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Peach brown rot control and the relationship of latent infection with postharvest disease[1]

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ABSTRACT

The peach brown rot, caused by *Monilinia fructicola,* is the main disease of the crop, causing significant losses during preharvest and postharvest. This study aimed to evaluate the performance of preharvest fungicide application on brown rot control and verify the role of latent infection and external contamination in postharvest disease. An experiment was carried out in the years 2014 and 2015 in order to evaluate the performance of six active ingredients (captan, iprodione, iminoctadine, tebuconazole, difenoconazole and azoxystrobin) during preharvest on brown rot control and the effect on latent infection. A second experiment was carried out to monitor the latent infection during growth and ripening of the fruit and in order to correlate it with the postharvest disease incidence. The data were submitted to analysis of variance (Anova) and the means were grouped by the Scott-Knott test ($p < 0.05$), using statistical software Sisvar. The active ingredients iprodione, tebuconazole and difenoconazole were the most efficient in controlling brown rot on the field, while iminoctadine has higher efficiency during postharvest control, acting on latent infections. The incidence of latent infections during fruit growth and ripening has a positive correlation with brown rot incidence at postharvest. The highest disease incidence after storage is due to the latent infections manifestation. Effective chemical control in the field, throughout the growing and ripening of fruit, is an important approach to postharvest brown rot control, even after cold storage and during shelf life at 20 °C.

Keywords: cold storage; fungicides; *Monilinia fructicola*.

RESUMO

Controle da podridão parda do pessegueiro e a relação da infecção latente na doença em pós-colheita

A podridão parda do pessegueiro, causada pelo fungo *Monilinia fructicola*, é a principal doença da cultura, causando danos significativos tanto em pré-colheita como pós-colheita. O estudo objetivou avaliar a aplicação pré-colheita de fungicidas, no controle da podridão parda e verificar o papel da infecção latente e contaminação externa na incidência da doença em pós-colheita. Foi conduzido um experimento nos anos de 2014 e 2015 para avaliar o desempenho de seis ingredientes ativos em pré-colheita (captana, iprodiona, iminoctadina, tebuconazol, difenoconazol e azoxistrobina) no controle da podridão parda e o efeito sobre infecções latentes. Um segundo experimento objetivou monitorar a infecção latente durante o crescimento e maturação dos frutos, correlacionando-a com a incidência da doença em pós-colheita. Os dados formam submetidos a análise de variância (Anova) e as médias agrupadas pelo teste de Scott-Knott ($p < 0,05$) com o software estatístico Sisvar. Os produtos iprodione, tebuconazol e difenoconazol foram os mais eficientes no controle da podridão parda a campo, enquanto o iminoctadine possui maior eficiência em pós-colheita, agindo inclusive sobre as infecções latentes. A incidência de infecções latentes tanto na fase de crescimento

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quanto maturação tem correlação positiva com a podridão parda em pós-colheita. A maior incidência da doença após o armazenamento foi em decorrência da manifestação de infecções latentes. O eficiente controle químico no campo, durante toda a fase de crescimento e maturação dos frutos é uma importante estratégia para o controle pós-colheita, inclusive após o armazenamento refrigerado e durante a vida de prateleira sob 20 °C.

Palavras-chave: armazenamento refrigerado; fungicidas; *Monilinia fructicola.*

INTRODUCTION

The peach brown rot, caused by fungus *Monilinia fructicola*, is the main disease of the crop, causing significant losses in pre and postharvest. These losses resulted from infection of flowers and fruit, during harvest and postharvest (Larena *et al.*, 2005; Villarino *et al.*, 2012). The fruit susceptibility to *M. fructicola* increase at the final stages of fruit development, during the maturation phase, and over the postharvest (Luo & Michailides, 2003; Villarino *et al.*, 2011). Postharvest losses in peaches normally occur during transport and storage and may reach 80% (Sestari *et al.*, 2008); even when performing the recommended prophylaxis measurements.

