Controlling *Gloeosporium* rot on Pinova apple fruits. Part 2: evaluation of different pre- and postharvest treatments

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Abstract

*In South Tyrol (Italy), the organic apple market is becoming increasingly interested in the variety Pinova. This variety is appealing in terms of yield, appearance and taste, and is less susceptible to apple scab (*Venturia inaequalis*) than other varieties commonly grown in South Tyrol. However, the variety is susceptible to* Gloeosporium *rot (Gloeosporium album), difficult to control especially in moist years and/or in case of delayed harvest. Under these conditions, postharvest yield losses of up to 50% may occur. Over the last years, several different approaches to reduce yield losses have been evaluated. Preharvest acid clay (Mycosin and Ulmasud) sprays and postharvest hot water dipping treatments showed highest efficacy in reducing* Gloeosporium *rot. The results obtained with these control tools were presented in Part 1,* while the activity of other products, which are *still under discussion for the use in organic organic farming, are presented in Part 2.*

Keywords apple, Pinova, *Gloeosporium* rot, potassium bicarbonate, Armicarb, copper, lime sulphur, potassium soap, Conserver, $CaCl_2$, Na-silicate, acid clay

Introduction

The variety Pinova has been developed at the Institut für Obstforschung (Institute of Fruit Research), Dresden-Pillnitz (Germany), and it has been granted European Community Plant Variety Protection in 1996. Examiners approved the variety for its high yields, interesting appearance, and remarkable taste (Peil & Hanke 2005, Steiner et al. 1998, Thomann 1999). Except for problems with *Gloeosporium* rot, the variety also shows excellent storage stability. Furthermore, the variety is less susceptible to apple scab (*Venturia inaequalis*) than other varieties commonly grown in South Tyrol, and therefore considered a positive enrichment of the variety assortment, particularly by marketers of organic fruit. However, it also has some weak points, such as a certain susceptibility to powdery mildew, the tendency to secondary flower formation, and especially the susceptibility to *Gloeosporium* rot (Hellmann 2006). At the moment, in organic apple growing, no effective preharvest and/or postharvest treatments against this disease exist, and the ethylen inhibitor MPC, recently introduced into the market, is not allowed in organic farming (Rizzoli & Acler 2009). Given the results of previous studies carried out in Switzerland (Weibel et al. 2005) and Germany (Maxin & Klopp 2004, Maxin et al. 2006), we decided to investigate whether and under what conditions preharvest acid clay sprays and postharvest hot water dipping treatments would prevent the appearance of *Gloeosporium* rot over a long term (see Part 1). The results of additional trials which aimed at evaluating the efficacy of other products (copper hydroxide, carbonates, potassium soap, lime sulphur, and others) in comparision to acid clays, are discussed in this article (Part 2). An effective method for the control of this diseae in organic farming would definitely positively affect the cultivation of organic apple cv Pinova.

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Material and Methods

Trial design and treatments

The trials were carried out from 2006 to 2008 in different organic apple cv Pinova study orchards, all located in South Tyrol, Italy.

In all trials, except for the trial conducted in 2006, a randomized complete block design with 4 replications per treatment was used. Treatments were applied either with a knapsack sprayer or with a motorized sprayer equipped with a transverse current blower. With the knapsack sprayer trees were sprayed until close to run-off, while with the motorized sprayer a spray volume of 500 l per meter canopy height was applied. For the post harvest treatments (hot water dipping), an immersion tub with a variable temperature regulation system was manufactured. Details on the different study sites, the tested treatments, the application timing and rates are summarized in Table 1 - 3.

Fruits were harvested on different picking dates. The first picking date (I HD) was set at 1 week before optimal fruit ripe for picking, the second picking date (II HD) at fruit ripe for picking (BBCH 87), and the third picking date (III HD) at approximately 1 week after fruit ripe for picking. To assess for disease progression over time in the different trials, at each study site, three untreated control treatments, one for each picking date, were set up. In treated plots, instead, fruits were harvested only at the 2nd and 3rd picking date in order to provide for high disease pressure. At each picking date, 4 boxes of apples (20 kg per box) were harvested from each plot. After harvest, and after the hot water dipping in the postharvest treatments, fruits were kept in a Regular Atmosphere storage room at 1°C temperature and 95% Relative Humidity until the end of February. Fruits were then removed from storage and exposed to an additional shelf-life period of 7 days at approximately 20°C.

