RIMpro Cloud Service info bulletin 2016-5
Zoelmond, June 8 2016

RIMpro-*Sooty Blotch*

A first version of the RIMpro-Sooty Blotch model was developed in 2003 and used by growers and consultants since 2004. The model was improved in 2011, based on the results of a research project in Germany. In 2016 the model is reviewed, and ported to the RIMpro Cloud platform. Individual users find the Sooty Blotch model in the list of models in the RIMpro main menu. Consultants can create interactive links to the model on their website using the URL:
http://www.rimpro.eu/faces/sb.xhtml?id=*your stationID*

Figure 1: Sooty Blotch symptoms on cultivar Topaz.

1- Quick start guide

Sooty Blotch (SB) is caused by a complex of fungi that develop on the fruit skin of most commercial apple varieties. Spores are splashed by raindrops from the wood onto the fruits, germinate, and can cause infections on the fruits from about 30 days after full bloom. After a number of humid hours, the growing mycelium changes colour and the typical SB symptoms become visible. Existing SB spots keep growing and can completely cover the fruit skin. Mycelium that is present on the fruits, but not yet visible at harvest time, can become visible during storage.

Weather data

The development of SB is bound to high humidity. Correct simulation of infection moments and disease progress is only possible with weather data that are truly representative of the within-tree microclimate. For weather stations placed outside orchards this in not the case.

