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STUDY ON *VENTURIA INAEQUALIS* PSEUDOTHECIA DEVELOPMENT, ASCOSPORE DISCHARGE AND PREDICTION OF APPLE SCAB

Beata MESZKA, Sylwester MASNY, Anna BIELENIN

Research Institute of Pomology and Floriculture
Skierniewice, Poland
E-mail: bmeszka@insad.pl, smasny@insad.pl, abielen@insad.pl

Abstract

Studies conducted on five apple cultivars during 2005–2008 showed that the highest number of *Venturia inaequalis* pseudothecia, ranging from 40 to 50 per 1 cm^2 of leaf surface occurred on 'McIntosh' and 'Cortland', while on 'Jonagold' and 'Idared' significantly lower number was observed. Usually ascospores matured the earliest on 'McIntosh' and 'Alwa' leaves. The calculation of cumulative degree-days index appeared to be unsuitable for forecasting of ascospore discharges. The evaluation of Italian A-scab model by using the archival data representing epidemiological and meteorological conditions in Central Poland (2005–2007) gave satisfactory results for simulated proportion of airborne ascospores in comparison to registered ascospores in orchard conditions. However, it is supposed that first predicted infections did not occur, because the first scab symptoms were related to later infections.

Key words: *Venturia inaequalis*, degree-days model, ascospores maturation, A-scab model.

Introduction

Apple scab caused by *Venturia inaequalis* (Cooke) Wint. is the most serious fungal disease of apple in Poland. It attacks foliage, blossoms and fruits, resulting in defoliation of trees and making fruits unmarketable. If it is not controlled, even more than 70 percent of fruits can be lost /MacHardy, 1996/. Fungus overwinters in infected fallen apple leaves on the orchard floor. During the winter and early spring, small black pseudothecia are developing. Temperature, leaf moisture and apple cultivar are major factors affecting development of pseudothecia /Schwabe, 1982/. Depending on a season, matured ascospores, are noted before bud break or in tight cluster phase. Observations of *V. inaequalis* pseudothecia development and ascospore maturation are very important for effective control of apple scab. Chemical control against apple scab should be started at the time when the first ascospores are ready to discharge. Various models of apple scab forecasting are known: VENTEM /Xu, Butt, 1993/, RIMpro /Trapman, Polfliet, 1997/ or A-scab /Rossi et al., 2000/.

The aim of this work was to study the influence of apple cultivar on the development and maturation of *V. inaequalis* pseudothecia, to evaluate the relationship between pseudothecia maturation and index of cumulative degree-days and applicability of A-scab model for prediction of apple scab.

Materials and Methods

The experiments were conducted during 2005–2008. Scabbed leaves of five cultivars, 'McIntosh', 'Cortland', 'Jonagold', 'Idared' and 'Alwa' from the Experimental Orchard at Dąbrowice (near Skierniewice), were collected in the autumn and stored during winter outside on the orchard floor in nylon mesh bags. The following spring, from the beginning of March, samples of 100 leaves of each cultivar were collected every 7 days, and microscopic observations for the presence of ascospores and their development were performed. The number of pseudothecia per 1 cm^2 of the four scab lesions on each leaf, was counted. Then, pseudothecia were taken (ten from each leaf), crushed on microscopic slides and then checked for maturity using a 5-degree scale (1 – pseudothecia without asci, 2 – pseudothecia with asci but no spores, 3 – less than 10% asci with ascospores, 4 – from 10 to 30% asci with ascospores and 5 – over 30% asci with matured ascospores /Borecki, 1962; Meszka, 2004/.

The index of cumulative degree-days (sum of average daily temperatures above 0^o C, measured in tree canopy) was calculated in each season from the beginning of January to the first ascospore discharge.

In 2008 season, an A-scab Italian model for prediction of apple scab was tested. The model was developed at the University of Piacenza in collaboration with the Plant Protection Service of Emilia-Romagna Region /Rossi et al., 2000/. In this model, calculation of meteorological data is started from February 1st. At that time, pseudothecia are not diversified yet (according to definition of James and Sutton in 1982). Simulation of their ontogenesis is a function of temperature, relative humidity, rainfall and leaf wetness duration.