Table 1: description of the study sites, and the spray equipment and experimental design used in the trials conducted from 2006 to 2008.

Year	Location	Height (m asl)	Planting year	Planting density	Treatment equipment	Experimental design
2006	St. Leonhard	640	2001	3,5 x 1,0 m	Knapsack sprayer	no replications, large plots
2007	Meran	650	2001	3,2 x 1,0 m	Knapsack sprayer	4 replications ,randomised
2008	Meran	730	2000	3,5 x 1,0 m	Sprayer	4 replications ,randomised

Assessments

After 5 months of storage and 7 days of shelf-life period at 20°C, the number of fruits showing *Gloeosporium* rot symptoms was recorded.

Statistical analysis

The percentages of fruits affected by Gloeosporium rot were compared across treatments using 1-way ANOVAs followed by Student-Newman-Keuls' test for posthoc comparisons of means ($P<0.05$). To improve homoschedasticity, data expressed in percentages were arc sin (radq(x/100)) -transformed. All analyses were performed with the statistics programme PASW 17.

Table 2: description of the different treatments tested in the trials conducted from 2006 to 2008.

Year	Treatment	Picking date	Trade name	Producer	Rate / 100 l
2006	Control	III HD	-	-	-
	Acid clay	III HD	Mycosin	Biofa	1000 g
	Potassium bicarbonate	III HD	Armicarb	Helena Chimical	510 g
	Potassium bicarbonate	III HD	PBC	ACEF	510 g
	Sodium bicarbonate	III HD	NaBC	Solvay	510 g
	Potassium carbonate	III HD	Kalikarbonat	ACEF	510 g
	Copper hydroxide	III HD	Kocide 3000	Dupont	20 g met. Cu
	Potassium soap	III HD	Flipper	Agroqualità	1000 g
	Sugar	III HD	Zucchero	Eridania	1000 g
	Lime sulphur	III HD	Calcium	Solfotecnica	1000 g
	Water glass	III HD	Sodio Silicato 38/40 Be	Torchiani	1000 g
	Yeast (dipping 60")	III HD	Boni Protect	Bio Protect	300 ml
2007	Control	I HD	-	-	-
	Control	II HD	-	-	-
	Control	III HD	-	-	-
	Acid clay	III HD	Mycosin	Biofa	1000 g
	Acid clay	III HD	Ulmasud	Biofa	1000 g
	Potassium bicarbonate	III HD	Armicarb	Helena Chimical	425 g
	Copper hydroxide	III HD	Copper (Kocide 3000)	DuPont	20 g
	Lime sulphur	III HD	Polisulfuro di Calcio	Polisenio	1000 g
2008	Control	II HD	-	-	-
	Control	III HD	-	-	-
	Potassium bicarbonate	II HD	Armicarb	Helena Chimical	700 g
	Potassium bicarbonate	III HD	Armicarb	Helena Chimical	700 g
	Acid clay	II HD	Ulmasud	Biofa	1000 g
	Acid clay	III HD	Ulmasud	Biofa	1000 g
	Acid clay	II HD	Mycosin	Biofa	1000 g
	Acid clay	III HD	Mycosin	Biofa	1000 g
	Copper hydroxide	II HD	Coprantol Hi Bio (25%)	Syngenta	60 g
	Copper hydroxide	III HD	Coprantol Hi Bio (25%)	Syngenta	60 g
	Water glass	III HD	SodioSilicato 38/40 Be	Torchiani	700 g
	$CaCl_2$ (in field)	III HD	Cloruro di calcio	Cesa	200 g
	$CaCl_2$ (in field + dipping 60")	III HD	Cloruro di calcio	Cesa	200g + 200g
	Microrganisms	III HD	Ekoprop Poliver	Blueline	100 g
	Fermentation output	III HD	Conserver	Blueline	100 g

Table 3: Timing of application of treatments in the different trials conducted from 2006 to 2008.

2006	2007	2008
25.08.06	04.08.07	22.08.08
01.09.06	10.08.07	29.08.09
08.09.06	16.08.07	08.09.08
15.09.06	23.08.07	12.09.08
22.09.06	30.08.07	19.09.08
30.09.06	06.09.07	26.09.08
-	14.09.07	-

Results

Table 4 – mean percentage of fruits affected by *Gloeosporium* rot in the different treatments and trials after 5 month of storage and 7 days of shelf-life period at 20°C. Different letters within the same trial indicate statistically significant differences (SNK test: P>0.05).

