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ACTION OF FUNGICIDES IN THE CONTROL OF ANTHRACNOSIS IN POST HARVEST OF BANANAS

Marcelo Vieira FERRAZ[1],
Luis Carlos Ferreira de ALMEIDA[2],
Marcos Vieira FERRAZ[3]

ABSTRACT

Little information exists about banana shelf life in Registro-SP. The experimental design was completely randomized in a 4x2 four fungicides, two concentrations for each fungicide and two degrees of maturation, plus a treatment using only water. The experiments were repeated in four seasons. For the analysis of diseases in acclimatized and not acclimatized bananas fruit was made a chi-square test with approach of Monte Carlo. The objective of this study was to evaluate the incidence of anthracnose in postharvest fruit-conditioned bananas and not acclimatized after application of fungicides. It was concluded for fruit conditioned that thiabendazole (500 mg L -1) during the summer is not recommended, during the fall is not recommended the use of azoxystrobin (250 mg L -1) and imidazole (500 mg L -1). During the winter all fungicides are recommended to control anthracnose in air-conditioned fruit.

Keywords: *Musa* sp, quality, health

RESUMO

Pouca informação se tem sobre a vida de prateleira da banana em Registro-SP. O delineamento experimental utilizado foi inteiramente casualizado em esquema fatorial 4x2. Objetivou-se com este trabalho avaliar a incidência de antracnose em pós-colheita de frutos de bananas climatizadas e não climatizadas após a aplicação de diferentes fungicidas. Concluiu-se para os frutos climatizados que o thiabendazole (500 mg L^{-1}) não é recomendado. Já no inverno todos os fungicidas são recomendados para o controle da antracnose nos frutos climatizados. Para os frutos não climatizados, os tratamentos mostraram-se ineficazes no verão, outono e primavera para o controle da antracnose.

Palavras-chave: *Musa* sp, qualidade, sanidade

[1] Professor Assistente Doutor, Departamento de Agronomia, Campus Experimental de Registro, Universidade Estadual Paulista-UNESP-Registro/SP-Brasil marcelo.ferraz@unesp.br
[2]Professor Assistente Doutor, Departamento de Agronomia, Campus Experimental de Registro, Universidade Estadual Paulista-UNESP-Registro/SP-Brasil luis.almeida@unesp.br
[3]Professor Doutor, Departamento de Produção Vegetal, Campus de Jaboticabal, Universidade Estadual Paulista-UNESP-Jaboticabal/SP-Brasil ferrazmarcos@yahoo.com.br

1 INTRODUCTION

In Brazil, with an estimated area of 530,195 ha and production of more than 7 million tons (IBGE, 2017), banana cultivation is of great economic importance and among the fruit is one of the fastest return crops on invested capital.

Postharvest diseases in banana fruits are of great importance. The fungus infects the still-green fruits, remaining quiescent until maturation, when dark lesions progressively develop (Bonett *et al*., 2010; Khleekorn and Wongrueng, 2014), thus compromising the quality of the fruit and its market value.

In order to control anthracnose, sprays or postharvest baths with fungicides, especially those from the benzimidazole family (Negreiros *et al*., 2013), have been observed. However, the effectiveness of these products has been reduced (Lima *et al*., 2007), which calls for alternatives and studies for the conservation of these products.

The acclimatization and comparison of fruits at different temperatures has been a strategy to know the temperature relationship and the mycelial growth, sporulation and germination of conidia of *Colletotrichum musae* (Coelho *et al*., 2010; Souza *et al*., 2012). The optimal range, according to Phoulivong *et al*. (2010) and Serra *et al*., (2011) and Phoulivong *et al*., (2010) is between 27 and 30 ° C.

In the State of São Paulo, located in southeastern Brazil, the main producing region is located in the Ribeira Valley, which has its main economic activity in banana farming, with an area of 35,000 ha occupying 65.1% of the agricultural land available in this region (IEA, 2017). If on the one hand this activity is very important for the Region as a whole, little is known about the effectiveness of the products used in the postharvest, especially those that prolong shelf life.

