Strategic irrigation can reduce apple scab (*Venturia inaequalis* (Cke.) Wint.)

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Abstract

Several Danish organic orchards seek methods to prevent apple scab without spraying. In the years 2011-2013 a new strategy was tested: Irrigation with water at strategic moments to prevent scab infection.

In the period from late April to late June 2011 and 2012, five organic orchards were irrigating the orchard floor to elicit the release of ascospores. The irrigation took place in dry periods 12 to 24 hours before rain forecast.

The goal was to empty the stock of ripe ascospores during dry spells, leaving them on the dry leaves to dry out, subsequently causing no infection. The best strategic moments for irrigation, was defined by using the local weather forecast and the scab-warning programme Rimpro based on data from climate stations located in the orchards.

The experiments showed that irrigation can cause the release of ascospores. In one orchard in 2012 the effect on the scab-attack was significant. Irrigation five times during spring reduced the percentage of apple scab from 47 % to 12 % in the apple cultivar 'Rubens'. This significant result was achieved in an orchard using both the strategic irrigation and preventive sprays with sulphur. In totally unsprayed orchards there was no significant effect of the strategic irrigation.

Closer studies of the ascospores took place at the University of Copenhagen in 2012 and 2013. The ascospore reaction to amount of water, water quality, drop size and the sound of rain was studied.

The pilot-trial was financed by "The foundation for Organic Agriculture" in 2011 and 2012. In 2012 and 2013 the investigations continued at the University of Copenhagen, financed by the Ministry of Food, Agriculture and Fisheries of Denmark.

Keywords: *Venturia inaequalis,* non-spraying, irrigation, prevention, organic apple production.

Introduction

The fungus disease Apple scab (*Venturia inaequalis* (Cke.) Wint.*)* is a big problem in apple production. Apple scab infects leaves and fruits, causing spots. The yield is reduced, especially in susceptible cultivars and in humid seasons. Some Danish organic growers use Sulphur sprays to reduce scab, but several organic growers in Denmark have chosen to grow apples totally unsprayed. In these orchards they seek alternative methods to prevent apple scab.

The fungus overwinters mainly in the old leaves on the orchard floor. The ascospores ripen during spring, and when it rains, they are discharged from the old leaves. The ascospores are then carried by the wind to the young leaves, where they can germinate and infect the leaf depending on temperature and the hours of leaf wetness (MacHardy 1996).

In 2008 and 2009 the weather in spring and early summer was dry with only a few showers of rain, and apple scab was a minor problem in Denmark.

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These two seasons with a very low level of scab-infections were the inspiration for developing a method to prevent scab by irrigating at strategic moments during dry spells.

The hypothesis is that if you irrigate the orchard floor, the ripe ascospores will be discharged, as if it was raining. The idea is only to irrigate, when the weather is still dry, and is forecasted to stay dry for a while, but rain is coming soon. If so, the ascospores will never be able to germinate and infect the leaves, but will dry out. When the rain comes, the stock of ripe ascospores will be low, and you would expect a lower risk of infection. Such a scab prevention method would be helpful to all fruit growers, no matter the production method.

Material and Methods

The investigations were carried out in 2011-2013.

In 2011 and 2012, the trials took place in five organic apple orchards. In three of them we established an irrigation system with sprinklers to irrigate the orchard floor. In two orchards, the growers used a wagon with a water tank and a sprinkler bar. (Figure 1)

The irrigation simulated short showers of rain during dry spells from beginning of April till the beginning of June.

In 2011 the growers decided themselves when to irrigate. Their decision was supported by the local weather forecast combined with the scab warning-system Rimpro, based on data from their own climate station. In 2012 their decision was also supported by my advice.

They were advised to turn on the irrigation in situations, when Rimpro indicated many ripe ascospores, and the weather was dry, and rain was forecasted the following day. In 2011 we counted on irrigating, when rain was forecasted after 12 hours. In 2012 we aimed to irrigate when rain was forecasted later than 24 hours. In 2012 we also paid attention to the air humidity, and irrigated if possible, when air humidity was forecasted to stay below 85 % RH within the following 24 hours.

The growers irrigated with at least 0.2 mm water (0.2 l/m^2). In 2012, each irrigation was repeated after 1 hour.

In the orchards with sprinkler-systems, we irrigated every other plot of 15m tree-row in 6 rows.