Interpretation of the graph

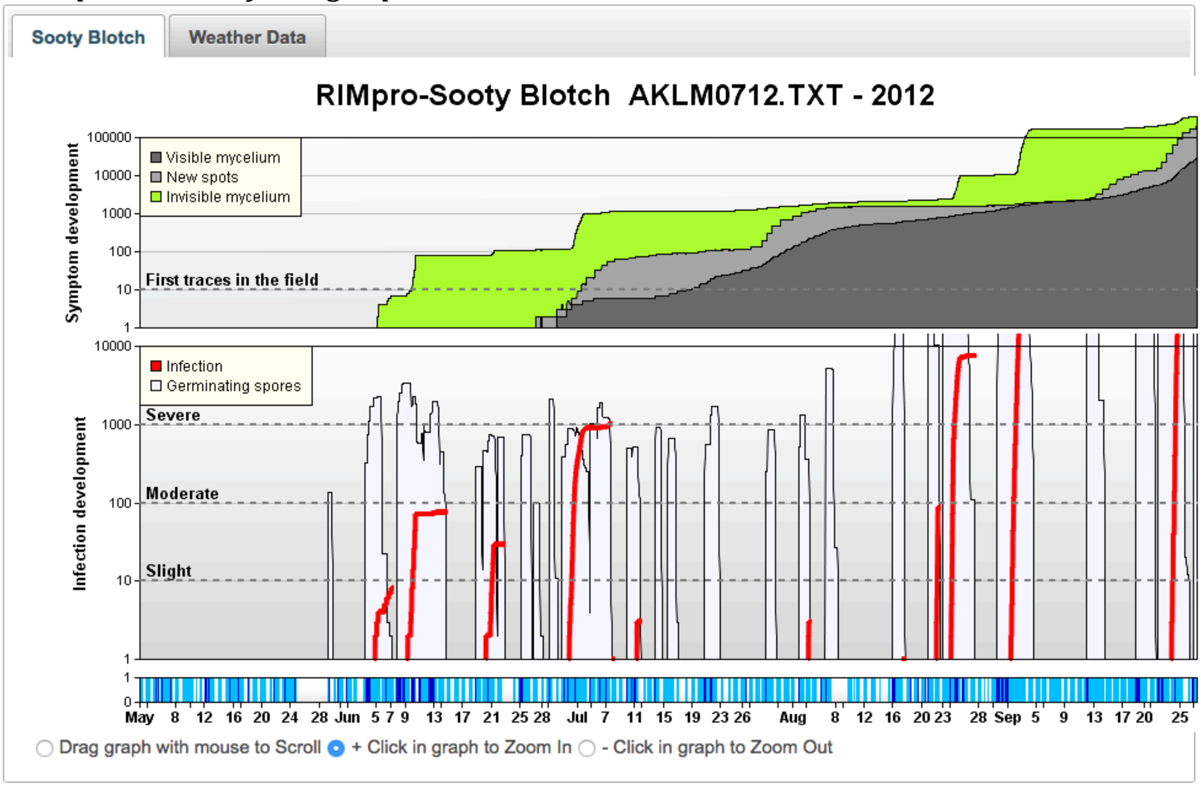


Figure 1: User output of the RIMpro Sooty Blotch model

The lower graph shows the rain- (dark blue) and crop wetness- (light blue) events as interpreted from the weather data according to the user settings for leaf wetness interpretation. The middle graph indicates the number of spores splashed onto the fruits (white), and the number of these spores that are able to infect as infection value (red line).
The upper graph indicates the disease development. The growing, but still invisible mycelium (green), the new SB spots resulting from a previous infection event (light grey), the increase of severity by the growing mycelium.

Validation

The model is based on published and un-published scientific information, and expert knowledge. The model output was validated using detailed field observations made in untreated apple orchards in The Netherlands and Southern Germany at the research centre for fruit production KOB in the years 2002 till 2015. Very first symptoms were found in the field within a few days from the date the model indicates a symptom value of 10. In some situations however the first infection indicated by the model does not result in visible symptoms, but the second infection event explained the first symptoms found in the field.

Management

Cultural methods to lower the air humidity in the orchard are not sufficient to manage SB at an economic level in orchards where SB is a main summer disease. In orchards with a low disease pressure 'slight' infections can be ignored. Fungicide treatments should be aimed at preventing infections. Stopping or reducing the growth of the mycelium on the fruits after infections have occurred is less effective.

In Europe, management of SB is currently mainly relevant for organic apple production systems. Copper (at reduced rate), and sulphur are not very effective to control SB. Lime sulphur applied shortly before or during infection development is effective. Lime sulphur or bicarbonate applied on wet fruits immediately after an infection has occurred is also effective. High volume sprays have proven more effective than concentrated sprays. Formulated bicarbonate fungicides are more effective than unformulated technical grade bicarbonate.

2- Background to the disease and the model

Sooty Blotch (SB) is caused by a complex of epiphytic fungi. In Europe *Peltaster sp.* are the predominant species found on fruits with SB symptoms. The SB causing fungi live on plants in the orchard surroundings, and inside the orchard on branches of fruit trees and mummified fruits. In untreated orchards the infection potential increases over years.
In central Europe first symptoms are found between mid June and mid August. After first symptoms have appeared, the disease incidence and severity increases during summer, proportional to rainfall and high humidity conditions. Rain-splash causes new infections, and under humid conditions the mycelium on infected fruits keeps growing until the complete fruit surface is covered with the olive-grey fungus. (Figure 1 and 2)

Figure 3: Disease development in time: Black >Red >Blue: Growth of the existing mycelium, and spread of the disease by new infections. (KOB, Germany, 2011)

