Yellow Sigatoka monitoring methods in the subtropical climate of Southern Brazil

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Abstract - The adoption of monitoring systems to control the Sigatoka disease complex represents one of the most significant advances in banana production worldwide. In this paper four methodologies for evaluating Yellow Sigatoka (Biological Pre Warning - BPW, Stage of Evolution - SE, Infection Index - II, and Youngest Leaf Spotted - YLS) were compared under experimental conditions, and two methods were selected for commercial orchards in subtropical conditions. These monitoring systems were submitted to correlation (P<0.05 error) and statistic descriptive analysis. The disease monitoring systems presented different values depending on the methodology in the experimental phase. The highest absolute values were verified in the BPW (8450 points), followed by SE (3213 points), II (36.3%), and YLS (9.7). The YLS presented a strong negative correlation with BPW (-80.7%), while the BPW and SE had a weak correlation (37%). In the commercial orchads BPW and YLS were compared, but the low frequency of the variable YLS limited its application for Sigatoka evaluation. After comparing the two systems in commercial orchards, we found that BPW should continue being the standard disease monitoring method on the coast of the state of Santa Catarina.

Index terms: *Mycosphaerella*; Biological pre warning; Youngest leaf spotted; Severity.

Métodos de monitoramento da sigatoka amarela da bananeira nas condições de clima subtropical no Sul do Brasil

Resumo - A adoção de sistemas de monitoramento para o controle do complexo de manchas de sigatoka representa um dos avanços mais significativos na produção de banana no mundo. Neste trabalho foram comparadas quatro metodologias de avaliação da sigatoka-amarela (Pré-aviso Biológico - PAB, Estágio de Evolução - EE, Índice de Infecção - II e Primeira folha Manchada - PFM), em regime experimental no período de 2012-2014 e duas metodologias foram selecionadas para ensaios comerciais no período de 2016-2018 em condições subtropicais. Esses sistemas de monitoramento foram submetidos à correlação (P<0,05) e análise estatística descritiva. Os sistemas de monitoramento de doenças na fase experimental apresentaram valores diferentes dependendo da metodologia. Os maiores valores foram observados no PAB (8450 pontos), seguido de EE (3213 pontos), II (36,3%) e PFM (9,7). O PFM apresentou forte correlação negativa com o PAB (-80,7%), enquanto o PAB e EE tiveram uma correlação fraca (37%). Nos ensaios comerciais, a baixa frequência da variável PFM detectada nas plantas limitou sua aplicação para avaliação da Sigatoka. Ao comparar os dois sistemas em pomares comerciais, verificou-se que a PAB deve continuar sendo o método padrão de monitoramento do mal-de-sigatoka no litoral catarinense.

Termos para indexação: *Mycosphaerella*; Pré-aviso biológico; Primeira Folha Manchada; Severidade.

Sigatoka disease complex (*Mycosphaerella* spp.) and Fusarium wilt (*Fusarium oxysporum* f. sp *cubense*) cause significant losses within banana producing regions of the state of Santa Catarina, South of Brazil. Black Sigatoka, caused by *Mycosphaerella fijiensis*, stands out for its aggressiveness and the significant losses it causes in tropical countries. Yellow Sigatoka, caused by *M. musicola*, is less aggressive, but still relevant in subtropical climate conditions. These diseases destroy the leaves, reduce the photosynthetic area, and cause drops in production (CHILLET et al., 2009). Yellow Sigatoka still is more prevalent in the banana production of the state of Santa Catarina, but this situation is slowly changing. Studies report that the incidence of Black Sigatoka is growing in the north of the state (DOS SANTOS et al., 2022).

Sigatoka complex monitoring methods have already been tested under field conditions, some of which have been applied in production regions of different countries. However, two systems stand out for being the most commonly used for monitoring the Sigatoka complex in different parts of the world: the Stage of Evolution (GANRY et al., 2008) method and the Biological Pre Warning System (BUREAU et al., 1992). Both methods are based on the evaluation of plant and disease variables to determine their development and the right time for disease control. The Biological Pre Warning has been used for Sigatoka control, with success, since 2000 in Santa Catarina (SÔNEGO et al., 2013), reducing the number of sprays by 50% within the state.