In the two orchards with water wagon the 6 rows were irrigated and compared to 6 rows without irrigation. Data was collected from the central 2 rows.

The degree of scab attack on the leaves and on the apples got registered in July on 5 trees in the middle of every 6-9 plots with sprinkler set-up, and in 12 plots within the water wagon set-up. The infection level on the apples got registered again in September, right before harvest.

In 2011 the five trial-hosts irrigated against scab from 4-12 times during April and May, and in 2012 they irrigated 4-8 times (Table 1).

The differences reflect the different climatic situations in the five orchards and their slightly different strategies of irrigation in 2011. Some of the hosts choose to irrigate once a week during dry spells to empty the stock of ascospores combined with irrigation the day before rain forecast. Other hosts choose only to irrigate the day before rain forecast.

Three of the orchards are managed without any fungicides; two of the orchards are sprayed with sulphur sprays.

Figure 1: The waterwagon from the orchard Harndrup. It is a resused mistsprayer, where the pump was geared up. Mounted with a bar with sprinklers

Figure 2: The experiment in Taastrup. The sprinklers are SpinNet microsprinklers, model 160 sprinkling only on the ground.

At the University of Copenhagen, at the location in Taastrup, more investigations were carried out in 2012 and 2013. The discharge of ascospores was observed in different types of spore traps to study the ascospore reaction to irrigation compared to rainfall. Different types of irrigation was tested: watercan (big drops), sprinkler (medium drops) atomizer (small drops), rainwater contra tapwater and also sound impact.

One row of 'Elstar' apples was established with a sprinkler system to test the strategic irrigation method also in Taastrup. The sprinklers were put up in every second plot of 7 trees, repeated 4 times. The degree of scab attack on leaves and fruits were counted in the 3 trees in the centre of every plot (Figure 2).

Results

In 2011 there was no effect of the irrigation in two orchards having less than 1 % scab due to a very dry spring. In both of the orchards, sulphur sprays were used to control scab.

In 2011 in other two orchards there was a tendency to a small effect of the irrigation while the level of scab in July was reduced. (Korsgaard 2012) The weather turned then very humid, and the level of scab rose fast in July and August. In September 39 - 74 % of the apples had spots caused by both scab and by "Elsinoe leaf and fruit spot" (*Elsinoe pyri)* also known as "Topaz-spots" (Glazowska *et al*. in press).

In 2012 the strategic irrigation resulted in a significant reduction of the scab attack in one orchard out of five (Table 1).

In the orchard "Harndrup" the strategic irrigation reduced the percentage of apple scab from 47 % to 12 % in the apple cultivar 'Rubens' in September. This statistically significant result was achieved in this orchard using both the strategic irrigation and preventive sprays with sulphur and bicarbonate. This grower was using a water wagon for sprinkling water on the orchard floor. 0,2 mm water was spread early in the morning, and repeated after 1 hour, five times during spring.

In the unsprayed orchards there was no significant effect of the strategic irrigation in 2012.

Table 1: Effect of strategic irrigation on the degree of infection with apple scab and *E. pyri* 2012

				July 2012	**July 2012**	**Sept. 2012**	**Sept. 2012**
Orchard	**Treatment**	**Other treatments**	**Apple Cultivar**	**% Leaves with scab**	**% Fruit with scab**	**% Fruit with Elsinoe-spot *(E. pyri)***	**% Fruit with scab**
Kysøko	Irrigated	Unsprayed	Holst. Cox	37,5			
Kysøko	Non irrigated	Unsprayed	Holst. Cox	37,2			
Lærkehøj	Irrigated	Unsprayed	Red Aroma	1,0	66,7*	92,7	6,7
Lærkehøj	Non irrigated	Unsprayed	Red Aroma	2,1	65,3*	95,5	12,0
Vellinge	Irrigated	Unsprayed	Red Gravenstein	17,7			
Vellinge	Non irrigated	Unsprayed	Red Gravenstein	18,9			
Bellinghus	Irrigated	Sulphur	Aroma	1,3	2,4	0	4,8
Bellinghus	Non irrigated	Sulphur	Red Aroma	5,7	3,9	0	4,1
Harndrup	Irrigated	Sulphur + bicarbonate	Rubens	1,7	1,5	0	12,2
Harndrup	Non irrigated	Sulphur + bicarbonate	Rubens	3,8	7,5	0	47,3

*) At this time it was not possible to differ between scab and Elsinoe spots.

