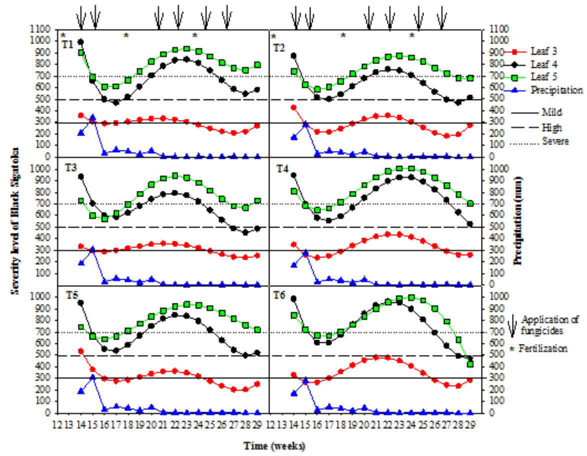

Figure 4. Severity of Black Sigatoka (*Mycosphaerella fijiensis* Morelet), in 'Barraganete' plantain, grown at the Río Suma Experimental Farm, Universidad Laica "Eloy Alfaro de Manabí", Extension in El Carmen, Ecuador, fertilized with different doses of MgO. The first application of fertilizer was made in week 12.

Guzmán and Villalta [7] confirmed the importance of regular weed control (herbicide or weeding) for proper disease control and the possibility of using low-lying live hedges, without detriment to BS control. Balanced mineral nutrition is also a relevant aspect. Elements such as silica, copper, calcium, boron, and zinc help to reduce the severity of the disease [28].

Analyzing the severity level in leaf 3 for each of the fertilization treatments, it was observed that the greatest incidences of BS occurred in week 14 in the control treatments (0), 25, 75 and 100 kg/ha of MgO; in week 15 for treatments 50, 100 and 125 kg/ha of MgO; in week 16 for treatments of 50 and 100 kg/ha of MgO; at week 18 in the treatment of 125 kg/ha of MgO; at week 20 and 21 for all treatments; at week 23 for 50, 75 and 125 kg/ha of MgO treatments; at week 24 in the treatment of 125 kg/ha of MgO; in week 25 in the treatment of 75 kg/ha of MgO and week 26 in all treatments except in the treatment 25 kg/ha of MgO (figure 4).

When analyzing the sample variance for the severity level of the disease in other leaves, statistical differences (P<0.01) were found for some of them due to the effect of the treatments depending on the evaluated leaf (3, 4, and 5). At week 14, differences were found in leaf 5 control treatment data, when compared with other treatments where MgO was applied. In week 18, differences were found in leaf 3 between treatments 125

(317.63; high severity level) and 0 kg/ha of MgO when compared with treatments 25 (156,67; mild severity level), 50, 75 and 100 kg/ha of MgO (figure 4).

Statistical differences were foundin weeks 21 and 22 for leaf 3 treatments 50, 100, and 125 kg/ha of MgO when compared with treatments 0, 25, and 75 kg/ha of MgO. Similarly, differences ($P<0.01$) were found in week 25 for leaves 3, 4, and 5. In leaf 3 the differences were between treatments 0, 75, and 125 kg/ha of MgO when compared with treatments 25, 50 and 100 kg/ha of MgO. In leaf 4, the differences were between the treatment 75 kg/ha of MgO when compared with the treatments of 0, 25, 50, 100, and 125 kg/ha of MgO; while in leaf 5 the differences were between treatments 0, 50, 75, 100, and 125 kg/ha of MgO when compared with the treatment 25 kg/ha of MgO (figure 4).

The progression of the disease is considered to have been very rapid when leaf 3, which was the youngest, was ill; so that, since the degree of infestation was mild, it was relatively low and can be controlled or managed through cultural practices and, if necessary, in the face of increased damage, with the use of protective or systemic fungicides, coinciding with what was pointed out by Muñoz and Vargas [29].

Concerning to leaves 4 and 5 in general, from week 21 onward, the severity levels values obtained were high (>300 to 500) and severe (> to 500); figure 4), although in the fields the leaves seem to be not so affected. These findings suggest some reflections on the situation in El Carmen, Ecuador, regarding agroecological and management conditions, which would lead to further research where the constant values that were used to determine the severity level of the disease in this area are adjusted according to the prevailing environmental scenarios.