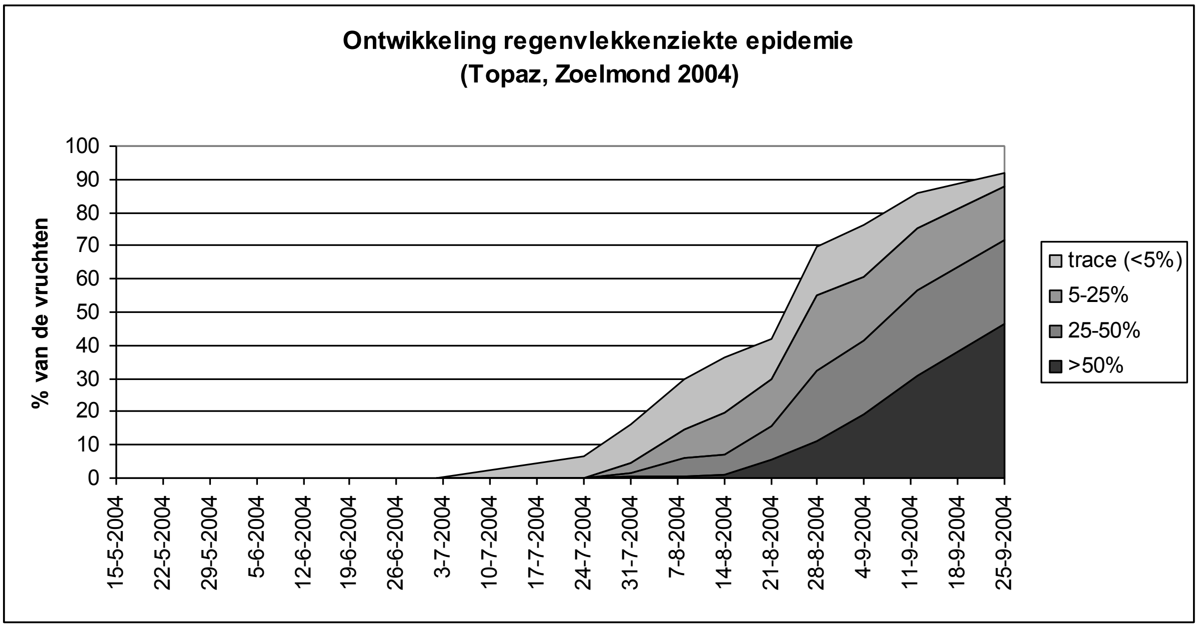


Figure 3: Disease development in an untreated orchard in The Netherlands in 2004: Percentage of fruit with traces, <5%, 5-15%, 25-50% or >50% of their skin surface covered with SB symptoms.

Sooty Blotch Management

Commercial apple varieties vary slightly in their susceptibility for SB. Early apple varieties 'escape' from the disease as they are harvested before the autumn dew and rain force a strong increase of the disease level.
In IPM apple production, the side effect of the regular fungicide program aimed at the control of other summer- and storage diseases, controls SB. In organic- and low fungicide input apple production systems, SB is an important disease that can make 100% of the fruits unmarketable. Organic fruit growers in Germany, Switzerland and Austria even constructed 'brushing machines' to brush away the SB symptoms from their apples during grading.

In some experimental situations, a few applications with strong fungicides early summer are highly effective. In most practical situations however this is not the case. Additional repeated applications during summer are necessary to keep the disease on an acceptable level at harvest. "Intelligent" strategies based on models allow an equal level of disease control as a 7-10 day fungicide spray schedule, with a reduced number of applications.
New infections caused by rain-splash can be forecasted by models and used for timing of fungicide applications. The complication in the control strategy is that the growth of existing colonies on the fruit skin is a continuous process. However as the SB fungi are living as epiphytes on the fruit skin, applications between infection event and symptom expression can affect the mycelium.

For organic apple production potassium bicarbonate and lime sulphur are the most important materials to control SB. For the control of SB, the formulation of bicarbonate seems to play a much more important role, than for control of apple scab or powdery mildew where technical grade bicarbonate is also effective. Applications on a (dew-) wet crop, or with high water volume (>1000 litre per hectare) are more effective than when sprayed under dry conditions and at low water volumes.

The preferred strategy is to apply effective fungicides shortly before or after infection events to prevent the fungus from initiating growth on the fruit skin. Stopping the mycelium already in place is more difficult and less effective.

Weather data

SB development is very local within an orchard, and within a tree, depending on the humidity conditions in the microclimate. Valid simulations for SB disease development are only possible using weather data that are truly representative for the within tree microclimate. Weather stations should be placed in the orchard, RH sensors should be calibrated, and leaf-wetness sensors should be well positioned in the crop, to allow valid disease simulations.

Vapour pressure deficit (VPD) is a more suitable unit to quantify the drying effect of the microclimate on the fungus, than the relative humidity (RH). All humidity parameters of the model use VPD (hPa) as unit.

Table 1. Vapour Pressure Deficit (hPa) for relative humidity values at different air temperature.