Table 2: The effect of strategic irrigation in relation to the number and times of irrigation and the times for scab-warning 2012

Orchard	Times of irrigation	Dates of irrigation	Dates of Scab-infection according to local Rimpro-warning.	Effect of irrigation on scab on leaves in July	Effect of irrigation on scab on fruit in Sept. .
Kysøko	11 and 13 a.m.	20/3, 6/4	11/4	+1 %	
		20/4, 4/5, 6/5, 9/5	10/5, 16/5		
		28/5, 6/6			
Lærkehøj	11 and 12 a.m.	5/4	11/4	-52 %	- 44 %
		20/4	25/4		
		4/5, 6/5, 8/5	10/5, 16/5		
		28/5	30/5		
Vellinge	9 and 10 a.m.	27/3, 4/4	11/4	-6 %	
		16/4	22/4		
		4/5, 7/5	9/5,16/5		
		29/5, 4/6	9/6		
Bellinghus	11 a.m., only one irrigation	4/4	10/4	-77 %	+ 17 %
		20/4	23/4, 26/4		
		3/5, 7/5	10/5		
Harndrup	8 and 10.a.m.	19/4	22/4, 25/4 , 26/4	-55 %	-74 %
		2/5, 6/5	9/5, 16/5		
		23/5, 5/6	8/6		

Comparing the different dates of irrigation with the dates of infection warning indicates big differences in strategy (Table 2).

At Kysøko they irrigated 8 times, but only 3 infection periods were forecasted by Rimpro. This strategy was not optimal.

At Harndrup, who got the best result, they irrigated 5 times and Rimpro forecasted 6 infection periods. The largest infection occurred the 9th of May. This was aimed to be

prevented by two irrigations at the 2nd and the 6th of May. All of the irrigations at Harndrup was followed by a dry period with RH below 85 % in at least 13,5 hours. In the case of the most important infection the 9th of May, there was a time window of 19 hours between the previous irrigation until humidity exceeded 85 % RH. That might explain the good results, while ascospores needs time both for discharging and successively for drying out.

At the University orchard in Pometet in Taastrup, the strategic irrigation was carried out in 2012 and 2013 in a row of Elstar.

The results from both years in Taastrup are rather disappointing, there was no effect of the strategic irrigation, and the infection level of scab in the Elstar was very high.

The absence of any effect in Taastrup might be due to the small plot size.

The study of ascospores has given various results. In 2012 the ascospore discharge was registered to occur in more than 5½ hour after irrigation. Rain provoked relatively more ascospores discharge than the irrigation with sprinklers.

In 2013 the ascospores discharged already from the 11th of April, 17 days before Green Tip. The 29th of April there was a shower of rain giving 0,2 mm in the afternoon. The reaction to that was measured in spore traps (Figure 3 and 4). Only 1 % in average of the pool of ascospores was discharged by 0,2 mm of rain, despite that there was app. 11 % ripe ascospores according to Rimpro.

Late in May the ascospore discharge after irrigating with respectively rainwater or tapwater was measured. The irrigation was done by water can, with large drops. The relative discharge of ascospores was only 82 % and 89 % when using tapwater in relation to rainwater. A maximum of 47 % of the pool of ascospores was discharged after one irrigation with 3,7 mm rainwater using a water can.

The study also showed, that the sound of rain does not affect the discharge of ascospores, nor does irrigation with mist.

Discussion

The conclusion of the orchard trials in 2011-12 is that in some seasons it is possible to reduce the infection of scab by strategic irrigation, but the strategy needs improvement.

The results suggest, that two irrigations in the morning, on the orchard floor with at least 0,2 mm water and with one hour interval is a good strategy. The irrigation should take place, when Rimpro indicates a large quantity of ripe ascospores. The weather forecast should promise at least 19 hours of dry weather and air humidity lower than 85 % RH. It also suggests that irrigation should not be done more often than just before infection periods are forecasted.

The trial in 2012 also indicates that the effect of strategic irrigation is displayed better in connection with the use of fungicides. Then infections are avoided in long wet periods, as you cannot prevent all of the infections by strategic irrigation. But strategic irrigation can lower the total risk of infection.

