Disease development of sooty blotch and its correlation to wetness hours

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Abstract

Since 2005 research has been done on the biology of the sooty blotch complex at the Research station for fruit growing (Kompetenzzentrum Obstbau Bodensee) at Lake Constance area. In several trials, for example bagging trials, disinfection of apples on the trees and monitoring of disease development over 7 years, we find a correlation between disease development and leaf wetness. The appearance of the first symptoms in the field but also the further development of infestation seems to be linked with a certain number of wetness hours. Thereby the development stages of the fruits seem to have no influence on the appearance of sooty blotch symptoms.

Keywords: sooty blotch, disease development, bagging experiments, wetness hours

Introduction

During the past years sooty blotch disease received a strong proliferation particularly in scab resistant varieties due to the diminished fungicide treatments. Especially in regions with a high amount of rain fall and humidity like the Lake Constance area, frequent summer treatments become necessary to avoid substantial losses of crops. Knowledge about the specific pathogens of the sooty blotch complex is limited. Although results of the research from North America are available, the transfer to German apple production is limited. Suitable knowledge about the identity of the local pathogens as well as their physiology relevant for infection is lacking. Since 2006 research on the infection biology of the sooty blotch complex has been done at the KOB Bavendorf. Results of bagging trials with focus on infection periods, efficiency of different plant protection strategies or susceptibility of different varieties were already presented within the scope of this conference (Mayr *et al.*, 2008, Mayr *et al.,* 2010). Based on a deeper understanding of the infection biology under western European conditions, the control of sooty blotch should be optimized in future by focusing on definable key events in the infection cycle. To reach this aim it is necessary to be able to describe several parameters which are relevant for infection, i.e. incubation period, more detailed. By using different methods, e.g. bagging trials, disinfection of fruit surface and monitoring of the infestation development, we could show that the duration of incubation as well as the further infestation development is influenced directly by the duration of wetness.

Material and Methods

To examine the influence of wetness on the first symptom expression and the further infestation development, different methods which are described below were applied. Infestation was assessed by using a six class scheme (0= without, 1= small spots 2= up to 10%, 3= 10-25%, 4= 25-50%, 5= >50% of the surface with symptoms).

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Disease severity can be calculated as an index using the following formula which takes into account the number of apples in each disease severity class.

$$P = \Sigma (n^*v) / (5^*N) *100$$

(P= disease severity index (%), N= total number of fruits, v = numerical value of the severity class: 0,1,2,3,4, 5, n: number of fruits in each severity class)

The weather data were determined with a weather station from the company “Thies”. For recording leaf wetness a sensor measuring the electric conductivity of a hemp string was used. The leaf wetness sensor was positioned inside the tree.

1. Monitoring of the disease development

To examine the disease development over the years, untreated '*Topaz*' apple trees were regularly monitored with regard to date of first symptoms and the further development of sooty blotch spots. Two times per week, beginning from the end of June, 250 marked and numbered apples were assessed for symptoms and classified in 6 severity categories. To establish a relationship between disease and fruit development as well as climatic parameters, phenological development and weather conditions were recorded. This disease survey has been carried out since 2005 and allows for seasonal comparisons of disease development.

To examine the correlation between fruit development stage and the appearance of first symptoms, starting with a fruit diameter of 25 mm, weekly thirty fruits of untreated '*Topaz*' trees were picked and laid out on a grass plain apart from apple trees to reach a higher amount of wetness. In contrast to incubation trials carried out in the years before under controlled conditions in incubator and moist chamber, this method led to the desired symptom expression.

2. Bagging trials

To find out when infections occur during the season, 8 x 30 fruits were put separate into waterproof bags starting middle of May with a fruit diameter of 25 mm. This allows a temporary protection against rain and infections. Subsequently the apples in the several experimental units were bagged out weekly. The infestation was assessed on the 9th of August and at harvest time in September by using the described assessment scheme.

In the opposite direction, in each case 30 apples were put into bags in a weekly interval starting middle of May. The apples remained in the bags until harvest in the middle of September. After harvest the bags were removed and the infestation on the apples was assessed. Subsequently the apples were laid out on a grass plain over a period of 4 weeks.