RH (%)	Air temperature (°C)			
	10	15	20	25
99	0.1	0.2	0.2	0.3
95	0.6	0.9	1.2	1.6
90	1.2	1.7	2.3	3.2
85	1.8	2.6	3.5	4.8
80	2.5	3.4	4.7	6.3
75	3.1	4.3	5.8	7.9

The Model

As *Peltaster sp.* are predominant in Europe, data on the effect of temperature and humidity on *Peltaster sp* are used to develop the functions and parameters for the model. But even between strains of *Peltaster,* differences in response to environmental parameters are reported. SB is caused by a complex of epiphytic living fungi, and in crop protection Sooty Blotch and Fly Speck are considered as one disease complex to be controlled.
The model can be seen as a general tool for the management of SB-FS as other fungi in the complex have higher temperature requirements and less secondary growth than *Peltaster.*
Default humidity parameters are set less sharp than indicated in lab studies in attempt to compensate for errors in humidity measurement, at the cost of overestimating the overall risk in some situations.
Like for all models on the RIMpro platform, the model is an open shell, and users can set most simulation parameters according to their ideas and experience. But it's strongly recommended not to touch the simulation parameters unless you are certain of what you are doing.

Inoculum

The SB causing fungi live on plants in the surroundings of the orchard, and on branches and mummified fruits in the orchard. In organic apple orchards the infection potential increases over years.

<u>Interpretation in RIMpro</u>

The model supposes an inexhaustible primary inoculum. From this inoculum, spores are distributed by rain-splash. During summer the inoculum increases proportionally to the level of visible spots.

Susceptibility of fruits

Central Europe in the years 2002-2015: the rain event that caused the first infection occurred between 34 and 74 days after full bloom. First symptoms were found between mid June and mid August. Often first symptoms are found in the stem cavity, or between two touching fruits, suggesting infections occurred when fruits were already hanging with their calyx down, and are caused by water and spores gathering in the stem cavity.

<u>Interpretation in RIMpro</u>

Start of the susceptibility period is expressed in days after full bloom. (Default 30 days after full bloom) The user has to set the date of full bloom for the location under the local parameters.

Splash distribution of spores

The spores are assumed to be rain-splash distributed. The occurrence of SB is associated with rainfall, and in several European languages the disease is called "rain specks". Quantitative relations between rain intensity and occurrence of SB have not been published.

<u>Interpretation in RIMpro</u>

Above minimum rain intensity necessary to create splashing, up till an upper limit of accumulated rain, the contamination of fruits with spores is assumed to be proportional to the rainfall. For the primary infections a fixed arbitrary number of spores is added to the infection process for every mm of rain over the splash threshold.

Germination and infection

The spores need free water or high relative humidity to germinate. The relation between development and temperature for *Peltaster sp.* was interpreted from the pooled data published by Johnson & Sutton (2000) and Batzer (2010), and unpublished data from Weber (2012). The optimum temperature range for germination and development is 15-25 °C. Weber found a higher development rate at 5-10 °C than the other authors.

<u>Interpretation in RIMpro</u>

The germination process progresses during rain, leaf wetness and hours with high RH. As 'on-farm' weather stations are often not situated within the tree canopy, and cheaper and older RH sensors are inaccurate in the high RH range, 3.0 hPa. is set as default max VPD value for germination (= 87% RH at 20°C.)

Conidia survival

Germinating spores stay viable on a dry plant surface for a few hours. For *Peltaster fruticola,* germination rate drops gradually with drying time. After 8 hours of dryness germination rate is 50% reduced (Johnson & Sutton 2000).

<u>Interpretation in RIMpro</u>

The fruit surface is considered dry when leaves are interpreted to be dry (using the users preferences for interpretation of leaf wetness in RIMpro) and the VPD is below threshold (Default =2.0 hPa). The default average survival time for germinating spores time is set to 480 minutes with a relative dispersion of 0.25. This forces the first spores to die after two hours of dryness, and the last spores after 800 minutes of dryness.

Symptom development

The fungus grows on the fruit surface. The disease becomes visible when the mycelium changes colour from transparent to olive grey. The pigmentation process is influenced by humidity conditions and by nutrients leaking through the cuticle (Batzer 2010). The time between

infection and appearance of first visible symptoms seems to be related to the number of effective wetness hours and seems independent from temperature. Symptoms can stay invisible for months of dry weather, and appear when the sum of wetness hours is completed late summer. (Buchleither 2012). Mycelium that is still invisible at harvest can finish the pigmentation process during storage causing unpleasant surprises for growers after storage.
Published values for the sum of wetness hours necessary for symptom expression vary considerably between studies, depending on the sensors used for wetness recording, the way RH is incorporated to estimate fruit skin humidity conditions, and the algorithm applied to accumulate effective wetness hours.