The present study aimed to evaluate the incidence of postharvest anthracnose in non-acclimatized and air-conditioned bananas fruit after the application of different fungicides in the four seasons of the year, in order to evaluate the best treatment to increase life of shelf of the fruits**.**

2 MATERIAL AND METHODS

Banana clusters of the Nanica cultivar harvested at the pre-climacteric stage of two-year commercial plantations of a single producer were used in the municipality of Registro,

São Paulo. Aiming for better fruit uniformity during postharvest maturation, in the field the bunches were plucked and the pencas selected, giving priority to the central bunches of the bunches, rejecting the two proximal bunches and the three distal bunches. The fruits were received at the Laboratory of Vegetable Production of UNESP, Experimental Campus of Registro, where each bunch was divided into bouquets with five fruits. After this process the banana fruits received the treatments, constituted by: Witness; thiabendazole (250 mg L^{-1}); thiabendazole (500 mg L^{-1}); propiconazole (250 mg L^{-1}); propiconazole (500 mg L^{-1}); azoxystrobin (250 mg L^{-1}); azoxystrobin (500 mg L^{-1}); imidazole (250 mg L^{-1}); and imidazole (500 mg L^{-1}).

For the application of the treatments, the fruits were immersed in the different fungicidal suspensions for three minutes. After the immersion time, the bouquets were removed, allowed to dry and packed in an export carton and kept at room temperature (± 25 ° C) throughout the process. Each box contained 4 bouquets with 5 fruits. This process of application of the fungicides was carried out in all the fruits of the experiment, that is, the same procedure was used for the non-acclimatized fruits and for the fruits that later would be air-conditioned. After the application of these treatments the climatization of the fruits was done, and for the non-air-conditioned bananas the climatization process was not done.

For acclimatization or induction of the maturation of the acclimatized bananas, acetylene (calcium carbide) was used in two applications with 24 hours each, with an exhaustion process lasting one hour between the two applications. The acetylene application process was carried out in the boxes with the bananas, and to this end the boxes were covered with a black plastic sealed on the side to prevent gas from leaving. Exhausting was done with the removal of the plastic and then acetylene was applied again, according to Silva *et al.* (2012).

The fruits were left unanalyzed when more than 50% of the control group reached a grade of 6 or higher on the Cavendish banana classification table (Figure 1).

Figure 1: Color index of the skin according to the classification of Cavendish banana group (Nanica and Grand Naine) during the ripening physiological processes. **Fonte:** Cavendish Banana classification (CEAGESP).

When the fruit reaches notes equal to or greater than 6, it is understood that they are ripe. Medina and Pereira (2016) using the Cavendish banana classification table indicate that, together with the age of the bunch, the color of the bark is a good indicator of the degree of maturity of the fruits, being this the main criterion for the harvest.

The experimental design was completely randomized using four fungicides at two concentrations (250 mg L^{-1} and 500 mg L^{-1}). Each experiment had three replications with four bouquets of five fruits, being repeated in the four seasons of the year (spring, summer, autumn and winter), always in the last month of each season, for both air-conditioned and non-air-conditioned bananas. The presence of the anthracnose was verified by manual inspection in each of the bouquets.

To compare the proportion of the presence of the anthracnose between the stations, a statistic was made of the multiple comparisons of Tukey proportions as described by Zar (2010). For each station in function of the treatments, the Chi-square test for contingency tables was used. This test presents a statistic resulting from the comparison, for each combination of treatments, of the frequencies theoretically expected with the frequencies observed. If there is no relationship between the variables studied, this statistic returns a non-significant p value, alternatively, if there is a dependence relation between the variables, the statistic will be associated with significant values of p. Considering that it is believed that there are expected frequencies smaller than 2, this impedes the execution of the classic Chi-square test, so the values of this statistic will be obtained by Monte Carlo simulation as described by Peat and Barton (2005). Reliability interval form. In situations where the Chi-square statistic returns values with significant p-intervals, the interpretation of which combinations are significant will be done by analyzing the standard Chi-square residuals, according to Siegel and Castellan (2006), which estimates, for each z-score value. In cases where this value is greater than 1.96, or less than - 1.96, the frequencies observed differ statistically from the expected values. Statistical analyzes were performed using SAS 9.4 TS Level 1M2 software, with values of p lower than 5%.