The control of the disease during postharvest is essential to reduce the inoculum in the field, preventing manifestation of the disease during fruit storage and marketing. Thereby, the chemical control with fungicide is the most efficient method, spraying the plants from flowering until the preharvest stages of fruit development (Holb & Schnabel, 2007; May-De Mio *et al.*, 2008; Moreira & May-De Mio, 2009; Casals *et al.*, 2012). Preharvest fungicide application is indispensable, especially for areas with high inoculum pressure, or in cases of damage caused by insects or hail during fructification (Luo *et al.*, 2001). Fungicides, such as iminoctadine, iprodione (Moreira & May De Mio, 2009; Pavanello *et al.*, 2015), trifloxystrobin/tebuconazole and difenoconazole (Pavanello *et al.*, 2015), reduced the brown rot incidence more than 85% after cold storage. Burnett *et al.*, (2010) observed that azoxystrobin and trifloxystrobin are able to reduce the sporulating areas by 60%, presenting a high curative ability to fight infections caused by the fungus *Monilinia fructicola*.

Immature fruit usually show no visual symptoms of infection with *M. fructicola*, but can harbor asymptomatic infections (latent). Latent infections may become active when the fruit ripen, exacerbating the disease incidence in harvest and postharvest (Emery *et al.*, 2000). These infections are more important in temperate and humid regions, where they can easily develop into rot, occurring throughout the growth period of the fruits and being positively correlated with the incidence of the disease at harvest and postharvest (Northover & Cerkauskas, 1994; Emery *et al.*, 2000, Xu *et al.*, 2007). Understanding the importance of latent infection of brown rot epidemiology could facilitate early detection of the risk of rot before harvest, influencing the decisions for the management of the disease. Furthermore, the efficient use of fungicides during the preharvest rot control is important to reduce peach loss, especially in postharvest, when the fruit is subject to injuries and more sensitive to latent infection. Thus, the aim of this study was to evaluate the performance of fungicides applied during preharvest on brown rot control of peach and to identify the role of latent infection and external contamination in the incidence of postharvest brown rot.

MATERIAL AND METHODS

The study was carried over the course of years 2014 and 2015, in a commercial orchard of peach in the city of Santiago, Rio Grande do Sul state, Brazil, located at an altitude of 409 m, 29º11’30"S and 54º52’02" W. The post-harvest experiment was carried out in Santa Maria, Rio Grande do Sul state, Brazil located at ab altitude of 85 m, 29º41’03" S and 53º48’25" W. The cultivar used was Eldorado with ten year old plants that were spaced 1.5 x 5 m in a Y-shaped conduction system.

Pre and postharvest control of brown rot

In the first year (2014), from October to December, the experimental design was a randomized block with four replications, seven treatments and experimental units of six plants. The treatments were the following products (active ingredients): [1] control (4 water applications); [2] captan (4 applications); [3] iprodione (4 applications); [4] iminoctadine (2 applications); [5] tebuconazole (3 applications); [6] difenoconazole (3 applications); [7] azoxystrobin (3 applications). The preharvest applications began 24 days before harvest, following the recommended doses for each active ingredient and adapting them to a spray volume of 1000 L ha^{-1} (Table 1).

Previous cultural practices for the implementation of the experiment consisted of fertilization, pest control, pruning and thinning fruit according to the technical recommendations for crop. The controlling of the disease began with the removal of mummified fruit during the dormancy period; thereafter chemical treatments were carried out from the flowering stage. The products used were mancozeb (200 g 100 L^{-1}) in full bloom and tebuconazole (100 mL 100 L^{-1}) in the fall of the petals. An application of mancozeb (200 g 100 L^{-1}) + difenoconazole (30 mL 100 L^{-1}) was conducted during thinning. After this period, preharvest applications were carried out as the experimental treatments.

In order to evaluate the incidence of the disease in the field, the incidence of brown rot was recorded weekly, taking into account the number of fruit with lesions in relation the total of fruit evaluated. The count was held every week until harvest and the results were expressed as a percentage of brown rot. After harvest, fruit without apparent infection were transported to the laboratory for evaluation of the postharvest incidence. A batch of fruit from each treatment was stored at -0.5 ± 0.2 °C, under a relative humidity (RH) of 96 ± 1%, for 40 days, whereas another batch was stored at 20 °C in order to assess the incidence of brown rot. In order to evaluate the protective efficiency of the treatment, another batch of fruit was submitted to injuries in the epidermis and then inoculated with fungus *Monilinia fructicola*. The isolate, the same experimental area, was cultivated on potato dextrose agar (PDA) and later formed a suspension of 10^5 mL^{-1} spores with the aid of a Neubauer chamber. Each fruit was drilled in the equatorial region, with the aid of a tip of 3 mm diameter and 5 mm in depth, where 30 μL spore suspension was inoculated. In fruit uninjured, inoculation was performed in a marked point in the equatorial region. After drying the inoculated aliquot, the fruit were stored and evaluated as aforementioned for the fruit without inoculation.