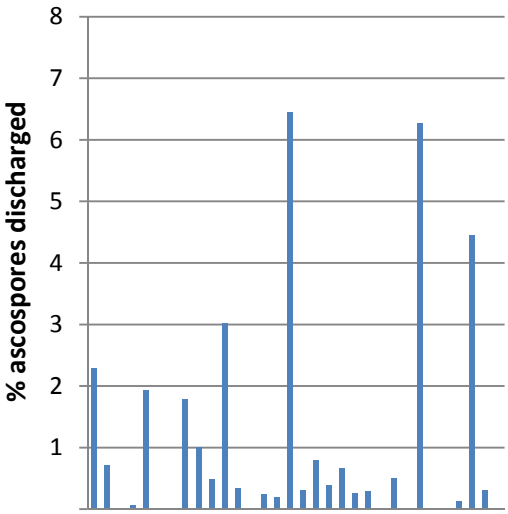

Figure 3: The relative discharge of ascospores on 32 spore trap slides as reaction to 0,2 mm of rain the 29th of April 2013 at 3 p.m. (7,7°C.)

Figure 4: Equipment for measuring discharge of ascospores in relation to irrigation with different sizes of drops. Two spore traps are used: Slideholders and a Burkard volumetric spore trap.

The high infection level of scab in the orchard Kysøko might be explained by overwintering conidia spores in the buds. Conidia spores can be found in winter buds, when the scab infection level in the previous autumn exceeded 40 %. (Holb et al.2005) That was the case in the orchard Kysøko in 2011, where the infection level was above 59 % in Sept. 2011. Infections by conidia spores from the buds cannot be prevented by strategic irrigation on the orchard floor. Conidia spores in buds also lower the certainty of Scab warning programmes.

To improve the strategic irrigation method, at least three **things about ascospores are important to know in order to decide when to irrigate:**

The amount of water needed for discharge? The period of time needed for discharge?

The viability of the ascospores under dry conditions, how long does it take to dry out?

MacHardy (1996) are listing a range of answers to these questions.

As little as 0,1 mm rain can induce discharge of ascospores, but 0,2 mm will discharge many spores (Hirst & Stedman 1962) In this experiment 0,2 mm of rain provoked only 1 % of the pool of ascospores and only 9 % of the amount of ripe ascospores. The fact, that irrigating with 3,7 mm of rainwater can release up to 47 % of the pool of ascospores indicates, that the amount of irrigation water should be more than 0,2 mm, and that rainwater should be preferred.

The discharge of ascospores takes place in a period of hours after rain. Hirst & Stedman (1962) found, that the discharge of ascospores peaks after 4,35 hours at 0 °C., 3,0 hours at 5 °C, 1,75 hours at 10 °C and only after 1,25 hours at 20 °C. Even after 8 hours some ascospores will be discharged, when temperatures are low 5-10 °C. Alt (2003) found, that discharge of ascospores most frequently begins right when rain starts and normally peaks at noon, but sometimes the discharge is delayed > 3 hours after rain start. The answers to how long time ascospores survive on a dry leaf are few and conflicting. In one study app. 80 % of the ascospores died after only 2-8 hours of sunny orchards conditions, in other studies ascospores survived 6 sunny days (MacHardy 1996).

Another question to consider in order to achieve valid data, is how far do ascospores normally fly? Burchill (1966) has stated that scab was never detected 15 m beyond the

source of ascospores. Kaplan (1986) found, that within 5,4 m from the source of ascospores, the density of airborne ascospores was diminished more than 99 %. This was taken into account in the plot design in Taastrup, but the plot design has to be reconsidered in the trials to be made in 2014-2017 in the project ProtecFruit. The size of the trial plots will be augmented and the time window between irrigation and forecasted rainfall will be adjusted to temperature, adding 1-5 hours extra on top of the 19 hours.

The quality of the weather forecast is very important. It is my experience that the Norwegian weather forecast www.yr.no is reliable and showing not only forecasted rain, but also forecasted air humidity. This makes it easy to recognize periods with 24 hours of air humidity below 85 % RH.

The perspective of the Strategic irrigation method is that it cannot stand alone as a preventive measurement. It is one tool among others to reduce the infection pressure.Other tools are pruning, collecting the overwintered leaves, low Nitrogen-level and to cover the trees with a roof.

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