3 RESULTS AND DISCUSSION

3.1 Refrigerated bananas

Table 1, below, presents the results for the presence and absence of anthracnose for each season of the year and the respective results of the statistical tests.

Table 1. Anthracnose presence in refrigerated bananas

Treatment	Season of the year							
	Summer		Autumn		Winter		Spring	
	Presence of Anthracnose							
	Yes	No	Yes	No	Yes	No	Yes	No
Witness	3	9	1	11	5[(a)]	7[(b)]	10	2
Azoxystrobin 250 mg L^{-1}	0	12	4[(a)]	8[(b)]	0	12	4[(b)]	8[(a)]
Azoxystrobin 500 mg L^{-1}	1	11	0	12	0	12	7	5
Imidazole 250 mg L^{-1}	0	12	0	12	0	12	11	1
Imidazole 500 mg L^{-1}	0	12	4[(a)]	8[(b)]	0	12	9	3
Propiconazole 250 mg L^{-1}	1	11	3	9	2	10	4[(b)]	8[(a)]
Propiconazole 500 mg L^{-1}	0	12	0	12	2	10	9	3
Thiabendazole 250 mg L^{-1}	3	9	1	11	0	12	10	2
Thiabendazole 500 mg L^{-1}	5[(a)]	7[(b)]	1	11	0	12	12[(a)]	0[(b)]
Total	13	95	14	94	9	99	76	32
Anthracnose Presence ratio [(c)]	13.7% (A)		13.0% (A)		8.3% (A)		70.4% (B)	
p-value chi-square [(d)]	0.009		0.041		0.002		0.001	

(a) Observed values higher than expected

(b) Observed values lower than expected

(c) Tukey test results for multiple comparisons of proportions - Equal capital letters in the row indicate that there are no significant differences between the proportions

(d) Chi-square statistic obtained by Monte Carlo Simulation

The multiple comparisons of the proportions of the anthracnose presence for each season showed no significant differences (p-value <0.05) between the summer, autumn and winter seasons with the results of the spring season differing significantly of the others. However, significant results for the chi-square test show that, for all seasons, the presence of

anthracnose did not occur independently of the treatments used, since all p-values were significant.

Thus, based on the results of the standard chi-square residuals, for the data of the air-conditioned bananas, shown in table 1, we have:

a) For the summer season there was a significant difference between the expected and observed values for the product thiabendazole in the concentration 500 mg L^{-1}, for this treatment, compared to the others, the incidence of anthracnose was higher than expected. These data differ from Coelho *et al*. (2010), who studied the storage of silver banana with fungicides kept under refrigeration, proved that the most efficient treatments for disease control were those in which the fruits were treated with the fungicide thiabendazole, both in the fruits stored at 20ºC and at 12ºC. In Brazil, the control of anthracnose in avocados of the Fuerte and Hass varieties has been done by immersing the fruits in procloraz and imazalil, and these two groups of fungicides are more efficient than thiabendazole (Fischer *et al*., 2011).

b) In the autumn there was a significant difference in the expected and observed values of azoxystrobin (250 mg L^{-1}) and imidazole (500 mg L^{-1}), even with these treatments the values observed for anthracnose were higher than expected. Little information is available on the response of these fungicides to postharvest banana, however Júnior *et al*. (2004) found that azoxystrobin at doses of 75 and 100 mg L^{-1} was increased by 0.5% ethoxylated nonylphenol and azoxystrobin (75 mg L^{-1} ia) with paraffinic mineral oil at 0.2 and 0.5%, can be used as an efficient alternative for anthracnose control in hose fruits, when accompanied by a postharvest treatment.

c) In the winter period, the significant difference occurs in the absence of fungicides, in the expected values for the anthracnose is higher than expected, from which it can be concluded that all the treatments that used fungicides were efficient. Although the treatments were efficient in anthracnose during the winter season, Senhor *et al*. (2009) state that with increasing restrictions on the use of fungicides due to food safety and environmental impact, the use of alternative methods to control postharvest diseases has been stimulated.

d) Finally, in the spring, it was the period that the incidence of anthracnose exceeded those of the other seasons. At this station the most effective treatments for anthracnose control were azoxistobin at 250 mg L^{-1} and propiconazole at 250 mg L^{-1}. It is interesting to note that the results for thiabendazole treatment (500 mg L^{-1}) can not control anthracnose, with results significantly lower than all other treatments including that of the control. Bananas treated with this product had more disease than expected.

