Controlling *Gloeosporium* rot on Pinova apple fruits. Part 1: preharvest acid clay sprays versus postharvest hot water dipping treatments

M. Kelderer[1], C. Casera. E., Lardschneider, A. Rainer

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, post harvest 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 are presented, while the activity of other products, which are still under discussion for the use in organic organic farming, will be presented in Part 2.

Keywords apple, Pinova, *Gloeosporium* rot, acid clay, Ulmasud, Mycosin, hot water dipping

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 as 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 MCP, 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. An effective method for the control of this disease in organic farming would definitely positively affect the cultivation of organic apple cv Pinova.

[1] VZ-Laimburg, 39040 Post Auer, Südtirol, Italien; Markus.Kelderer@provinz.bz.it

Material and Methods

Trial design and treatments

The trials were conducted from 2005 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 completely randomized 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.

Table 1: Description of the study sites, the spray equipment and the experimental design used in the trials conducted from 2005 to 2008.

Year	Location	Height (m asl)	Planting year	Planting density	Spray equipment	Experimental design
2005	Auer	220	2001	3,5 x 1,0 m	Sprayer	4 replications ,randomised
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

Fruits were harvest on different picking dates. The first picking date (I HD) was set at 1 week before optimal fruit ripe for picking (BBCH 87), the second picking date (II HD) at fruit ripe for picking, 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 (16 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 cold storage and exposed to an additional shelf life period of 7 days at approximately 20°C.

Table 2: Description of the different treatments tested in the trials conducted from 2005 to 2008.

Year	Treatment	Picking date	Trade name	Applied rate (g/hl) / Dipping conditions
2005	Control	I HD	-	-
	Control	II HD	-	-
	Control	III HD	-	-
	Acid clay	III HD	Mycosin	1000
	H_2O	III HD		50°C x 120"
2006	Control	I HD	-	-
	Control	II HD	-	-
	Control	III HD	-	-
	Acid clay	III HD	Mycosin	1000
	H_2O	III HD	-	50°C x 180 "
	H_2O	III HD	-	50°C x 60 "
2007	Control	I HD	-	-
	Control	II HD	-	-
	Control	III HD	-	-
	Acid clay	III HD	Mycosin[1]	1000
	Acid clay	III HD	Ulmasud[1]	1000
	Acid clay	III HD	Mycosin[2]	1000
	Acid clay	III HD	Mycosin[2]	500
	Acid clay	III HD	Ulmasud[2]	1000
	Acid clay	III HD	Ulmasud[2]	500
	H_2O	III HD	-	50°C x 60"
	H_2O	III HD	-	50°C x 180 "
	H_2O	III HD	-	55°C x 60 "
	H_2O	III HD	-	55°C x 120 "
	Control (hot water dipp.)	III HD	-	-
2008	Control	I HD	-	-
	Control	II HD	-	-
	Control	III HD	-	-
	Acid clay	II HD	Ulmasud	1000
	Acid clay	III HD	Ulmasud	1000
	Acid clay + H_2O	III HD	Ulmasud	1000 + 50°C x 180“
	Acid clay	II HD	Mycosin	1000
	Acid clay	III HD	Mycosin	1000
	Acid clay + H_2O	III HD	Mycosin	1000 + 50°C x 180“
	H_2O	II HD	-	50°C x 180 "
	H_2O	III HD	-	50°C x 180 "

[1] Treatment application up to mid August
[2] Treatment application from mid August up to harvest

Table 3: Timing of application of treatments in the different trials conducted from 2005 to 2008.

2005	2006	2007	2008
30/08/05	25/08/06	06/07/07	22/08/08
06/09/05	01/09/06	13/07/07	29/08/08
-	08/09/06	20/07/07	08/09/08
-	15/09/06	27/07/07	12/09/08
-	22/09/06	04/08/07	19/09/08
-	30/09/06	10/08/07	26/09/08
-	-	16/08/07	-
-	-	23/08/07	-
-	-	30/08/07	-
-	-	06/09/07	-
-	-	14/09/07	-

Assessments

After 5 months of cold 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.

In 2005 in Auer, 5 different treatments were compared. No preharvest open field sprays were applied in 4 out of the 5 treatments. Three treatments acted as untreated control treatments, but fruit samples for storage were collected on 3 different successive picking dates (HD) in order to evaluate disease progression over time. In treatment 4, fruits were harvested at the 3rd picking date, and then exposed to postharvest hot water dipping at 50°C for 2 minutes. In treatment 5, instead, the plots were sprayed with the acid clay Mycosin before harvest, and fruits were collected at the 3rd picking date and then transferred to storage.

After storage and 7 days of shelf life period at 20°C, the percentage of fruits affected by *Gloeosporium* rot in the untreated control amounted to 9.1% on fruits harvested the 1st picking date, 12.9% on those harvested the 2nd picking date, and 33.4% on those harvested the 3rd picking date. In the Mycosin-based treatment, the percentage of diseased fruits was 29.2 %, and the efficacy in disease reduction was 12.5%. In the postharvest hot water dipping treatment, 20.7% of the fruits showed disease symptoms, and the efficacy of the treatment was 22.8%. No significant differences among treatments were recorded (Table 4).