This led to six applications of fungicides for the entire period evaluated, which were scheduled after field inspections and the incidence and severity level of the disease determined in weeks 14 and 15 (mancozeb (100 g) + tebuconazole + triadimenol (20 mL) + a mixture of alkylaryl and polyglycol 12.5% (two applications, eightday interval), in weeks 20 and 22 (difenoconazole (20 mL) + propineb (100 g) + a mixture of alkylaryl and polyglycol12.5% (two applications, 15day interval) and in weeks 24 and 26 (carbendazim (20 mL) + mancozeb (100 g) + a mixture of alkylaril and polyglycol 12.5% (two applications, 15 days interval), surgery and weekly leaf removal. On the other hand, the application program of preventive and curative fungicides for BS should be designed considering the fungicides active ingredients different mechanisms to reduce the risks of the development of resistance to those molecules.

All the aforementioned is in agreement with Cervantes *et al.* [21] who reported that the chemical management of BS has been carried out with the use of protective and systemic fungicides in aqueous suspension, in oil and water emulsions or direct mixture with mineral oil alone, with activators of host resistance mechanisms, and most recently through the use of nutrition-related compounds, both of chemical and natural origin. However, the overlap of the applied products with the presence of mineral oil, suggests an impediment to the penetration of sunlight to the leaves, which affects the content of chlorophyll, photosynthesis and therefore crop yields.

This methodology was used to determine the early detection of BS symptoms in leaves 3, 4 and 5; however, to be able to establish the severity level requires great precision in the recognition of the disease symptomatology, this knowledge allows to establish the frequency and level of cultural management and fungicides with both protective and systemic action; This makes it possible to have indicative values of the damage level present in the plantation.

Pérez [30] indicated that the use of fungicides for disease protection receives important attention, because in areas with adequate rainfall regimen for banana production of susceptible clones, if chemical controls are not applied, satisfactory disease control is not achieved.

It has been pointed out that through fertilization, it is nutritionally promoted the presence of epiphytic populations of chitinolytic and glucanolytic bacteria that have bioregulatory capacity on the pathogen and are naturally found in the ecosystems of cultivated plants [31]. However, in the rainy season, there was less availability of macronutrients such as sodium, magnesium and ammonium; in addition, to the protein content favouring epiphytic microbiota [32].

This control strategy seeks to reduce the inoculum of the pathogen, before environmental conditions favor its dissemination and establishment. Therefore, it is important to reach its maximum efficacy in times of low pressure of the disease such as the dry season, and thus achieve more abundant and effective populations of antagonist microbiota in rainy seasons, where the pressure of the disease is strongest [30].

Conclusions

The equations of the polynomial models predict that the lowest incidence of the disease occurs with the lowest dose of Mg (25 kg/ha of MgO), perhaps due to the mobilization of Mg to the vacuoles to act in the maintenance of the osmotic potential, as well as to store the Mg found in excess within plants.

The management of Black Sigatoka should remain focused on the integration of cultural and chemical procedures.Changes in consumer perceptions of healthier products and public concern to stop environmental pollution will have a marked influence on the control technologies being implemented.

It is necessary to consider the different Musaceae production scenarios, on one hand, the use of materials, cultivars or varieties less susceptible to the disease, especially in areas with high rainfall regime; and secondly the need for activities to promote such materials, cultivars or varieties at the level of consumers highlighting the benefits in quality, less pollution, health benefits, among others, in improving the quality of life of the population.

References

[1] Soorianathasundaram, K., Narayana, C.K. and Paliyath, G.: Bananas and Plantains. Encyclopedia of Food and Health. Oxford: Academic Press,320-327 (2016).

[2] Barrera V., J., Barraza A., F. and Campo A., R.: Efecto del sombrío sobre la Sigatoka negra (Mycosphaerella fijiensis Morelet) en cultivo de plátano cv Hartón (Musa AAB Simmonds). Rev. U.D.C.A Act. & Div. Cient. Vol. 19, N° 2 (2016) 317-323.

[3] Hidalgo, M., Tapia, A., Rodríguez, W. and Serrano, E.: Efecto de la Sigatoka negra (Mycosphaerella fijiensis) sobre la fotosíntesis y transpiración foliar del banano (Musa sp. AAA, cv. Valery). Agron. Costarricense. Vol. 30, N° 1 (2006) 35-41.