Year	Treatment	Harvesting date	% affected fruits	Statistic
2006	Control	III HD	38,8	c
	Mycosin 1000 g / hl	III HD	7,7	a
	Armicarb 510 g / hl	III HD	8,3	ab
	PBC 510 g / hl	III HD	45,3	c
	NaBC 510 g / hl	III HD	36,0	c
	Kalikarbonat 510 g / hl	III HD	44,0	c
	Kocide 3000 20 g met Cu / hl	III HD	14,4	b
	Flipper 1000 g / hl	III HD	77,6	d
	Sugar 1000 g / hl	III HD	44,7	c
	Calcium 1000 g / hl	III HD	43,0	c
	SodioSilicato 38/40 Be 1000 g 7 hl	III HD	48,0	c
	Boni Protect 300 ml / hl	III HD	57,9	c
2007	Control	I HD	13,0	a
	Control	II HD	17,9	a
	Control	III HD	82,0	c
	Mycosin 1000 g / hl	III HD	71,1	c
	Ulmasud 1000 g / hl	III HD	47,4	b
	Armicarb 425 g / hl	III HD	77,8	c
	Copper (Kocide 3000) 20 g / hl	III HD	73,7	c
	Polisulfuro di Calcio 1000 g / hl	III HD	85,8	c
2008	Control	II HD	28,2	bcd
	Control	III HD	43,9	d
	Armicarb 700 g / hl	II HD	24,0	abcd
	Armicarb 700 g / hl	III HD	46,5	d
	Ulmasud 1000 g / hl	II HD	11,4	ab
	Ulmasud 1000 g / hl	III HD	14,6	abc
	Mycosin 1000 g / hl	II HD	8,1	a
	Mycosin 1000 g / hl	III HD	22,4	abcd
	Coprantol Hi Bio (25%) 60 g / hl	II HD	21,1	abcd
	Coprantol Hi Bio (25%) 60 g / hl	III HD	25,1	abcd
	SodioSilicato 38/40 Be 700 g / hl	III HD	20,7	abcd
	Cloruro di calcio 200 g / hl	III HD	35,7	cd
	Cloruro di calcio 200 g + 200 g / hl	III HD	43,4	d
	Ekoprop Poliver 100 g / hl	III HD	26,8	bcd
	Conserver 100 g / hl	III HD	14,2	abc

In 2006, 10 preharvest treatments (spray applications) and 1 postharvest treatment (dipping) were compared (Table 4). The treatments based on preharvest applications of water glass, lime sulphur, sugar, potassium carbonate, sodium carbonate and unformulated potassium bicarbonate on fruits of the 3^{rd} picking date did not result in a significant decrease of *Gloeosporium* rot-infested fruits compared to the untreated control, and neither did the postharvest dipping of fruits into Boni Protect. Highest *Gloeosporium* rot levels were recorded for the Potassium soap-based preharvest treatment (considerably higher than in the untreated control treatments). Preharvest applications of copper hydroxide, Armicarb (a formulated product with potassium bicarbonate as active ingredient), and the acid clay Mycosin, instead, significantly reduced disease incidence on fruits of the 3rd picking date, with efficacy values ranging from 62.9% for copper hydroxide to 78.6% for Armicarb and 80.1% for Mycosin.

In 2007, we decided to evaluate again the efficacy of some of the products tested in 2006, that is the acid clays Mycosin and Ulmasud, Armicarb, copper hydroxide (20g pure copper per 100 l), and lime sulphur on fruits of the 3rd picking date. In this trial, disease pressure was extremely high (82% *Gloeosporium* rot infested fruits on untreated control fruits of the 3rd picking date; Table 4), and none of the tested treatments resulted in a significant reduction of the percentage of diseased fruits except Ulmasud (efficacy: 42.2%).