During harvest and postharvest, disease incidence was evaluated at two and four days of shelf life (20 ± 0.5 ºC). Four replicates of 20 fruit from each treatment were analyzed for all evaluations. The chamber temperature was controlled by electronic thermostats and monitored daily by a thermometer with mercury bulb, with accuracy of 0.2 °C, inserted into the flesh of a fruit and RH monitored by a psychrometer. When necessary, the atmosphere was humidified in order to maintain > 96% humidity.

Evaluation of latent infection

During the second year (2015), from July to December, we evaluated the incidence of latent infections during growth and ripening of fruit and correlated this data with the disease occurrence in postharvest. Samplings were held at the fall of the sepals, during thinning of fruit, 30 days after thinning (DAT), 15 days before harvest (DBH) and during harvest, in two cultivars and from plants that were and weren't submitted to fungicide application. The cultivars used were 'Maciel' and 'Eldorado', dual purpose. The 'Maciel' is characterized by the present yellow flesh, firm, non-fondant with sweet-sour flavor and soluble solids content between 11 and 16 °Brix, with flowering in late July to early August and harvest in the second to third week from December. Cultivar Eldorado delayed, with flowering in late August and harvest in the last days of December. It also has yellow flesh, firm and adherent to the core, with sweet-sour flavor, with 15 to 17 °Brix and acidity quite pronounced. The phytosanitary treatment for disease management was with mancozeb, captan, procymidone, iminoctadine, tebuconazole and iprodione, the former two were applied at flowering and the others were used in alternation, with an application during thinning and four during preharvest. At each sampling

Table 1: Characteristics of fungicides and date of application of fungicides and dates and volumes of rainfall in December in Santiago, RS, Brazil (crop 2014)

Treatments	Characteristics of fungicides and dates of applications							
	Mode of action	Safe range (Days)	Doses	24 DBH* Nov/30	14 DBH Dec/08	7 DBH Dec/15	3 DBH Dec/18	1 DBH Dec/21
Control	-	-	-	X**	X	X		
Captan	Contact	1	240 g $100L^{-1}$	X	X	X		X
Iprodione	Contact	3	150 mL $100L^{-1}$	X	X		X	
Iminoctadine	Contact	14	150 mL $100L^{-1}$	X	X			
Tebuconazole	Systemic	7	100 mL $100L^{-1}$	X	X	X		
Azoxistrobina	Systemic	7	16 g $100L^{-1}$	X	X	X		
Difenoconazol	Systemic	10	30 ml $100L^{-1}$	X	X			
Harvest: 22 of December								

Dates of rainfall							
Date	Dec/1	Dec/ 4-5	Dec/7	Dec/11-12-13	Dec/16	Dec/19-20-21	Total
Volume (mm)	7.2	22.8	26.6	97.8	8.0	113.2	275.6

*DBH: Days before harvest; ** Date of applications date, 80 fruit were randomly selected from eight trees, which were randomly distributed in the orchard, put in paper bags and sent to the laboratory.

Determination of latent infection in green fruit

The fruit were surface sterilized for one minute in a 70% ethanol solution, followed by one minute in 0.5% sodium hypochlorite and then washed three times in sterile water. Unripe fruit were immersed in a paraquat solution (6 mL L^{-1}) for 1 minute in order to induce senescence in the tissues and activate latent infections (Northover & Cerkauskas, 1994). After the treatment, all fruit were placed in a humid chamber inside of plastic receptacles containing moistened filter paper, the temperature was held at 20 °C. The incidence of the disease was evaluated every 48 hours during six days. During this period, the fruit internally infected by the pathogen expressed abundant sporulation, which was clearly distinguishable from other fungal infections.