However, other methods based on the Youngest Leaf Spotted, Infection Index, and climate variables have already

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been tested under field conditions (OROZCO-SANTOS et al., 2013), but few studies have been conducted on Sigatoka complex monitoring in subtropical climates. This study aims to compare Yellow Sigatoka monitoring methods under experimental and commercial orchard conditions in the subtropical climate of the state of Santa Catarina, Brazil.

This study was carried out in two phases: experimental and commercial. The experimental phase was composed of an experimental orchard formed with *in vitro* plantlets of cv. Dwarf Prata (AAB) bananas, evaluated from May 2012 to May 2014. Banana plants were cultivated with a spacing of 2.5 × 2.5m, in a 2420m^2 experimental area. Banana plantation management was carried out according to technical recommendations for this crop, except for fungicide spraying (LIVRAMENTO & NEGREIROS, 2016). The families were conducted in the mother-daughter-granddaughter system, with shoots being thinned when necessary. Plantation and maintenance fertilizers were applied based on soil analysis. Weed management was carried out by hand, during the first six months of their implantation, followed by manual mowing during the experiment. The region's climate is classified as subtropical humid with a hot summer (Cfa), according to the Köeppen classification.

Four methods of disease monitoring were tested under experimental conditions: Biological Pre Warning (BPW); Stage of Evolution (SE); youngest Leaf Spotted (YLS); Infection Index (II). The BPW system evaluates the youngest leaves (2, 3, and 4), assigning a value for each type of lesion present, as well as for intensity of the lesion on the leaves (BUREAU et al., 1992). The SE evaluates more leaves (1, 2, 3, 4, and 5) and scores only the most advanced symptoms of leaf disease, but without considering lesion intensity (GANRY et al., 2008). The SE calculation also corrects the gross sum of the disease according to leaf emission. The leaf emission rate was calculated using the Brun scale, which evaluates cigar leaf growth in decimals from 0.0 to 0.8. YLS is evaluated as the first leaf that has 10 spots with gray centers (CARLIER et al., 2003). Sigatoka Infection Index is quantified by assessing the severity of banana leaf disease using the Stover scale, with indexes from 0 to 50%, by means of the following formula: Infection Index =% (IF): [Σn × b / (N- 1) × T] × 100, in which: n = the number of leaves at each Stover scale level; b = degree according to the scale; N = the number of degrees employed in the scale (6); T = the total number of leaves evaluated (CARLIER et al., 2003). Disease monitoring methods were evaluated weekly for ten plants marked in the experimental area under natural infection conditions.

In the second phase of the study, two monitoring methods were applied in commercial orchards in order to compare the standard model (Biological Pre-Warning – BPW) with the alternative method selected in the experimental phase (Youngest Leaf Spotted – YLS). The methods were applied, as described in the experimental phase, in three sites in Criciúma (site 1) and Siderópolis (sites 2 e 3), municipalities in the southern coast of the state of Santa Catarina, from March 2016 to November 2018. During this period, 37 disease evaluations were performed at each location.

The monitoring sites were located on small plantations of Grande Naine (AAA) cultivars. Banana plantation management was conducted according to technical recommendations for this crop (LIVRAMENTO & NEGREIROS, 2016), including fungicide spraying for Sigatoka disease complex control, as indicated by the BPW method. Alerts for control practices, such as defoliation and spraying, were issued when the gross sum of the disease reached 800 points. The fungicides were sprayed with a cannon sprayer coupled to a tractor. The spray suspensions were prepared by mixing fungicides, mineral oil, and water. Fungicide doses and spray solution volume were determined following the manufacturers' recommendations.

The disease data from the experimental phase were submitted to descriptive analysis, using Pearson correlation at 5% probability of error. Disease progress curves were also plotted. The disease development data in commercial orchards were analyzed by plotting disease progress curves for BPW and by frequency distribution (%) for the YLS variable during all period of the experiment.