Results and Discussion

Development and number of pseudothecia on apple leaves were closely related to apple cultivar. The highest number ranging from 40 to 50 per 1 cm^2 of lesion, was observed on 'McIntosh' and 'Cortland' leaves in 2005–2006 (Table 1), while lower number was found on 'Jonagold' leaves, with about 25 pseudothecia per 1 cm^2 scab lesion and 'Idared' cultivar (from 18 to 26). During seasons 2007 and 2008, the total number of *V. inaequalis* pseudothecia on 'McIntosh' and 'Cortland' cultivars was lower by about 50% as compared to 2005 and 2006. It was probably correlated with the lower level of disease intensity in these years. However, the number of pseudothecia on the 'Jonagold' and 'Idared' was similar to that in the previous years. The number of pseudothecia on 'Alwa' leaves, determined in 2007 and 2008, was between 27 and 38 per 1 cm^2 of lesion.

Table 1. The effect of apple cultivar on pseudothecial density

Cultivar	The average number of pseudothecia / 1 cm^2 scab lesion			
	2005	2006	2007	2008
McIntosh	51.5 b*	46.2 c	14.4 a	25.5 ab
Cortland	42.2 b	39.3 bc	27.4 b	21.6 a
Jonagold	25.8 a	29.2 ab	26.0 b	22.6 a
Idared	25.8 a	17.9 a	–	–
Alwa	–	–	26.8 b	38.2 b

* Means in columns followed by the same letter do not differ according to Duncan test at the 5% significance level

The pseudothecia maturation strongly depended on apple cultivar (Table 2). In 2005 and 2008, the first matured pseudothecia (>30% asci with ascospores) containing ascospores ready to be discharged were observed on the leaves of 'McIntosh' and 'Alwa'. On 'Cortland' and 'Jonagold' leaves, pseudothecia maturated more slowly and they were ready for discharge about one week later. In our earlier investigations, the differences between ascospore maturity on different apple cultivars were greater, sometimes more than 10 to 14 days /Meszka et al., 2002/. During 2006 and 2007, ascospores on the leaves of all studied apple cultivars reached maturity at almost the same time. In our studies, the time when the last ascospores were noted in pseudothecia was similar for all cultivars. It occurred usually in the second half of June.

Our study showed that apple cultivar influence pseudothecia number and maturation of ascospores. The number of pseudothecia on 'McIntosh' and 'Cortland' leaves was significantly greater than on the leaves of other cultivars like 'Jonagold' and 'Idared'. The correlation between apple cultivar and pseudothecial density was observed also by Smith and MacHardy (1992). In their study the highest number of pseudothecia was observed on 'Red Delicious', 'Rome' and 'Spartan' leaves, lower on 'Golden Delicious' and 'McIntosh' and the least on 'Mutsu' and 'Stayman' cultivars. They also found differences in ascospores productivity and maturation depending on cultivars. The first matured ascospores were observed on 'Stayman' leaves, although the lowest number of pseudothecia was noted on this cultivar. Maturation of ascospores on 'McIntosh' leaves was a little lower. Similar results were obtained by Moller (1980) in California. The information about the time of ascospores maturity is very useful for choosing the best cultivar in scab management prediction program. In the conditions of Poland 'McIntosh', 'Cortland' and 'Alwa' seem to be suitable for this purpose.

Temperature is an important factor in the formation and development of *V. inaequalis* perithecia /Wilson, 1928; Trapman, 1994/. The temperature between 4 to 10^{o} C in the late autumn and early winter is favourable for pseudothecia production and about 18^{o} C is optimal for their maturation /MacHardy, 1982/. Comparison of pseudothecia maturation and index of cumulative degree-day showed big differences in the last 2005–2008 seasons. The first discharges of ascospores from 'McIntosh' leaves

were observed when the index of cumulative degree-days was between 144–287 (Table 3). Our previous investigations with use of cumulative degree-days, showed that the first discharge of ascospores from 'McIntosh' leaves was observed when index was between 319–360 /Meszka et al., 2002/. Such great differences indicate the uselessness of this index for predicting the occurrence of apple scab.

Table 2. Percentage of matured pseudothecia (>30% asci with ascospores) in different time