Determination of latent infection in mature fruit

In order to detect latent infection in mature fruit (harvest), 80 fruit from each treatment and cultivar were sterilized according to the previous procedure, with the exception of the paraquat application. Another batch of 80 fruit were only sprayed with sterile water and, placed in a humid chamber at a temperature of 20 °C and evaluated for six days. This procedure was performed in fruit after harvest. Following a batch of fruit was evaluated and another stored for 35 days under refrigeration at -0.5 ºC and relative humidity (RH) of 96 ± 1%, to verify the role of latent infection in disease incidence at postharvest.

The parameters evaluated were: a) total brown rot incidence in fruit with no sterilization; b) latent infection: incidence of rot in fruit that had been submitted to superficial sterilization; c) external contamination: determined by the difference between incidence of total decay and latent infections; d) brown rot incidence in field: monitoring the incidence of brown rot until the time of harvest, in all 8 plants used for each treatment (4 replicates of 2 plants). All results were expressed as percentage of fruit with rot.

Statistical analysis

The data, prior to analysis of variance (ANOVA), were submitted to the errors normality test (Lilliefors) and the parameters that were not normal (evaluation of latent infection, pre and postharvest control of brown rot and determination of latent infection in mature fruit) were transformed by arc.sen $\sqrt{x/100}$. Means were grouped by the Scott-Knott test at $p < 0.05$, with software Sisvar-version 5.3-UFLA (Ferreira, 2011), and after between the variables the incidence of latent infection *Monilinia fructicola* on different dates and the incidence disease at harvest and postharvest was used Pearson correlation at $p < 0.05$.

RESULTS AND DISCUSSION

Performance of fungicides in controlling preharvest brown rot

The active ingredients difenoconazole, tebuconazole and iprodione showed greater efficiency in the brown rot control in the field in comparison to other products tested, with 90.9%, 90.2% and 90.6% of control, respectively (Figure 1C). Although rainfall levels were high during the period of application (Figure 1A and B), and the fact that these products are widely used by fruit growers, their efficiency was still assured, being important alternatives for brown rot management of peach culture. High rainfall and relative humidity in the months of development and maturation of fruit (October to December), as observed in the year of the study (Figure 1A), predisposes to increased infections and in this case the intensification of applications is required, and the use of fungicides efficient. This result confirms those obtained by Pavanello *et al.*, (2015) with satisfactory preharvest control of brown rot with difenoconazole, tebuconazole, procymidone, azoxystrobin and trifloxystrobin / tebuconazole. Holb & Schnabel (2007) found that the triazoles have a high protective activity reinforcing the control of brown rot. This can be observed in Table 1, where the presence of fungi from latent infection is low with tebuconazole. Nevertheless, although the iminoctadine fungicide did not present the best preharvest control, this fungicide resulted in a low incidence of latent infections at harvest, resulting in high control of postharvest brown rot (Table 2).

Performance of fungicides to control of postharvest brown rot

In postharvest, during exposition of the fruit at 20 °C, the incidence of brown rot showed significant interaction between fungicides and the time of evaluation, at harvest and after storage (Table 2). At harvest, plus two days of shelf at 20 °C, iprodione, iminoctadine, tebuconazole and difenoconazole resulted in no incidence of the disease, while after cold storage iminoctadine was the one who controlled at 100% brown rot. When comparing the evaluation period, only iminoctadine did not increase the incidence of brown rot after cold storage. After four days of exposure to 20 °C, the iminoctadine fungicide, followed by tebuconazole resulted in the lowest incidence of the disease, both at harvest and after cold storage, with control of 98.1% and 97% at harvest, 96.2% and 73.9% after storage, respectively. The preharvest iminoctadine application has been found effective in control of postharvest brown rot in the states of Rio Grande do Sul and Paraná (Moreira & May-De Mio, 2009), even during long periods of fruit storage (Pavanello *et al.*, 2015).

The effect of fungicides applied during preharvest on fruit that had suffered injuries after harvest can be seen in Table 3. When fungicides were applied, the injuries were found to cause an increase of disease incidence, except for the treatment with Iprodione with 71.3% control the disease for up to two days at 20 °C. At four days at 20 °C, the lowest incidence was found with the application of iminoctadine fungicide in injured fruit (52.9% of control), while iminoctadine and tebuconazole controlled 94.7% and 89.6% respectively in the fruit without injury. After cold storage, besides the iprodione fungicide, captan also delayed the incidence of decay up to two days at 20 °C, however after four days the incidence in injured fruit was higher for all treatments. During this period, in fruit without injuries, iminoctadine fungicide resulted in same behavior at the time of harvest, with 94.5% disease control (Table 3).