<u>Interpretation in RIMpro</u>
Infection and symptom expression are depending on within tree microclimate. RIMpro accumulates wetness hours from rain, leaf wetness sensors and low VPD, which result in an effective humidity sum (EHS). Parameters provide:
- Maximum VPD to add the hour to the EHS. (Default =2.0 hPa)
- Minimum length of the humid period to be added to EHS (Default 0 minutes)
- Average and variation in the (EHS) for symptom expression. The default values of 400 humid hours as average, and a dispersion of 0.10 make the first symptom appear 300 humid hours after the infection event, and the last after 500 humid hours.

Secondary infections and disease progress
The disease incidence (number of infected fruits) increases during summer with the accumulation of infections caused by rain-splashed spores. On infected fruits, the severity increases with the growth of the fungus on the fruit skin. The growth of the fungus on the fruit skin is dependent on humidity conditions and is driven by temperature. The newly grown mycelium again needs an effective humidity sum to become visible.
The rate of increase of the epidemic is not only depending on weather conditions but also on fungicides used against other diseases, nutrients, and probably the species composition of the SB population.

<u>Interpretation in RIMpro</u>
The inoculum for the secondary infections is proportional to the disease severity (visible mycelium).
Parameters provide:
- Maximum VPD for growth of the mycelium on the fruit skin. (Default =2.0 hPa)
- Average and variation in the effective heat units necessary for doubling of the population on the fruit skin.

Validation
Detailed observations on the development of SB in untreated apple orchards were made in the Netherlands (2002-2005), and at the research centre KOB at Lake Constance in Germany (2004-2015). The last data were used for the validation of the recent model version.
From June till harvest, at several days interval, 250 fruits were checked for SB symptoms. For each individual fruit, disease severity was noted as the percentage of the fruit skin covered with SB symptoms (0= none, 1 = trace, 2 =<10%, 3=10-15%, 4=25-50%, 5 >50%). Disease severity was calculated from the percentage of fruits in each class as:
(class1+2*class2+3*class3+4*class4+5*class5)/100. (Buchleither 2012).
The date of the rain event that caused the first visible symptoms was an expert interpretation of the weather data in the period before the first symptoms were found in the field.

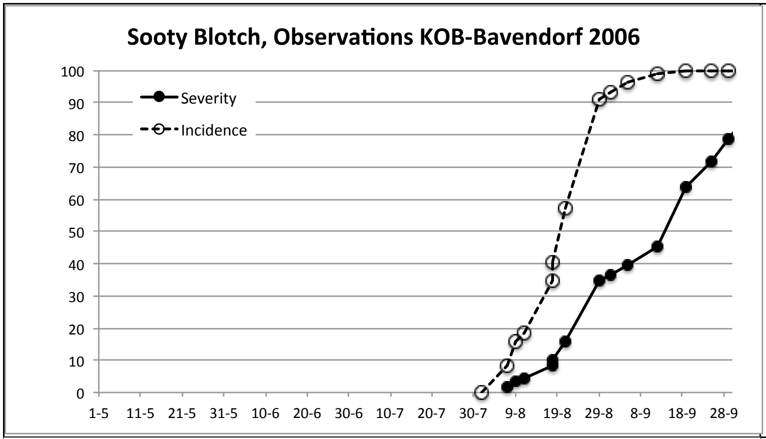
The results of observations were compared to the output of the model. (Table 2) For all simulations the default model parameters were used, and the date of full bloom for each individual year. Data of three different types of weather stations standing in an orchard at research centre KOB were available. The weather data collected by the LTZ weather station could be used for all years. For some years the Campbell and Thies data files were not available or had to be dropped as either RH values, or leaf wetness values, or data on rainfall were partly missing or incorrect.