3. Disinfection of the fruit surface in the field

For each experimental unit 30 apples were chosen and marked in untreated trees of the variety '*Topaz*'. On the 22nd of June, before the appearance of the first symptoms in the field, the surface of the marked fruits was disinfected by dipping the fruits into alcohol and sodium hypochloride. Thereby we used the following dipping sequence: alcohol (70%) – sodium hypochloride – alcohol (70%) – distilled water. The fruits were dipped 15 sec. into each solution. Fruits of the control unit were dipped only into distilled water. Disease infestation was assessed every 14 days starting on the 21st of July.

Results

1. Monitoring of the disease development

In the last years we find a trend in the correlation between the date first symptoms occurred and the sum of leaf wetness hours between petal fall and first symptoms, according to the method of Brown & Sutton (1995). After this method all moist periods beginning from the first rain 10 days after petal fall with a duration of more than 4 hours were accumulated. During the past 7 years a sum of 240 to 285 wetness hours was necessary for the appearance of the first symptoms in the field. These values are very similar to the amount calculated by Sutton for Northern America (Sutton *et. al.*, 2002).

Table 1: Summary of temporal appearance of different growth stages and sooty blotch symptoms as well as the corresponding accumulated wetness hours in the years 2005-2011 at KOB, Bavendorf.

Parameter	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
Full bloom	30.04.	06.05.	18.04.	02.05.	25.04.	29.04.	19.04.
“Petal fall"	09.05.	16.05.	27.04.	08.05.	04.05.	12.05.	24.04.
T-stage	18.06.	28.06.	31.05.	14.06.	27.05.	17.06.	03.06.
Harvest time	04.10.	27.09.	13.09.	18.09.	22.09.	24.09.	20.09.
First symptoms of sooty blotch	**20.07.**	**05.08.**	**20.06.**	**15.07.**	**07.07.**	**22.07.**	**05.07.**
All apples with symptoms	08.09.	19.09.	31.07.	05.09.	24.08.	26.08.	05.08.
Number of days between full bloom and first symptoms	81	91	63	74	73	84	77
Accumulated wetness hours (till first symptoms)	**278**	**285**	**241**	**205**	**240**	**287**	**275**

The observations allow the conclusion that the appearance of the first symptoms is primarily correlated with the wetness duration. The annual weather conditions as well as the phenological development stages of the fruits seem to play a minor part. If young fruits are transferred into a more humid environment, the incubation time can be shortened compared to the natural development in the tree. Exemplarily for the years 2009-2011 the results from the actual experiment year are shown in table 2.

The fruits which were laid on the grass weekly, starting from the 19th of May with a fruit diameter of 25 mm, developed symptoms much earlier than the fruits that remained in the trees. Thus the fruits laid out on the 3rd of June showed the first symptoms already on the 17th of June, 19 days before the appearance of the first symptoms in the control trees (5th of July). The more wetness hours the apples reached on the tree before laying out on the grass, the faster the symptoms developed under the more humid conditions.

The symptoms appeared in each case on the part of the fruit which had contact to the ground, no matter with which side they were laid on the grass. The incubation duration could be clearly shortened by transferring the apples into a more humid environment. In addition, it could be shown that infections are already possible before the fruit reaches “T-stage” and thus also before the wax layer on the fruit surface is fully developed.

Table 2: Disease severity index of apples laid out on grass at different points in time.