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
2005	Control	I HD	9,1	a
	Control	II HD	12,9	ab
	Control	III HD	33,4	b
	Mycosin 1000 g /hl	III HD	29,2	b
	H_2O 50°C x 120"	III HD	20,7	ab
2006	Control	I HD	21,5	b
	Control	II HD	31,9	b
	Control	III HD	38,8	b
	Mycosin 1000 g /hl	III HD	7,7	a
	H_2O 50°C x 180 "	III HD	10,5	a
	H_2O 50°C x 60 "	III HD	39,6	b
2007	Control	I HD	13,0	a
	Control	II HD	17,9	a
	Control	III HD	82,0	d
	Mycosin[1] 1000 g /hl	III HD	64,4	bc
	Ulmasud[1] 1000 g / hl	III HD	58,0	bc
	Mycosin[2] 1000 g /hl	III HD	71,1	bcd
	Mycosin[2] 500 g /hl	III HD	73,9	cd
	Ulmasud[2] 500 g / hl	III HD	47,4	b
	Ulmasud[2] 500 g /hl	III HD	63,3	bc
	H_2O 50°C x 60"	III HD	39,6	b
	H_2O 50°C x 180 "	III HD	19,9	a
	H_2O 55°C x 60 "	III HD	23,4	a
	H_2O 55°C x 120 "	III HD	31,0	ab
	Contol (hot water dipp.)	III HD	43,6	b
2008	Control	I HD	23,3	abc
	Control	II HD	28,2	cd
	Control	III HD	43,9	d
	Ulmasud 1000 g / hl	II HD	11,4	ab
	Ulmasud 1000 g /hl	III HD	14,6	ab
	Ulmasud 1000 + 50°C x 180“	III HD	8,3	a
	Mycosin 1000 g /hl	II HD	8,1	a
	Mycosin 1000 g /hl	III HD	22,4	abc
	Mycosin 1000 g / hl + 50°C x 180“	III HD	6,9	a
	H_2O 50°C x 180 "	II HD	10,3	ab
	H_2O 50°C x 180 "	III HD	17,5	ab

[1] Treatment application up to mid August
[2] Treatment application from mid August up to harvest

In 2006 in Sankt Leonhard in Passeier, 6 treatments were compared. In addition to the 3 untreated control treatments, one for each of the 3 different picking dates, a treatment based on preharvest applications of Mycosin, and 2 different postharvest hot water dipping treatments were tested.
After storage, the percentage of *Gloeosporium* rot affected fruits was 21.5% on fruits of the 1st picking date, 31.9% on those of the 2nd picking date, and 38.8% on those of the 3rd picking date. The percentage of diseased fruits was 7.7% in the Mycosin treatment (efficacy: 80.1%), 10.5% in fruits exposed to hot water dipping at 50°C for 3 minutes (efficacy: 73.0%), and 39.6 in fruits exposed to hot water dipping at 50°C for 1 minute. This latter treatment did not show any efficacy in reducing *Gloeosporium* rot on stored fruits. Mycosin and hot water dipping at 50°C for 3 minutes resulted in percent values of diseased fruits, which were comparable to those of untreated control fruits of the 1st picking date and significantly lower than those of untreated control fruits of the 2nd and 3rd picking date and of fruits dipped in hot water for just 1 minute (Table 4).
In the trial conducted in 2007 in Meran, 14 treatments were compared. Again, 3 untreated control treatments, one for each of the 3 different picking dates, were used to establish disease progression over time. In 6 additional treatments, the efficacy of two different acid clays (Mycosin and Ulmasud), tested at different application rates and timings, was evaluated. Four postharvest hot water dipping treatments were used to compare different temperatures and time intervals of hot water dipping. Infestation values recorded for the hot water dipping treatments were compared to those observed in an additional 4th untreated control treatment, designated as Control (Hot water dipp.) in Table 4.
After storage and 7 days of shelf life period at 20°C, in the untreaed control, 13.0% of the fruits of the 1st picking date were affected by *Gloeosporium* rot, 17.9% of those of the 2nd picking date, and 82.0% of those of the 3rd picking date. In all the other treatments, fruits had been harvested at the 3rd picking date. Mycosin and Ulmasud applied between Juli and August only slightly reduced the percentage of diseased fruits (efficacy: 21.5% and 29.3%, respectively). Also applications from mid August on did not result in a considerable reduction of the infestation. Mycosin applied at the recommended field rate (1000 g/hl) showed an efficacy of approximately 10%, and that of Mycosin applied at half the recommended field rate was even lower. Slightly better results were obtained with Ulmasud: the percentage of infested fruits was reduced from 82.0% to 47.4% when the product was applied at the recommended field rate, and to 63.3% when the product was applied at a lower than recommended rate (Table 4). The percentage of *Gloeosporium* rot-infested fruits in the untreated control of the hot water dipping treatments amounted to 43.6%. Percent infestation was reduced to 39.6% by hot water dipping at 50°C for 1 minute, to 19.9% by hot water dipping at 50 °C for 3 minutes, to 23.4% by hot water dipping at 55°C for 1 minute, and to 31.0% by hot water dipping at 55°C for 2 minutes (see Table 4 for statistical analysis).
Also in 2008, the trial was conducted in Meran, and 11 treatments were compared. Three out of the 11 tested treatments were used to assess for diease progression over time, 3 to assess for the efficacy of preharvest sprays of Ulmasud, 3 to evaluate that of preharvest sprays of Mycosin, and 2 treatments to establish the efficacy of post harvest hot water dipping alone. In the acid clay-based treatments (3 per product), applications and picking dates were scheduled as follows: 1. preharvest application of acid clay, harvest of fruits the 2nd picking date, and transfer to storage; 2. preharvest application of acid clay, harvest of fruits the 3rd picking date, and transfer to storage; 3. preharvest application of acid clay, harvest of fruits the 3rd picking date, postharvest hot water dipping at 50°C for 3 minutes, and transfer to storage. In addition, postharvest hot water dipping alone at 50°C for 3 minutes was applied also to fruits collected the 2nd and 3rd picking date.