The disease monitoring systems in the experimental orchard presented very different values depending on the methodology. The highest absolute values were verified in the BPW system, followed by SE, II, and YLS (Figure 1ABCD). The BPW system resulted in the highest disease values, reaching 8450 points, followed by the SE system with 2662 points, II with 37, and YLS with 10 points during the colder seasons (autumn-winter). Notably, higher values in the BPW, SE, and II systems mean greater disease severity, whereas the opposite is true for the YLS variable. So, lower values of YLS in an orchard means that the young leaves are probably heavily infected and Sigatoka severity is progressing.

In spring and summer, the BPW and SE methods resulted in similar disease values (Figure 1AB). The similarity of the systems is related to the leaf emission rates: high leaf emission rates (> 0.8 leaves week plant^{-1}) make the values similar, whereas low rates (< 0.4 leaves week plant^{-1}) resulted in distinct disease values for BPW and SE systems. The different curves in the seasons evaluated resulted in a weak correlation (37.7%) of the methods.

Comparisons of the other methods indicated a strong correlation between BPW with II and YLS, with 81.2% and -80.7%, respectively. In the case of the Stage of Evolution (SE), the correlations were weaker with 52.5% for II and -36.2% for YLS (Table 1).

During the validation phase in commercial orchards, there was great variation of disease severity in the commercial sites (Figure 2), fact related with the management of the orchards. The delay of the fungicide application after the recommendation to spray in site 2 was detected in a previous experiment (SONEGO et al., 2013), fact that reduces the efficiency of the system. In terms of absolute values, the BPW system again reached the highest values with disease peaks reaching 3100 points during the cold seasons. The YLS variable, in turn, wasn't always detected since many plants had no advanced symptoms of the disease. This variable was probably affected by the removal of the older leaves, a common practice for Sigatoka control. Histograms show that the frequency of plants with the YLS variable