Nr.	laid out in grass	leaf wetness hours	disease severity index P (%)								days till symptoms
			10.6.	17.6.	24.6.	1.7.	8.7.	15.7.	21.7.	29.7.	
1	19.05.	41	0,0	0,0	7,0	32,0		40,0			37
2	26.05.	67	0,0	0,0	12,1	24,1	39,3	42,2	62,2	62,9	30
3	03.06.	120	0,0	2,1	11,0	31,0	37,9	47,6	60,7	58,6	14
4	10.06.	159	0,0	0,0	4,7	17,2	27,9	37,2	45,3	45,3	14
5	17.06.	204		0,0	2,0	19,3	43,3	59,3	53,5	63,3	8
6	24.06.	255			0,0	5,9	24,0	44,1	51,7	67,3	8
7	01.07.	274				0,0	7,6	33,1	57,2	79,3	8
8	08.07.	288					0,0	33,3	60,0	87,6	8

2. Bagging trials

In the bagging trials, a correlation between wetness duration and the appearance of symptoms could also be observed. On the apples which were temporarily protected against spores and rain by bags, the first symptoms appeared after bagging out also after more than 200 wetness hours. Apples of treatment "I", which were bagged out on the 15th of July, still showed no symptoms on the 9th of August after 202 accumulated wetness hours (table 3). However, apples of treatment "H", which have been bagged out one week earlier and reached a total of 272 wetness hours till assessment date, showed first symptoms. Furthermore, the disease severity index (P%) of the apples bagged out at different dates increased nearly linearly to the sum of wetness hours accumulated till assessment date.

Table 3: Disease severity index (P%) of different bagging variants on the 9th of August 2011.

No.	bagging period	P (%) on August 9	leaf wetness hours
A	13.05.-19.05.	75,6	519
B	13.05.-26.05.	75,2	493
C	13.05.-03.06.	60,0	440
D	13.05.-10.06.	44,0	401
E	13.05.-17.06.	23,0	356
F	13.05.-24.06.	16,2	305
G	13.05.-01.07.	8,5	286
H	13.05.-08.07.	2,3	272
I	13.05.-15.07.	0,0	202

In contrast to the monitoring, the apples of the single bagging treatments were directly surrounded by already infested (unbagged) apples after bagging out. At the time when the apples of variation "I" were bagged out, a disease severity index (P%) of 20% was assessed on the unbagged apples which increased to 70% until the first assessment date on 9th of August. Even with high inoculum in immediate vicinity it seems as if a certain wetness duration was necessary for incubation.

In the counter-rotating trial beginning middle of May apples without visible symptoms were bagged continuously in a weekly chronology. The apples of the 8 bagging periods remained in bags till harvest. Bagging periods between 118 and 68 days were given. At harvest time apples were taken out of bags and were transferred in the humid environment in the grass. Symptom development could be prevented by avoiding wetness temporarily with bags. Only after reentry into humid conditions visible sooty blotch symptoms appeared. Figure 1 shows the disease severity index (P%) of the fruits 17 days after they have been laid out on the grass. The more wetness hours were already reached before bagging the apples, the higher was the disease severity index (P%) after laying out on the grass.