At harvest, the prevention of mechanical damage and immediate cold storage constitute the most effective decay prevention measures. Martins *et al.*, (2005) showed correlation between the frequency of fruit mechanical damage and decay incidence. Thus, the use of fungicides that can delay decay incidence by injury in the epidermis is an important strategy for reducing the inoculum in postharvest, reducing losses.

Relationship of latent infection with postharvest brown rot

The incidence of latent infection in fruit the cultivar Eldorado was diagnosed in all samples, while in fruit of cultivar Maciel latent infection appeared from the thinning until harvest, as shown in Table 4. Regarding the magnitude of symptoms, we observed that the closer the harvest, the greater the manifestation of latent infection. Several authors reported that closeness of fruit ripening favors the expression of latent infections, which can also occur during postharvest or senescence (Luo *et al.*, 2001; Mari *et al.*, 2003; Luo & Michailides, 2003; Villarino *et al.*, 2012). In this study, the infection was probably facilitated by environmental conditions favorable to disease, such as high temperature (+/- 20 °C) and high relative humidity, observed mainly in the months from October to December, that are the dates of collection after thinning, 15 days before harvest and harvest of this study (Figure 2). In addition, the high concentration of inoculum in the area due to the early ripening cultivars (Granada, Eldorado and Maciel) in the experimental area, can also explain the high incidence of latent infections in the 'Eldorado', which maturation occurred in mid-December. The potential inoculum, humidity and temperature are critical factors in disease prediction (Luo & Michailides 2001, Bannon *et*

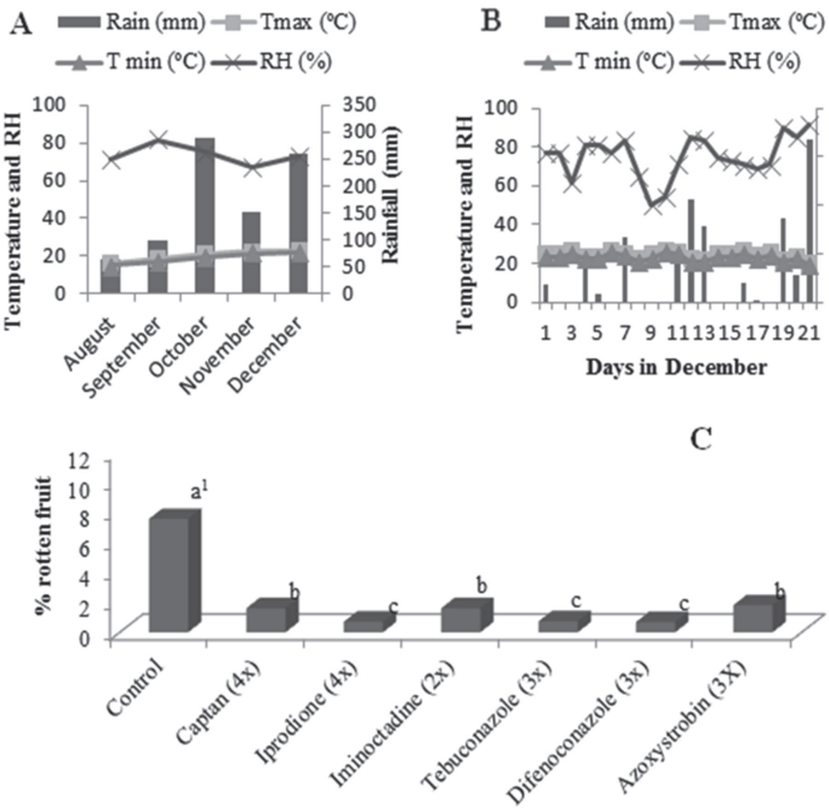

Figure 1: Rainfall, relative humidity (RH) and temperature recorded at the weather station in Santiago, RS (A and B) (Crop 2014). Incidence of brown rot at harvest, after treatments preharvest with fungicides in peaches cv. Eldorado (C). 1 Means followed by equal letters belong to the same group by Scott-Knott test ($p < 0.05$).

al., 2009, Gell *et al.*, 2008). In order for latent infections to develop, wetness needs to be maintained for longer than 22 hours when temperature is 8 °C or for 5 hours when temperature is 25 °C (Gell *et al.*, 2008).

