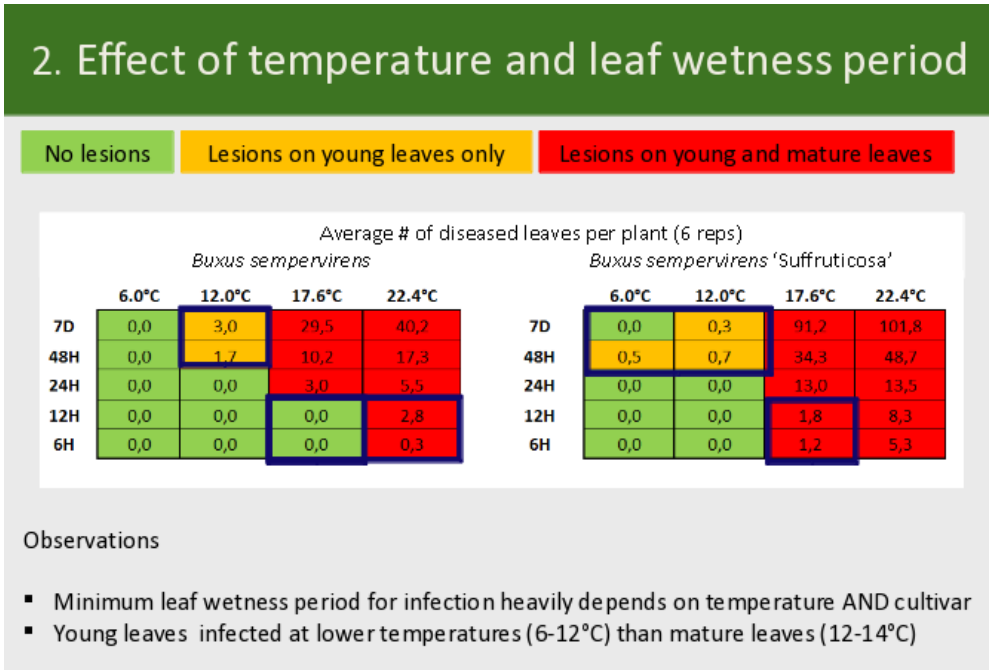
Model of Boxwood blight developed from data by Gehesquiere et al, 2012

First version 3/6/2013 by Leonard Coop, OSU IPPC

note: Key results with salmon colored background

I. Main reference for model construction: 1. Presentation by Gehesquiere et al 2012:



I. Additional refs for model construction: 2. Boxwood Blight Webinars posted to http://www.anla.org

"Boxwood Blight Update: Where we are and where we hope to be" & "Boxwood Blight: A Year of Research"

notes:

1) Temperature range for infection: 41-85 optimum 77F (5-29.4 optimum 25C)

2) Rain not required for infection – any form of free water

3) Rainfall may induce initial spore release and distribution from microsclerotia

4) Possibly cool climate loving, not yet reported in south

Ia. Parameter to use for upper threshold based on note 1 above: 29.4 C (85 F) (more data would be helpful to better define this value)

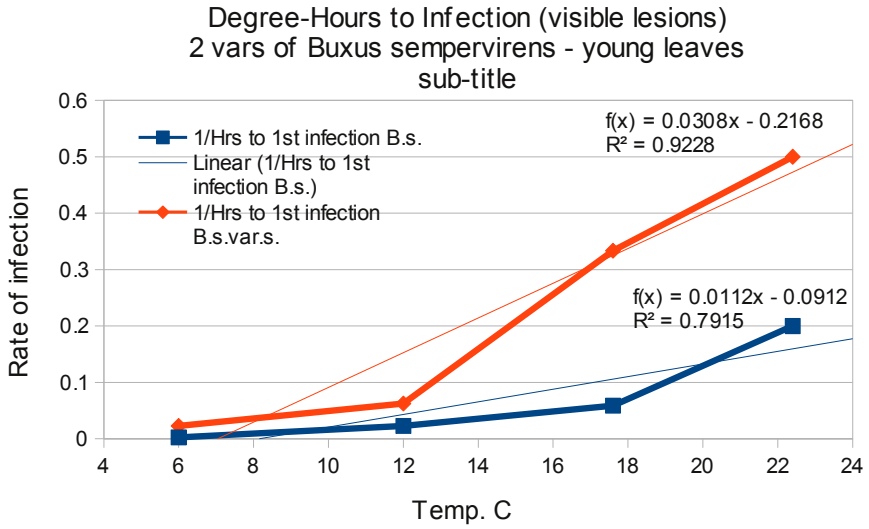
II. Model of first infections for 2 Boxwood vars, young and mature leaves