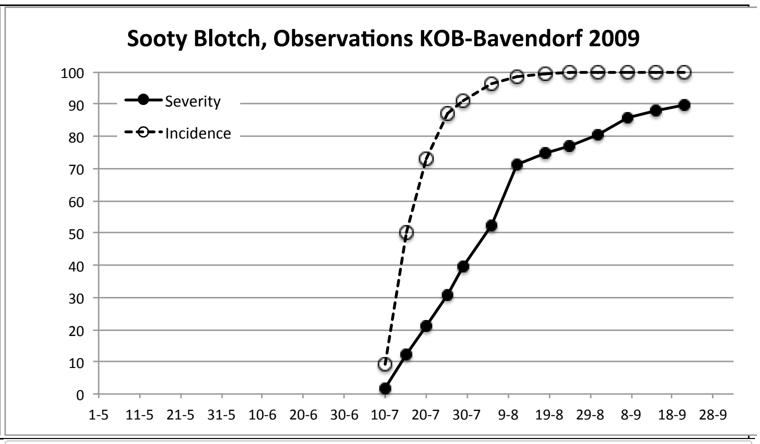
Results and conclusions

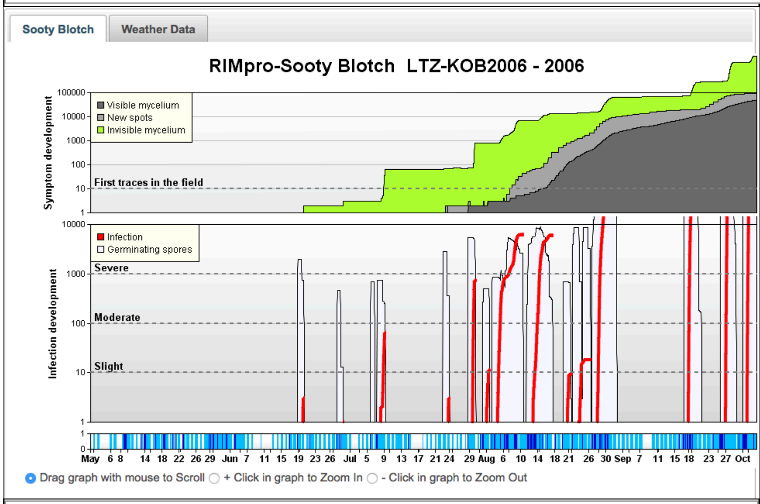
- For some years there are important differences in simulation results between the weather stations used. The data of the Thies station were found unusable for the simulations.
- With correct weather data input, the symptom level 10 in the model output was reached within a few days from the date the first symptoms were found in the orchard.
- In two years (2007, 2014) the model could not explain the first infection event as the recorded temperature during the infection event was near and below the development threshold of the disease.
- In years with a very low disease level in the field (2013, 2015), the model overestimated the infection risk.

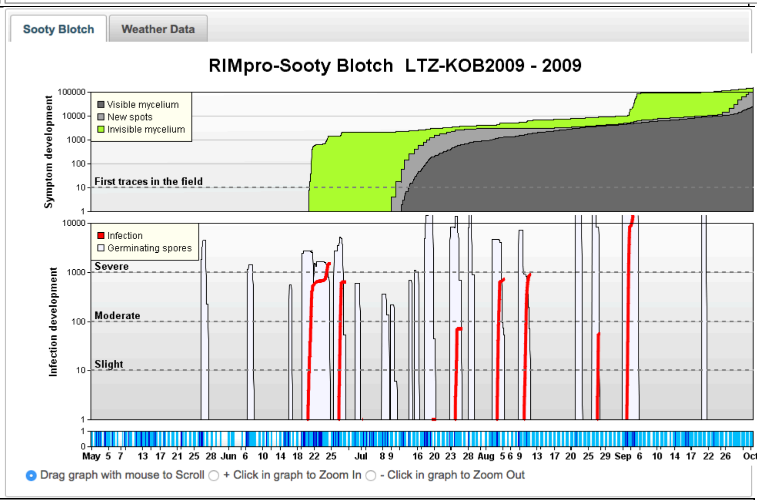
Table 2: Comparing the date the first Sooty Blotch symptoms were found in the field, with the date the model reached the initial symptom level 10, using data of three different types of weather stations in the same orchard. Data KOB Bavendorf, Germany.