The low incidence of latent infections in fruit treated with fungicides is probably due to the efficiency of products used in disease control, acting as preventives and curatives, reducing the onset of symptoms, including postharvest period (Table 4). The use of appropriate protective fungicides can protect the fruit, reduce sporulation and inoculum survival supplies (Ogawa *et al.*, 1995). The incidence of latent infections were virtually not found in the cultivar Maciel, which was treated with fungicides, In cultivar Eldorado the manifestation occurred at the beginning of fruit growth and at harvest, which coincides with the period of greatest rainfall and relative humidity (September, October and December of 2014) and that probably reduce the efficiency of applied products (Figure 2). Factors that predispose the incidence of latent infections such as temperature, humidity and high concentration of inoculum, associated with favorable growth stages of the disease, may have influenced the control strategies. Susceptibility to brown rot infection is dependent on the developmental stage of the fruit (Gell *et al*., 2008). The immature fruit during the pit hardening stage are more resistant to infection by *Monilinia* spp. than mature fruit (Lee & Bostock, 2007; Xu *et al*., 2007; Gell *et al*., 2008).

At harvest, both latent infection and the infection from surface spores were found to have the same weight on the epidemic of the disease, regardless of the use of fungicides, and this significantly reduced the incidence of rot, regardless of the cultivar (Table 4). After cold storage, the results also showed no interaction between the causes of brown rot (external contamination and latent infection) with the use of fungicides, where there is greater incidence of brown rot from the latent infection and without the application of fungicides. A reduction of chemical and mechanical resistance to the development of the pathogen is noticed with the advance of maturation and especially after cold storage. With maturation, physiological and biochemical responses in the host can trigger changes and activate the pathogen, which would leave its phase of low metabolic rate (quiescent) and would stimulate pathogenicity factors, resulting in an active parasite development (Prusky, 1996; Fischer *et al.*, 2010). The greater sensitivity of fruit maturation can also be related to pH and content of soluble solids, since total soluble solids include reducing sugars and other molecules readily consumed by fungi (Walker & White, 2005). The

Table 2: Effect of fungicides on the incidence of latent infection by *M. fructicola* in mature fruit, for six days at 20 °C and postharvest brow rot incidence after harvest and 40 days of cold storage (CS) to -0.5 ºC, four days at 20 °C. Santa Maria, RS, Brasil (crop 2014)

Preharvest treatments	**Rot caused by latent infection (%)**	
	2 days	**6 days**
Control	20.8a	87.5a
Captan (4x)	3.75c	42.0d
Iprodione (3x)	8.75b	75.0b
Iminoctadine (2x)	0.00d	5.00f
Tebuconazole (3x)	3.52c	26.9e
Difenoconazole (2x)	7.82b	60.2c
Azoxystrobin (3x)	6.25b	54.3c
CV (%)	**15.2**	**9.04**

Preharvest treatments	**Postharvest brown rot incidence (%)**			
	2 days at 20 °C		**4 days at 20 ºC**	
	After harvest	**AfterCS**	**After harvest**	**After CS**
Control	20.0 aB[(1)]	51.2 aA	68.7aB	86.2 aA
Captan (4x[(2)])	7.38 bB	11.2 cA	21.0 bB	42.5 cA
Iprodione (4x)	0.00 dB	11.2 cA	14.7 bB	46.2 bA
Iminoctadine (2x)	0.00 dA	0.00 dA	3.75 eA	3.25 eA
Tebuconazole (3x)	0.00 dB	12.5 cA	6.25 dB	22.5 dA
Difenoconazole (3x)	0.00 dB	10.1 cA	12.5 cB	38.6 cA
Azoxystrobin (3x)	3.75cB	16.2 bA	21.2 bB	51.2 bA
Mean	4.44	16.0	21.1	41.5
CV (%)	**13.9**		**10.5**	

[1] Means followed by equal letters, lowercase in the columns and uppercase in the lines, belong to the same group by Scott Knott test ($p < 0.05$). [2] Number of preharvest applications

fungus *Monilinia fructicola* is known for having the ability to infect green fruit and manifesting itself mainly after storage, this fact reinforces the importance of appropriate chemical treatment in the field, aiming to protect the flowers and fruit, both in the initial stage of development as during harvest.