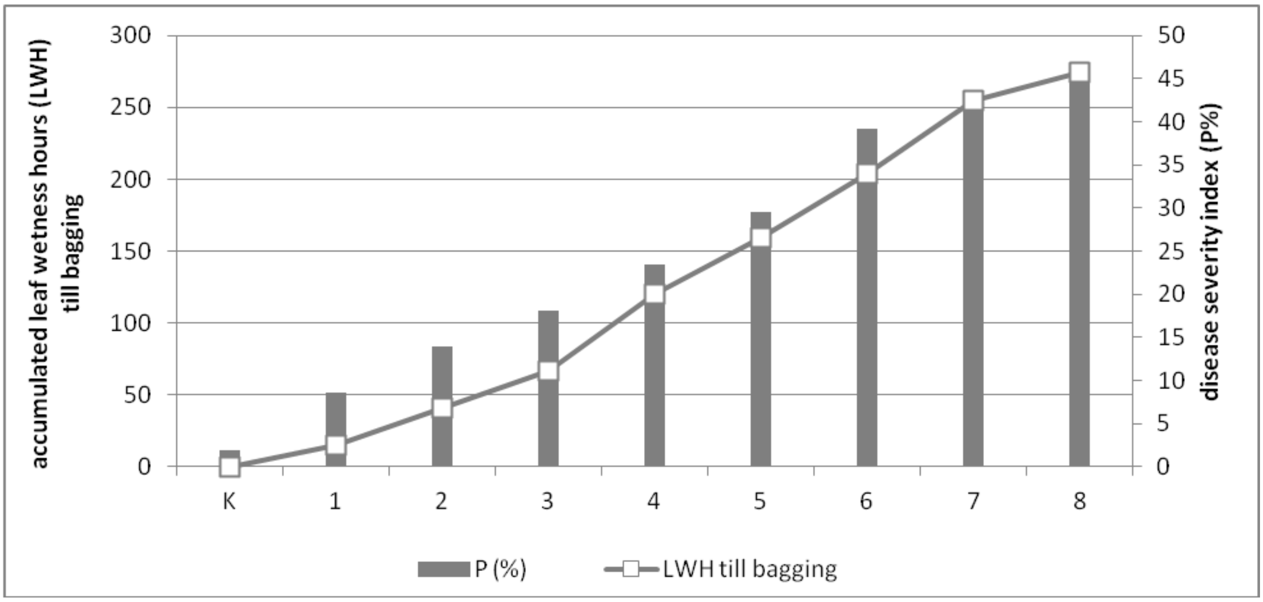

Figure 1: Disease severity index (P%) of different bagging variants after 17 days on the grass.

3. Disinfection of fruits

The apples which have been surface-disinfected on the tree on the 22nd of June showed a clearly lower disease severity index than the control apples on the assessment dates 21st of July, 1st of August and 15th of August (fig. 2). On the 21st of July and after an accumulated sum of 170 wetness hours, the disinfected fruits still showed no symptoms (fig. 3). At this time a severity index of 28,7% was assessed in the control apples. The first visible spots on the disinfected apples were observed on 1st of August, 40 days and 240 accumulated wetness hours after disinfection date. A disease severity index (P%) of 2,8% was assessed on this date. 13% of the apples showed first symptoms (severity class 1), 87% were still free of symptoms. At this time the untreated control already had a severity index of 49,3%.

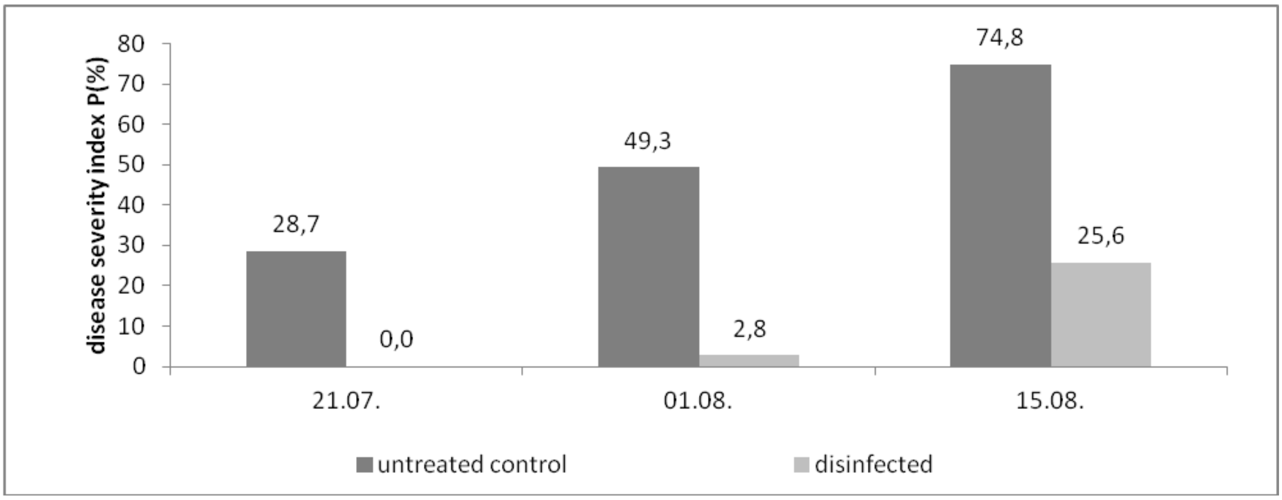

Figure 2: increase of the disease severity index (P%) of disinfected and untreated apples between 21st of July and 15th of August.