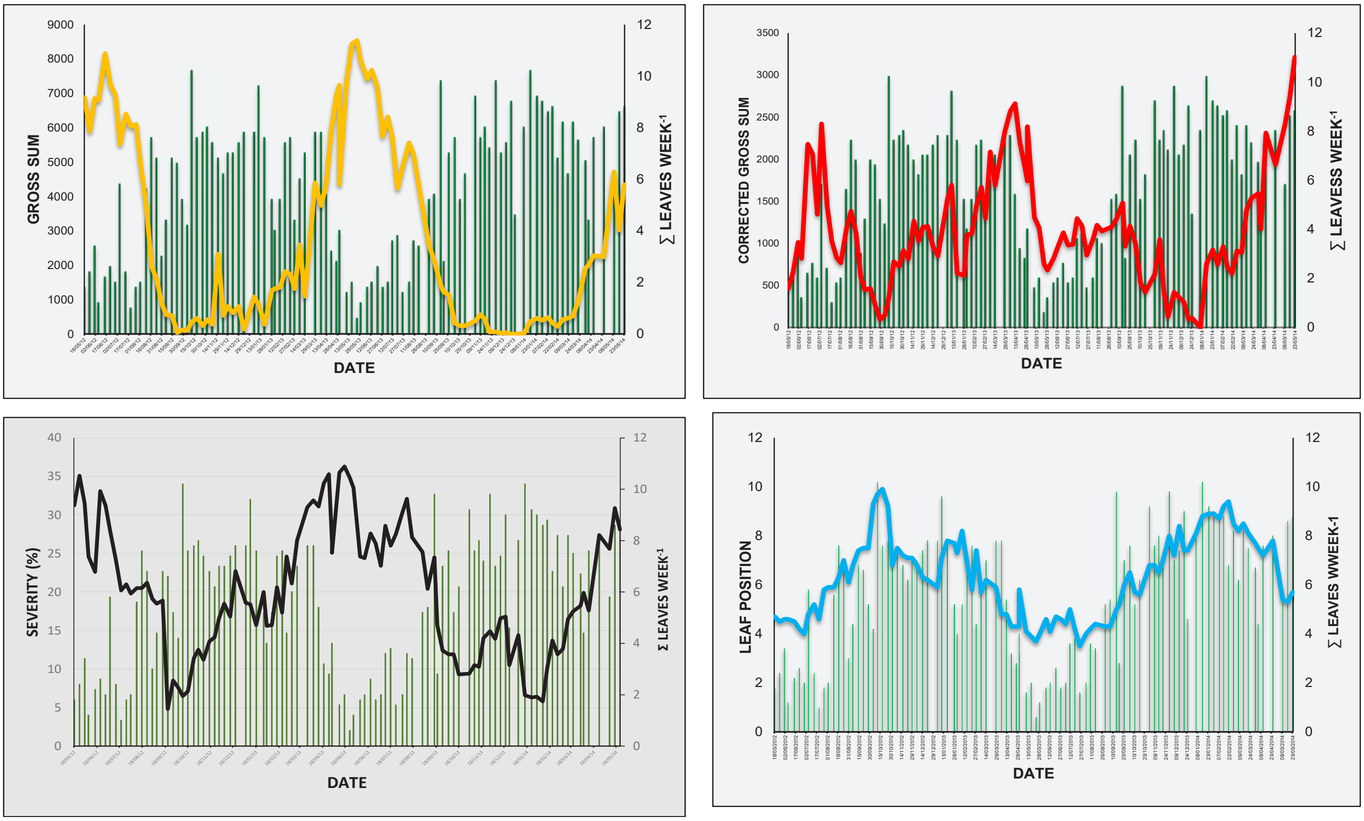

Figure 1. Yellow Sigatoka progress curves for the Bioclimatic Pre-warning (A), Stage of Evolution (B), Infection Index (C), and Youngest Leaf Spotted (D) methods and how they relate to leaf emission in Dwarf Prata banana cultivar, under experimental conditions in the subtropical climate of the southern coast of the state of Santa Catarina, Brazil, 2012-2014

Figura 1. Curvas de progresso da Sigatoka Amarela pelos métodos do Pré-aviso bioclimático (A), do Estágio de Evolução (B), do Índice de Infecção (C), da Primeira folha manchada (D) e sua relação com a emissão foliar em bananeira do cultivar Prata Anã, em condições experimentais no clima subtropical do Litoral Sul de Santa Catarina no período de 2012-2014

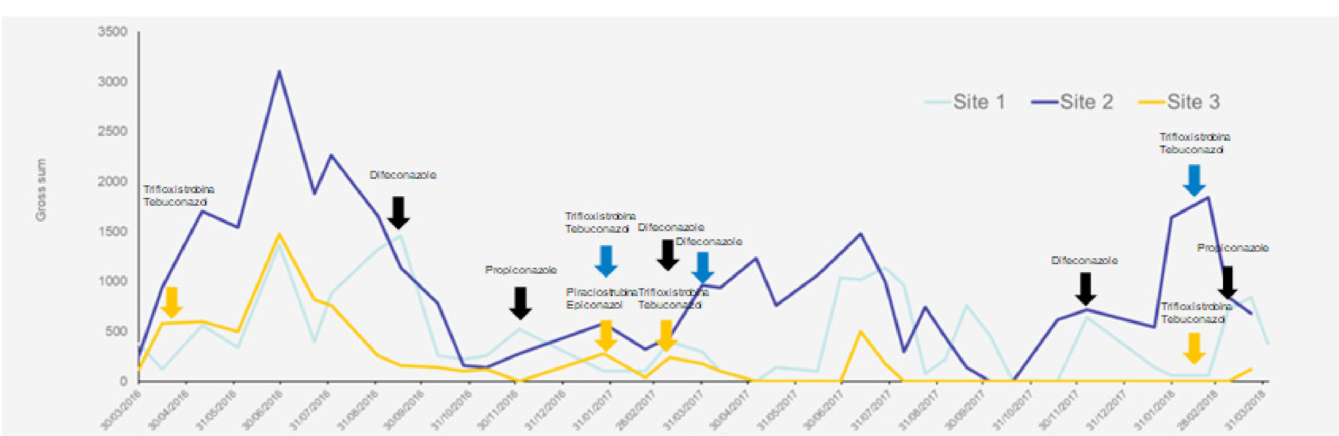

Figure 2. Sigatoka progress curves for the Bioclimatic Warning System at three disease monitoring sites in commercial banana orchards, under subtropical climate conditions, from 2016 to 2018

Figura 2. Curvas de progresso da Sigatoka pelo método Pré aviso bioclimático em três pontos de monitoramento da doença em pomares comerciais de bananeira sob condições de clima subtropical no período de 2016 a 2018

was very low at the sites (Figure 3). The higher frequency of YLS in 10 plants occurred in site 2, in only 5% of evaluations.