Monitoring latent infection allows us to correlate the postharvest disease occurrence with different collection periods during fruit development. We observed that the closer the harvest, the greater the correlation between the incidence of latent infection to the manifestation of the disease in postharvest, both right after harvest as well as

Table 3: Fungicidal effect of products applied in the field of 'Eldorado' peaches in control of brown rot in injured fruit at harvest. Santa Maria, RS, Brazil (crop 2014)

Preharvest treatments	Brown rot incidence (%)			
	After harvest			
	2 days at 20 ºC		4 days at 20 ºC	
	With injury	No injury	With injury	No injury
Control	26.2 aA[(1)]	26.7aA	87.5 aA	71.2 aB
Captan (4x[(2)])	18.0 bA	1.25 cB	89.6 aA	20.0 cB
Iprodione(3x)	7.50 dA	6.25 bA	65.0 cA	36.5 bB
Iminoctadine (2x)	15.0 cA	1.25 cB	41.2 eA	3.75 dB
Tebuconazole (3x)	12.5 cA	1.25 cB	52.5 dA	7.38 dB
Difenoconazole (2x)	13.0 cA	2.50 cB	62.4 cA	23.8 cB
Azoxystrobin (3x)	8.98 dA	3.81 bB	77.9 bA	25.4 cB
Mean	14.5	6.14	68.3	26.9
CV (%)	**34.6**		**9.28**	
	After 40 days cold storage			
Preharvest treatments	**2 days at 20 ºC**		**4 days at 20 ºC**	
	With injury	**No injury**	**With injury**	**No injury**
Control	36.2 aA	35.9 aA	100.0 aA	91.0 aB
Captan (4x)	5.00 cB	10.0 bA	97.4 aA	33.7 bB
Iprodione (3x)	2.50 cB	7.50 bA	77.5 cA	47.5 bB
Iminoctadine (2x)	0.00 dA	0.00 cA	33.7 dA	5.00 dB
Tebuconazole (3x)	7.50 bA	0.00 cB	70.0 cA	21.6 cB
Difenoconazole (2x)	10.3 bA	3.75 bB	79.7 cA	35.0 bB
Azoxystrobin (3x)	5.00 bA	4.88 bA	91.2 bA	38.3 bB
Mean	6.30	8.87	78.5	38.8
CV (%)	**35.5**		**9.41**	

[1]Means followed by equal letters, lowercase in the columns and uppercase in the lines, belong to the same group by Scott Knott test ($p < 0.05$). [2] Number of preharvest applications.

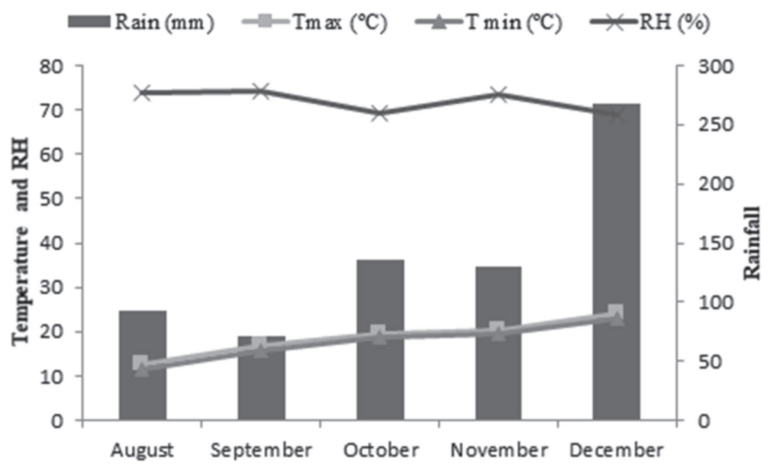

Figure 2: Rainfall, relative humidity (RH) and temperature, recorded at the weather station in Santiago, RS, Brazil (crop 2015).