After storage and 7 days of shelf life period at 20°C, *Gloeosporium* rot in the untreated control treatments amounted to 23.3 % for the 1st picking date (I HD), 28.2 % for the 2nd picking date (II HD), and 43.9% for the 3rd picking date. In the Ulmasud-based treatments, percent infestation was 11.4 % on fruits of the 2nd picking date (efficacy: 59.4%), 14.6% on fruits of the 3rd picking date (efficacy: 66.7 %), and 8.3% on fruits exposed to preharvest applications of Ulmasud, followed by postharvest hot water dipping (efficacy: 81.2%). Similar results were obtained with the Mycosin-based treatments (efficacy: 71.4 %, 49.1 %, and 75.7%, respectively). In fruits exposed to postharvest hot water dipping alone, the percentage of *Gloeosporium* rot-infested fruits was 10.3% on those of the 2nd picking date and 17.5% on those of the 3rd picking date (efficacy: 63.4 and 60.1%). Statistically treatments can be grouped as reported in Table 4.

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 1, the results obtained with preharvest acid clay (Mycosin and Ulmasud) sprays and postharvest hot water dipping treatments are reported.

In 2005, the efficacy of 2 preharvest applications of Mycosin was compared to that of postharvest hot water dipping at 50°C for 2 minutes, but none of the tested treatments provided satisfactory disease control: the efficacy of Mycosin amounted to 12.5%, and that of the hot water dipping treatment to 38.1%.

In 2006, the number of open field preharvest applications was increased to 6, and the duration of the hot water dipping to 3 minutes. This resulted in a promising increase in efficacy values (80.1% for 6x1000 g/hl Mycosin and 73.0% for 3 minutes of hot water dipping at 50°C).

In 2007, we thus decided to further investigate the products available on the market, the timing of the applications, and the application rates of acid clays. For the hot water dipping, we also tested higher temperatures. Ulmasud always provided better disease control than Mycosin, and for both products an evident dose-response effect emerged: the efficacy of the products was always considerably lower than at the higher rate. No clear differences with regard to timing of the applications emerged: both applications up to mid August and applications from mid August on were able to suppress *Gloeosporium* rot on stored fruits, but the efficacy was low. This may be due to the high disease pressure (82.0% diseased fruits in the untreated control). In the postharvest hot water dipping treatments, disease pressure was much lower (43.6% diseased fruits in the untreated control), and best results were obtained when fruits were dipped in hot water at 50°C for 3 minutes.

Due to the high disease pressure observed in 2007, in 2008 we decided to repeat the trial by testing similar treatments, and to evaluate their efficacy on both fruits harvested at the 2nd and 3rd picking date. In addition, the efficacy of a combination of preharvest sprays and postharvest hot water dipping was investigated. In 2008, *Gloeosporium* rot infestation in the untreated control was 28.3% and 43.9% on fruits of the 2nd and 3rd picking date, respectively. Under these trial conditions, the efficacy of the preharvest acid clay

treatments ranged from 49.1 to 71. 4%, while that of the combination of preharvest acid clay sprays with postharvest hot water dipping always exceeded 75% (75.7 and 81.2%, respectively).

To summarize, both preharvest acid clay sprays and postharvest hot water dipping treatments can reduce *Gloeosporium* rot on fruits, but harvesting fruits at the appropriate timing is of sound importance to efficiently reduce losses due to *Gloeosporium* rot.

References

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

Maxin, P., Klopp, 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**