The YLS and II methods have already been used to evaluate disease evolution in some studies (QUIRINO et al., 2014; ROCHA et al., 2012), but none suggested its application under commercial conditions. However, our data showed that the low frequency of YLS on commercial properties was problematic. To overcome this problem the correction N + 1 (in which N = number of leaves) should be adopted in commercial conditions. Further studies should quantify standard values for YLS in commercial conditions since this is an easy and fast method to be applied directly by producers in the future. The II method stands out for quantifying the disease

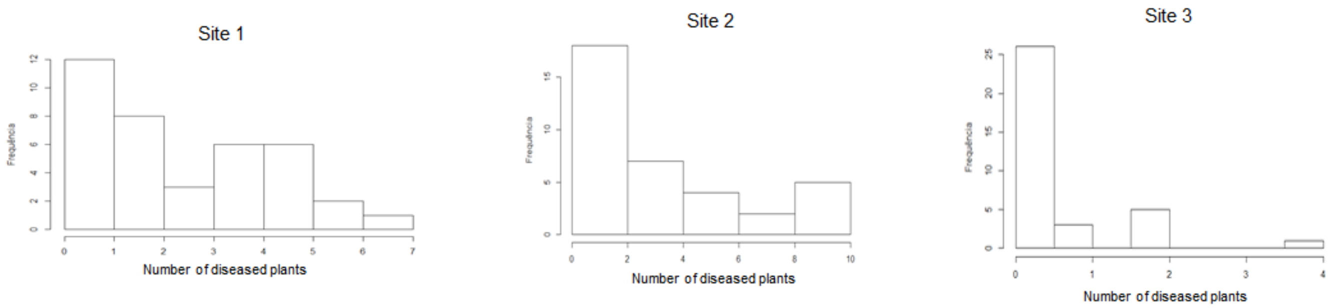

Figure 3. Frequency distribution (%) for the number of plants/evaluations with Sigatoka lesions according to YLS at three monitoring sites in commercial banana orchards, under subtropical climate conditions, from 2016 to 2018
Figura 3. Distribuição de frequência (%) do número de plantas com lesões da Sigatoka, de acordo com a variável YLS em três pontos de monitoramento em condições de clima subtropical no período de 2016 a 2018

Table 1. Correlations between the variables Leaf Emission (LE) and Gross Sum (Bioclimatic pre-warning), Correct Gross Sum (Stage of evolution), severity (Infection Index), leaf position (Youngest leaf spotted) in the monitoring of Sigatoka for Dwarf Prata cultivar in the southern coast of the state of Santa Catarina, Brazil, 2012-2014
Tabela 1. Correlações entre as variáveis para as variáveis de Emissão foliar (EF), Soma Bruta (Pré Aviso Bioclimático), severidade (Índice de Infecção), Primeira Folha Manchada (YLS) e Soma Bruta corrigida (Estágio de Evolução) no monitoramento da Sigatoka em bananeira do cultivar Prata Anã no Litoral Sul de Santa Catarina, no período de 2012-2014

Variables	Leaf Emission	Gross Sum	Corrected Gross Sum	Infection Index	YLS
Leaf emission	-	-78.7**	1.2	-59.3**	69.9**
Gross Sum		-	37.7**	81.4**	-80.7**
Corrected gross sum			-	52.3**	-36.2**
Infection index				-	-80.0**
YLS					-

ns- not significant, * - significant at 5% of probability and ** - significant at 1% of probability by F test.

on all leaves, which, despite being interesting, makes this method laborious. The BPW method, in turn, is the standard disease evaluation system in several producing regions, especially on Santa Catarina's coast. In Brazil, some authors have successfully tested the application of BPW with slight modifications to decision criteria (FERREIRA et al., 2003; RIOS et al., 2013).

Based on these results, Biological Pre-Warning should remain being the standard disease evaluation system. Not only has this method proven to be effective but it can also help monitor the evolution of Sigatoka complex disease in different producing regions of Santa Catarina's coast.

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