Observed					**Simulation**		**Remarks**
Year	Full Bloom	First Infection	First Symptoms	Station Type	Symptoms >10	Diff. Days	
2005	30-4	15-6	15-7	LTZ	11-07	**4**	
2006	6-5	7-7	5-8	LTZ	08-08	**-3**	
2007	18-4	28-5	20-6	LTZ	13-07	-23	First infection May 28 not explained by the model. Recorded temp (6-8°C) was near the lower development threshold.
				Thies	08-08	-49	Thies station much too late.
2008	2-5	5-6	15-7	LTZ	27-06	18	Clear infection conditions on June 5, but first symptoms were found later than expected.
				Campbell	25-06	20	
				Thies	13-08	-69	Thies station much too late.
2009	25-4	21-6	7-7	LTZ	11-07	**-4**	
				Campbell	12-07	**-5**	
2010	29-4	20-6	22-7	LTZ	12-07	10	From the first infection indicated by the model using LTZ data no symptoms were found in the field. Second infection correct.
				Campbell	24-07	**-2**	
				Thies	02-08	-43	Thies station much too late.
2011	19-4	19-6	5-7	LTZ	12-08	-38	First infection missed using the LTZ data.
				Campbell	30-06	**5**	
				Thies	13-08	-55	First infection missed using the Thies data.
2012	26-4	9-6	3-7	LTZ	05-07	**-2**	
				Campbell	03-07	**0**	
2013	23-4	6-7	20-8	LTZ	03-07	48	Low severity level in the field - Moderate severity level in the model.
2014	18-4	30-6	21-7	LTZ	09-08	-19	First infection June 25 not explained by the model. Recorded temp (6-14°C) was near the lower development threshold.
2015	27-4	17-6	26-8	LTZ	25-07	32	Very low severity level in the field - Low severity level in the model
				Campbell	06-07	51	Very low severity level in the field - High severity level in the model


Sooty Blotch, Observations KOB-Bavendorf 2006
Severity
Incidence


Sooty Blotch, Observations KOB-Bavendorf 2009
Severity
Incidence


Sooty Blotch
Weather Data
RIMpro-Sooty Blotch LTZ-KOB2006 - 2006
Visible mycelium
New spots
Invisible mycelium
First traces in the field
Symptom development
Infection
Germinating spores
Severe
Moderate
Slight
Infection development
Drag graph with mouse to Scroll
+ Click in graph to Zoom In
- Click in graph to Zoom Out