Apple cultivar	2005 season (the first discharge of ascospores 16 April–the last 21 June)									
	5. III	14. III	26. III	3. IV	10. IV	16. IV	23. IV	14. V	21. V	4. VI
McIntosh	0	4	8	15	**19***	**22**	**36**	**54**	**36**	29
Cortland	0	0	4	18	**20**	**14**	**47**	**33**	**35**	33
Jonagold	0	0	1	15	**15**	**14**	**20**	**52**	**42**	25
Idared	0	0	2	20	**15**	**12**	**28**	**52**	**40**	21
2006 season (the first discharge of ascospores 14 April–the last 17 June)										
McIntosh	0	0	0	3	**33**	**75**	**84**	**58**	**13**	2
Cortland	0	0	0	16	**46**	**75**	**92**	**71**	**14**	4
Jonagold	0	0	0	6	**25**	**88**	**80**	**57**	**12**	4
Idared	0	0	0	12	**23**	**77**	**69**	**51**	**12**	2
2007 season (the first discharge of ascospores 9 April–the last 4 June)										
McIntosh	2	4	**44**	**42**	**50**	**44**	**50**	**34**	20	8
Cortland	32	23	**83**	**91**	**86**	**91**	**80**	**34**	24	8
Jonagold	17	25	**59**	**78**	**81**	**59**	**70**	**32**	24	6
Alwa	0	17	**55**	**63**	**88**	**86**	**71**	**64**	24	16
2008 season (the first discharge of ascospores 29 March)										
McIntosh	0	6	16	**52**	**73**	**66**	**47**	32	17	
Cortland	0	0	23	**46**	**52**	**52**	**58**	30	14	
Jonagold	0	0	21	**29**	**63**	**79**	**57**	30	15	
Alwa	0	18	42	**40**	**56**	**48**	**66**	33	17	

* Numbers in bold in the table mean period in which the highest number of maturated ascospores was observed

Table 3. Values of degree-days index for the first ascospore discharges from 2005 to 2008

Season	Date of the first ascospore discharge	Degree-day index in a day of the first ascospore discharge
2005	April 15	274
2006	April 14	144
2007	April 9	287
2008	March 29	225

Evaluation of Italian A-scab model by using the archival data representing epidemiological and meteorological conditions in Poland showed good agreement between the predicted data and the first observed *V. inaequalis* ascospore discharges in 2005 and 2006. However, in 2007 the simulated data needed to be corrected for the long dry period from March 24 to April 8 and the average daily values of relative humidity lower than 80%.

In 2007, we carried out a systematic assessment of the dynamics of apple scab development. On the basis of the forecast of ascospore discharges, it was possible to compare the risk of *V. inaequalis* infections and symptoms of scab occurrence simulated by the A-scab model with the real occurrence of the disease. The obtained results showed that ascospore discharges forecasted by the A-scab model for March 21, April 9 and 10 were confirmed by microscope observations of ascospore presence in the air. However, visible scab symptoms on apple trees cv. 'McIntosh' forecasted for April 9, 25 and 26, were not observed (Table 4). In 2007, the first scab symptoms were not observed until May 18. An intensive apple scab development occurred towards the end of May as a result of large ascospore discharge and infection periods during the blooming phase (from May 7 to 16). These were the main ascospore discharges in 2007 because they constituted 40% of the total period in which ascospores were registered. Large ascospore discharges, amounting to 79% of the total number of ascospores, were also predicted for that time by the A-scab model. Thus data obtained by simulation were almost fully confirmed with observations on real scab occurrence. Preliminary results obtained in Italy showed that by using A-scab model it is possible to save up to 20–30% of chemical applications with the same level of effectiveness in control of apple scab. /Bugiani et al., 2008/.

Table 4. Simulated dates of ascospore discharges and scab symptom occurrence according to A-scab model and consistence with real disease symptoms occurrence in 2007

Lp.	Simulated date of		Consistence with real disease symptoms occurrence
	ascospore discharges (confirmed by biological observations)	scab symptoms occurrence	
1.	21 III	9 IV	–
2.	9 IV	25 IV	–
3.	10 IV	26 IV	–
4.	18 IV	4 V	+/–
5.	7 V	19 V	+
6.	8 V	20 V	+
7.	9 V	21 V	+
8.	10 V	21 V	+
9.	11 V	22 V	+
10.	13 V	23 V	+
11.	16 V	26 V	+
12.	26 V	4 VI	(+)
13.	31 V	9 VI	(+)
14.	3 VI	11 VI	(+)

(+) – small participation of primary infection in disease development

Conclusions

1. Development of pseudothecia on apple leaves depends on apple cultivar.

2. Leaves of 'McIntosh', 'Cortland' and 'Alwa' were very suitable for observations of pseudothecia development and ascospores maturation.

3. The calculation of cumulative degree-days index appeared to be unsuitable for forecasting of ascospore discharges.

4. Italian A-scab model appeared to be very reliable in prediction of ascospores release in 2005, 2006 and 2007.

5. A-scab model can be useful for farmers to make decisions about control of apple scab, however, more research is needed.

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