3.2 Non-refrigerated Bananas

Table 2 shows the results of the treatments performed, for each season of the year for non-refrigerated bananas.

Table 2. Anthracnose presence of bananas non refrigerated.

Treatment	Season of the year							
	Summer		Autumn		Winter		Spring	
	Presença de Antracnose							
	Yes	No	Yes	No	Yes	No	Yes	No
Witness	1	11	0	12	4	8	2	10
Azoxistrobina 250 mg L^{-1}	1	11	0	12	8	4	2	10
Azoxistrobina 500 mg L^{-1}	0	12	0	12	3	9	0	12
Imidazole 250 mg L^{-1}	0	12	0	12	7	5	1	11
Imidazole 500 mg L^{-1}	1	11	0	12	3	9	3	9
Propiconazole 250 mg L^{-1}	1	11	0	12	$9^{(a)}$	$3^{(b)}$	0	12
Propiconazole 500 mg L^{-1}	1	11	0	12	6	6	2	10
Thiabendazole 250 mg L^{-1}	0	12	0	12	$9^{(a)}$	$3^{(b)}$	1	11
Thiabendazole 500 mg L^{-1}	0	12	0	12	$1^{(b)}$	$11^{(a)}$	1	11
Total	5	103	0	108	50	58	12	96
Anthracnose Presence ratio [(c)]	4.9% (A)		-		86.2% (B)		11.1% (A)	
p-value chi-square [(d)]	1.000		-		0.003		0.693	

(a) Observed values higher than expected

(b) Observed values lower than expected

(c) Tukey test results for multiple comparisons of proportions - Equal capital letters in the row indicate that there are no significant differences between the proportions

(d) Chi-square statistic obtained by Monte Carlo Simulation

The results of Tukey's multiple comparisons test showed no significant differences in the occurrence of anthracnose for the summer and spring seasons, since the chi-square statistics indicate that there is no dependence between the treatments and the presence of the

disease. It is recommended the application of these products for the control of anthracnose for uncontaminated bananas in these seasons, the same being recommended for autumn, where no fruit presented symptoms of the disease.

In the winter, the chi-square results indicate that, in the winter season, the presence of the disease is not independent of the treatment (p-value <0.05). The chi-square residue analysis showed that the presence of anthracnose occurred on a larger scale than expected in the treatments with thiabendazole (250 mg L^{-1}) and propiconazole (500 mg L^{-1}), ie bananas treated with these products had a greater incidence of the disease. In this sense, these products are not indicated for the control of anthracnose in unheated bananas during winter. Negreiros (2010) studied banana fruits 'Nanicão' and 'Prata', concluded that thiabendazole was efficient in the control of anthracnose only for the cultivar 'Prata', prolonging the incubation period of the disease in fifteen days and reducing its severity up to sixteen days after treatment. At the same time, even in this season, the treatment with the highest efficiency was thiabendazolee (500 mg L^{-1}).

4 CONCLUSION

It can be concluded that for the control of the anthracnose in the acclimatized fruits the summer is not recommended, in the autumn the use of azoxystrobin (250 mg L^{-1}) and imidazole (500 mg L^{-1}) is not recommended. In winter, all fungicides are recommended for the control of anthracnose in conditioned fruits. In the spring, only propiconazole (250 mg L^{-1}) and azoxystrobin (250 mg L^{-1}) were effective in controlling anthracnose. As for the non-conditioned fruits, the treatments were ineffective in summer, autumn and spring for anthracnose control. Only thiabendazole (500 mg L^{-1}) controlled the disease in the winter for the non-conditioned

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