In 2008, the efficacy of preharvest applications of Armicarb, Ulmasud, Mycosin, and copper hydroxide was evaluated on fruits of both the 2nd and 3rd picking date, while that of preharvest applications of water glass, Ekoprop Poliver, Conserver, and of $CaCl_2$ (both preharvest applications and postharvest dipping) was established on fruits of the 3rd picking date. Armicarb and $CaCl_2$ provided negligible disease control (below 20%), while partial disease reduction was obtained with copper hydroxide (efficacy: respectively 25.1 and 42.9% on fruits of the 2nd and 3rd picking date), water glass (efficacy: 52.8%), Ekoprop Poliver (efficacy: 38.9%), the acid clays Mycosin and Ulmasud (efficacy: 49.1-71.4%), and Conserver (efficacy: 67.7%).

Discussion

The variety Pinova is an interesting variety for organic apple growing because of its good appearance, excellent taste, and high and consistent yields. Also plant protection is not extremely challenging, because the variety shows relatively low susceptibility to apple scab, the major fungal disease on apple. Furthermore, Pinova is suitable for long term storage, because fruit firmness and taste are preserved over a long period of time. However, during and after storage, problems may arise due to *Gloeosporium* rot. In case of delayed harvest, yield losses of up to 50% may occur. Our studies aimed at evaluating tools for suppressing *Gloeosporium* rot in organic farming, and they have been described in 2 different articles (Controlling *Gloeosporium* rot on Pinova apple fruits, Part 1 and 2).

In Part 2, the results obtained with additional products, which are under discussion for the use in organic farming, are reported. The tested products are: unformulated carbonates (K-carbonate, K-bicarbonate, Na-bicarbonate), formulated K-bicarbonate (Armicarb), lime sulphur, $CaCl_2$, water glass (Na-silicate), copper hydroxide, K-soap, sugar, Boni Protect (active ingredient: *Aurobasidium pullulans*) used as postharvest dipping treatment, Ekoprop Poliver (a mixture of different microrganisms) and Conserver (a ferment).

The acid clay-based treatments acted as reference treatments. Preharvest applications of K-soap considerably increased *Gloeosporium* rot on stored fruits, and the unformulated carbonates, lime sulphur, sugar, water glass, $CaCl_2$ and Boni Protect did not provide satisfactory disease control.

Armicarb gave very good results the first year, but these results were not confirmed the following years.

Copper hydroxide and Ekoprop Poliver showed partial efficacy in reducing disease incidence, while efficacy values obtained with Conserver were comparable to those recorded for the acid clays. However, Ekoprop Poliver and Conserver were tested only in one study year, and their efficacy should therefore be confirmed in additional trials.

References

Hellmann, M. (2006). Gloeosporium - Fruchtfäulebekämpfung bei ‚Pinova'. *Obstbau*, **(8)**, 425-426

Maxin P., Kolpp K. (2004). Zur Wirtschaftlichkeit des Heißwasserverfahrens. 11th International Conference on Cultivation Technique and Phytopathological Problems in Organic Fruit-Growing. Fördergemeinschaft Ökologischer Obstbau e. V. Weinsberg, (11), 75-78

Maxin P., Fieger-Metag, N., Benduhn, B., Kruse, P., Heyne, P. (2006). Stand der Umsetzung des Heißwasserverfahrens nach vierjähriger Versucharbeit auf den Obstbaubetrieben in Norddeutschland. 12th International Conference on Cultivation Technique and Phytopathological Problems in Organic Fruit-Growing. Fördergemeinschaft Ökologischer Obstbau e. V. Weinsberg, (12), 118-120

Peil, A., Hanke, M. V. (2005). Apfelzüchtung in Deutschland – vom Samen zur Sorte. *Forschungsreport*, **(2)**, 10-13

Rizzoli, W., Acler, A. (2009). Versuche zur Bekämpfung der Gloeosporium Fruchtfäule bei Pinova. *Obstbau Weinbau*, **(7/8)**, 267-271

Stainer, R., Tscholl, H., Thomann, M. (1998). Pinova – eine Sorte für Mittelgebirgslagen? *Obstbau Weinbau*, **(9)**, 271-273

Thomann, M. (1999). Pinova – erste Erfahrungen im Anbau und Vermarktung. *Obstbau Weinbau*, **(10)**, 289-290

Weibel, F, Hahn, P., Lieber, S., Häseli, A., Amsler, T., und Zingg D. (2005). Lutte contre Gloeosporium (album et perennans) des pommes biologiques Post-Recolte avec des produits oxidants et des eaux électrolytiques et Pre-Recolte avec differents produits biologiques entre 2001-2004. *Journées Techniques Fruits & Légumes et Viticulture Biologiques,* **120**