[4] Rodríguez, P. and Cayón, G.: Efecto de Mycosphaerella fijiensis sobre la fisiología de la hoja de banano. Agr. Col. Vol. 26, N° 2 (2008) 256-265.

[5] De Bellaire, L., Fouré, E., Abadie, C. and Carlier, J.: Black leaf streak disease is challenging the banana industry. Fruits. Vol. 65, N° 6 (2010) 327-342.

[6] Etebu, E. and Young, W.: Control of black sigatoka disease: challenges and prospects. Afr. J. Agr. Res. Vol. 6, N° (3) (2011) 508-514.

[7] Guzmán, M. and Villalta, R.: Efecto del método de control de malezas sobre el desarrollo de la Sigatoka negra y la producción del banano (Musa AAA, cv. Grande naine). CORBANA. Vol. 33, N° 60 (2007) 50-52.

[8] Barrera, J., Cayón, G. and Robles, J.: Influencia de la exposición de las hojas y el epicarpio de frutos sobre el desarrollo y la calidad del racimo de plátano "Hartón" (Musa AAB Simmonds). Agr. Col. Vol. 27, N° 1 2009 73-79.

[9] Chen, Z.C., Peng, W.T., Li, J. and Liao, H. Functional dissection and transport mechanism of magnesium in plants. Seminars in Cell & Developmental Biology. Vol. 74 (2018) 142-152.

[10] Medina Jiménez, F.: Nutrición magnésica de la platanera. Granja. Vol. 13 (2016) 22-23.

[11] Jin, X. L., Ma, C. L., Yang, L. T. and Chen, L. S.: Alterations of physiology and gene expression due to long-term magnesium-deficiency differ between leaves and roots of Citrus reticulata. J. Plant Physiol. Vol. 198 (2016) 103-115.

[12] Guo, W.: Magnesium homeostasis mechanisms and magnesium use efficiency in plants. pp. 197-213. In: Plant Macronutrient Use Efficiency. Molecular and Genomic Perspectives in Crop Plants. M.A. Hossain, T. Kamiya, D.J. Burritt, L.-S. P. Tran and T. Fujiwara (Eds.). Elsevier. Academic Press. (2018).

[13] Instituto Nacional de Meteorología e Hidrología (INAMHI).: Anuario meteorológico. N° 53-2013. Quito, Ecuador. Recuperado de http://www.serviciometeorologico.gob.ec/docum_ institucion/anuarios/meteorologicos/Am_2013.pdf. (2017).

[14] Avellán Vásquez, L., Cobeña Loor, N., Estévez Chica, S., Zamora Macías, P., Vivas Cedeño, J., González Ramírez, I. and Sánchez-Urdaneta, A.B.: Exportación y eficiencia del uso de fósforo en plátano 'Barraganete' (Musa paradisiaca L.). Revista Fitotecnia Mexicana. Vol. 43, N° 1 (2020) 25-33.

[15] Statistical Analysis System (SAS). 2020. SAS STUDIO user's guide: Statistics. Versión 15.1. SAS Institute Inc., Cary, NC USA. https://support.sas.com/documentation/onlinedoc/stat/index proc.html#stat151

[16] Fouré, E.: Les Cercosporiosis des bananiers et des plantains au Cameroun, Mycosphaerella fijiensis et M. musicola: amélioration des stratégies de lutte intégree par des études épidémiologiques et la lutte génétique. Centre Régional Bananiers et Plantains. Cameroun. In: Biological and Integrated Control of Highland Banana and Plantain Pests and Diseases. Gold and Gemmill Ed. Cotonou, Benin. (1991), 290-304.

[17] Orozco-Santos, M., García-Mariscal, K., Manzo-Sánchez, G., Guzmán-González, S., Martínez-Bolaños, L., Beltrán-García, M., Garrido-Ramírez, E., Torres-Amezcua, J.A. and Canto-Canché, B. La sigatoka negra y su manejo integrado en banano. Libro Técnico Núm. 1. SAGARPA, INIFAP, CIRPAC, Campo Experimental Tecomán. Tecomán, Colima, México. (2013), 152.

[18] Calle, H. and Yangali, J.: La Sigatoka Negra en el Ecuador. En: I Seminario Internacional Metodología para la evaluación de prueba de eficacia para plaguicidas en los principales cultivos del Ecuador. SAGAT. Recuperado de http://www.agrocalidad.gob.ec/wp-content/uploads/2014/

12/PresentacionSigatokaH-Calle-JYangali.pdf. (2014).