Sooty Blotch
Weather Data
RIMpro-Sooty Blotch LTZ-KOB2009 - 2009
Visible mycelium
New spots
Invisible mycelium
First traces in the field
Symptom development
Infection
Germinating spores
Severe
Moderate
Slight
Infection development
Drag graph with mouse to Scroll
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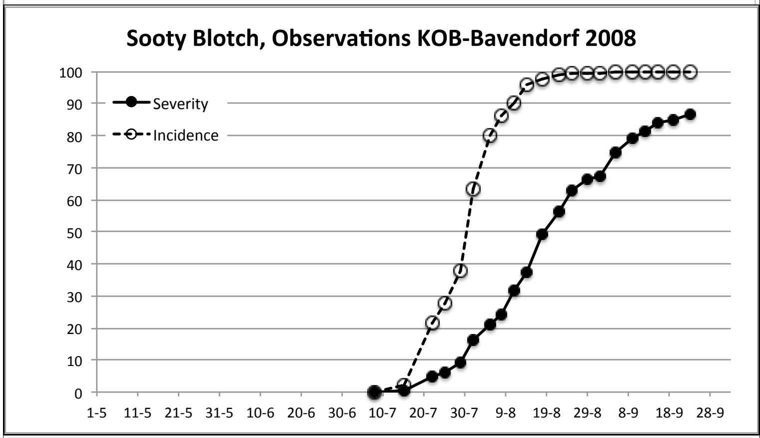
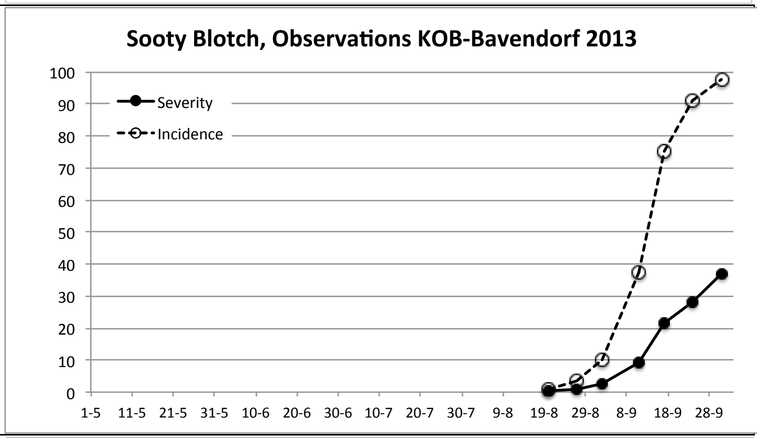
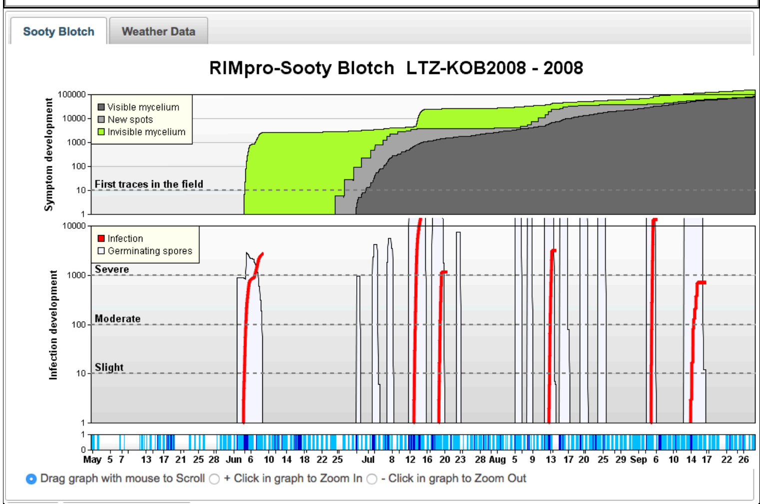

Sooty Blotch, Observations KOB-Bavendorf 2008
Severity
Incidence


Sooty Blotch, Observations KOB-Bavendorf 2013
Severity
Incidence


Sooty Blotch
Weather Data
RIMpro-Sooty Blotch LTZ-KOB2008 - 2008
Visible mycelium
New spots
Invisible mycelium
First traces in the field
Symptom development
Infection
Germinating spores
Severe
Moderate
Slight
Infection development
Drag graph with mouse to Scroll
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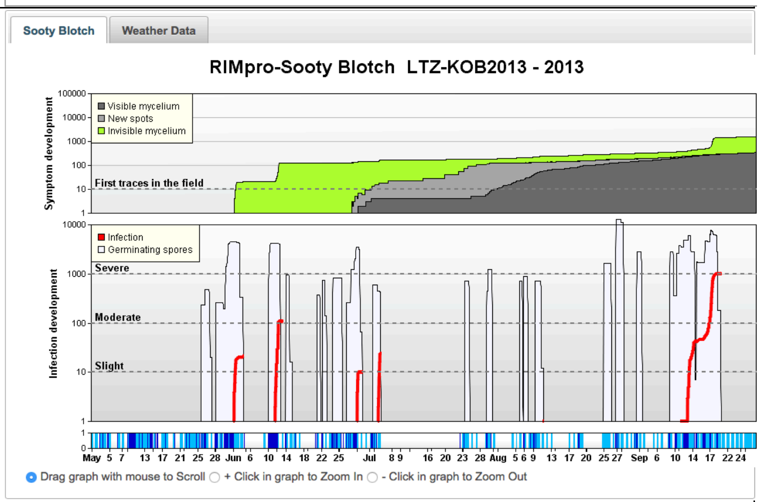
Sooty Blotch
Weather Data
RIMpro-Sooty Blotch LTZ-KOB2013 - 2013
Visible mycelium
New spots
Invisible mycelium
First traces in the field
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