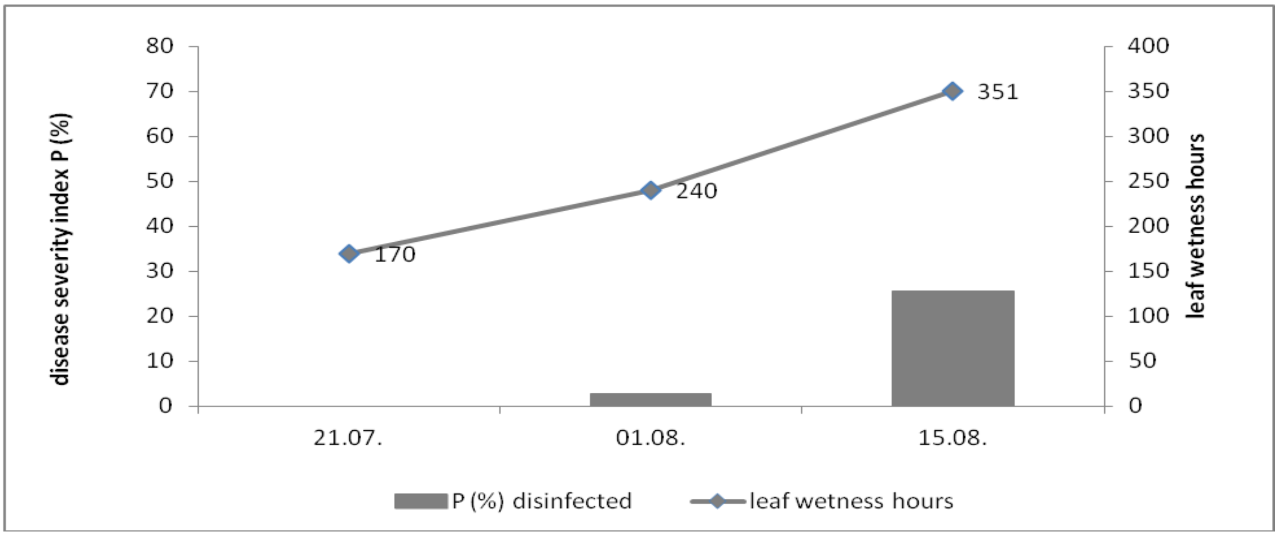

Figure 3: development of leaf wetness hours and disease severity index (P%) of disinfected apples between 21st of July and 15th of August.

Discussion

Working with wetness hours, the methodology of the leaf wetness measurement plays a central role. A calibration of leaf wetness sensors is not possible due to a lack of appropriate norms. Thus, the presented threshold values for leaf wetness can only be seen in relation with the leaf wetness sensor used in our investigations. By using different leaf wetness sensors and divergent positioning of the sensors these values can deviate due to different methodology. By continuous use of the same leaf wetness sensors and positioning over the years the results have been reproduced in our trials. The following conclusions can be derived from our investigations:

For symptom development a certain sum of wetness hours seems to be necessary. In the Lake Constance area during the past 7 years a range of 240 – 285 accumulated wetness hours according to the method of Brown & Sutton (1995) was necessary for the appearance of the first symptoms in the field. Even if a high inoculum already exists in the orchard, a comparable threshold value seems to be necessary for the incubation. The earlier the wetness duration which is necessary for the incubation was achieved, the earlier the first symptoms appeared. If humidity is prevented, the symptom development can be inhibited or delayed. Also after time periods of more than 110 days without wetness, symptoms develop after reentry into humid conditions within a few days and even apart from apple orchards. Under humid conditions symptoms appear even on young fruits with a diameter < 25 mm. Thus, the development stage of the fruits does not seem to play a role for symptom appearance. In the last years it was supposed that the T-stage might play a role in the pathogens biology as from around this stage a process known as 'leaching' starts when soluble substances are released out through the cuticle. Sooty blotch pathogens live only on the cuticula surface and feed on the substances released from the fruit. Thus the leaching process was supposed to be linked with the disease infection cycle.

Acknowledgements

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