[19] Orozco-Santos, M., Orozco-Romero, J., Pérez-Zamora, O., Manzo-Sánchez, G., Farías-Larios, J. and da Silva Moraes, W.: Prácticas culturales para el manejo de la Sigatoka negra en bananos y plátanos. Tropical Plant Pathology. Vol. 33, N° 3 (2008) 189-196.

[20] Sáez Sáez, V. and Puche, M.: Uso de índices climáticos para el estudio del hongo sigatoka negra (Mycosphaerella fijiensis Morelet) en cultivos de plátanos. Estación Chama, sur del lago de Maracaibo Terra Nueva Etapa. Vol. XIX, N° 28 (2003) 11-33.

[21] Cervantes Alava, A,R., Sánchez-Urdaneta, A.B. and Colmenares de Ortega, C.B.: Efecto de las aplicaciones de fungicidas comerciales sobre el contenido de clorofila en e l cultivo de banano (Musa AAA). Agroecosistemas. Vol. 7, N° 3 (2019) 45-49.

[22] Álvarez, E., Pantoja, A. Lederson Gañán and Ceballos, G.: La Sigatoka negra en plátano y banano. Guía para el reconocimiento y manejo de la enfermedad, aplicado a la agricultura familiar. Organización de las Naciones Unidas para la Alimentación y la Agricultura (FAO). CIAT/FAO. (2013), 7.

[23] Mira, J., Díaz, A. and Hernández, M.: Influencia del régimen de lluvias sobre la productividad bananera de Urabá. En: Memorias. XXXIV Congreso Sociedad Colombiana de Control de Malezas y Fisiología Vegetal. COMALFI, Bogotá. (2004), 72.

[24] Turner, D.W., Fortescue, J.A. and Thomas, D.: Environmental physiology of the bananas (Musa spp.). Brazilian Journal of Plant Physiology. Vol. 19, N° 4 (2007) 463-484.

[25] Aristizábal, M. and Jaramillo, C.: Identificación y descripción de las etapas de crecimiento del plátano Dominico Hartón (Musa AAB). Agro. Vol. 18, N° 1 (2010) 29-40.

[26] Hernández, Y., Giménez, G. and Gómez, M.: Flowering locus T y Constan en Musa: Nuevos genes que participan en la transición floral en plátano Musa AAB cv. Hartón Enano. Rev. Fac. Agron. (LUZ). Vol. 27, N° 4 (2010) 524-554.

[27] Villalta, R. and Guzmán, M.: Capacidad de esporulación de Mycosphaerella fijiensis en tejido foliar de banano depositado en el suelo y efecto anti-esporulante de la urea. CORBANA. Vol. 31, N° 58 (2005) 41-43.

[28] Azofeifa, D., Martínez, I., Furcal, P., Serrano, E. and Guzmán, M.: Efecto de la fertilización foliar con Ca, Mg, Zn y B en la severidad de la Sigatoka negra y en el crecimiento y la producción del banano (Musa AAA, cv. Grande naine). CORBANA. Vol. 33, N° 60 (2007) 41-44.

[29] Muñoz Ruiz, C. and Vargas Jarquín, E.: Manejo de Sigatoka negra (Mycosphaerella fijiensis var. difformis Morelet) en plátano cv. "Curarré" en San Carlos, Zona Norte. Tecnología en Marcha. Vol. 18, N° 3 (2005) 38-52.

[30] Pérez Vicente, L.: Manejo convencional y alternativo de la sigatoka negra en bananos: Estado actual y perspectivas. Fitosanidad. Vol. 10, N° 1 (2006) 55-72.

[31] Patiño H., L.F., Bustamante R.E. and Salazar P., L.M.: Efecto de sustratos foliares sobre la sigatoka negra (Mycosphaerella fijiensis Morelet) en banano (Musa × paradisiaca L.) y plátano (Musa acuminata Colla). Agricultura Técnica. Vol. 67, N° 4 (2007) 437-445.

[32] Salazar, L.M., Patiño, L.F. and Bustamante, E.: Sustratos foliares para el incremento de bacterias quitinolíticas y glucanolíticas en la filosfera de banano. Rev. Facultad Nacional de Agronomía (Colombia). Vol. 59, N° 2 (2006) 3449-3465.

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