Table 4: Monitoring of latent infections *Monilinia fructicola* in five sampling dates, brown rot in the field and in postharvest and the role of latent infection and external contamination in postharvest rot incidence. Santa Maria, RS, Brazil (crop 2015)

Treatments		Latent infections(%)			Brown rot incidence (%)				
		Sepals falling	Thinning	30 DAT[4]	15 DBH[5]	Harvest	Rot Field[6]	7days 20 ºC	CS + 7 days 20 ºC
Maciel	-fung.[2]	0.00	4.00	8.00	27.5	42.0	14.4	84.4	88.9
	+ fung.[3]	0.00	1.00	0.00	0.00	0.00	1.07	2.22	31.1
Eldorado	-fung.	4.00	5.00	2.50	10.0	46.6	15.7	82.2	100.0
	+ fung.	2.00	2.50	0.00	0.00	11.1	4.06	20.0	55.6

Role of latent infection and external contamination postharvest rot

		Causes brown rot at harvest				Causes of brown rot after 40 days of storage			
		Total rot infection	Latent contamination	External	Mean	Total rot	Latent infection	External contamination	Mean
Maciel	- fung.	84.4 a[1]	42.0	42.2	42.1a	88.9 a	53.3	35.6	44.4 a
	+ fung.	2.22 b	0.00	2.22	1.11b	31.1 b	28.8	2.30	15.5 b
	Mean		21.0 A	22.2 A			41.1 A	22.2 B	
	CV (%)	**17.9**	**14.9**			**10.1**	**4.21**		
Eldorado	-fung.	82.2 a	46.6	35.6	41.1 a	100.0	57.7	42.3	50.0 a
	+ fung.	20.0 b	11.1	8.90	10.0 b	55.5	40.0	15.5	27.7 b
	Mean		28.8A	22.2 A			48.8 A	28.9B	
	CV (%)	**17.7**	**26.3**			**16.6**	**7.91**		

[1] Means followed by equal letters belong to the same group by Scott Knott test ($p < 0.05$) [2] - fung.: Fruit not treated with fungicides.[3]+fung.: fruit treated with fungicide. [4]DAT: Days after thinning. [5]DBH: Days before harvest.[6]Cumulative rot values field to harvest.

Table 5: Pearson correlation between the incidence of latent infection *Monilinia fructicola* on different dates and the disease incidence at harvest and postharvest

Correlation *Pearson*	**Sepals Falling**	**Thinning**	**30 DAT(2)**	**15 DBH(3)**	**Harvest**	**Postharvest**	**After 35 days CS(4)**
Sepals Falling	1						
Thinning	*ns(1)*	1					
30 DAT	*ns*	*ns*	1				
15 DBH	*ns*	*ns*	0.96	1			
Harvest	*ns*	0.51	0.66	0.74	1		
Postharvest	*ns*	0.48	0.68	0.78	0.94	1	
After 35 days CS	0.48	*ns*	0.52	0.61	0.91	0.95	1

[1]No significant correlation ($p > 0.05$).[2] DAT: Days after thinning. [3]DBH: Days before harvest. [4] CS: cold storage.

after cold storage (Table 5). According to Emery *et al.*, (2000), although the detection of latent infections during the fruit's ripening period is important for the understanding of likely brown rot epidemics, it does not provide information in sufficient time to control the disease during preharvest. However, in this study, there was a significant correlation between the incidence of latent infection in immature fruit and the incidence of postharvest rot, confirming results obtained for Luo & Michailides (2001) & Xu *et al.*, (2007). This reinforces the importance of management strategies throughout the growth phase of fruit for disease control in the postharvest, especially after cold storage. Latent infection plays an important role in postharvest disease incidence, which may correspond to more than 50% of brown rot (Table 4).

CONCLUSIONS

Applications in the field of iprodione, tebuconazole and difenoconazole are efficient in the preharvest brown rot control, while the iminoctadine has efficacy in the disease control in postharvest, as well as acting on latent infections.

Wounds on the skin of the fruit increase the incidence of the fungus *Monilinia fructicola*, however preharvest iprodione application delays the disease.

The incidence of latent infections of the fruit has a positive correlation with postharvest brown rot, reinforcing the need for proper control of the disease during the preharvest in order to extend the postharvest life of fruit.

After cold storage, the highest incidence of brown rot is due to the manifestation of latent infections.

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