Based on first infection data only, main reference

IIa. Analysis of results from Gehesquiere et al.: young leaves

Temp C	Approx. hrs to 1st infection B. sempervirens	notes	Approx. hrs to 1st infection B. s. v. Suffrut	notes
6	400	estimated	44	near but < 48h
12	44	<48 >24h	16	
17.6	17	closer to 12 than 24l	3	sample data coarse
22.4	5	Near 6h maybe less	2	sample data coarse

Data for graph:	Temp C	1/Hrs to 1st infection	1/Hrs to 1st infection B.s.var.s.
	6	0.003	0.023
	12	0.023	0.063
	17.6	0.059	0.333
	22.4	0.200	0.500
	slope (b)	0.0111898	0.030786
	intercept (a)	-0.091239	-0.21676
	r2	0.791	0.923



IIb. Proposed model for first infection of young leaves (x-intercept method):

B. sempervirens (susceptible cultivar):

X-intercept -a/b = 8.154

Dhs (1/b) 89.367

Model: above 8.1 C, evidence of first infections in young foliage occur after 89 DHs during periods of leaf wetness

B. sempervirens "Suffruticosa" (highly susceptible cultivar):

X-intercept -a/b = 7.0409

Dhs (1/b) 32.4823

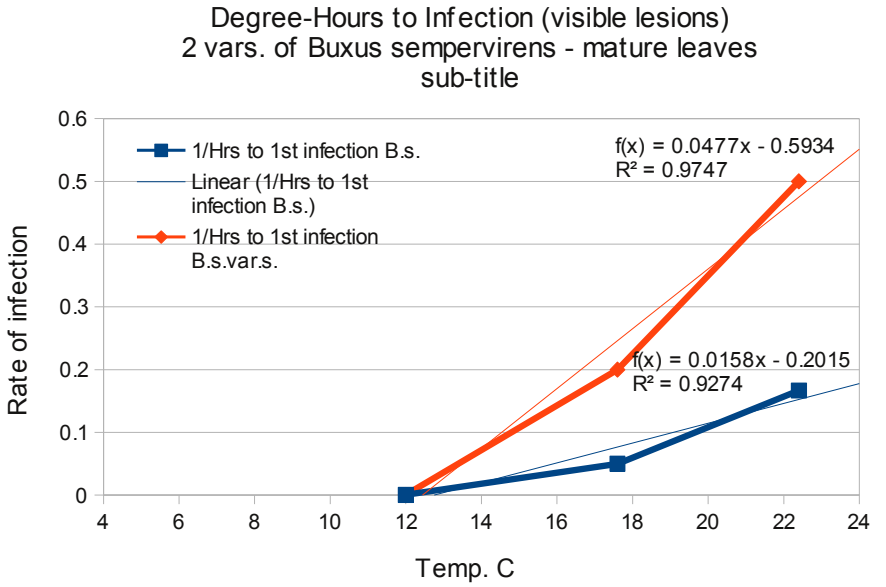
Model: above 7.0 C,evidence of first infections in young foliage occur after 32 DHs during periods of leaf wetness

Combined models using a common threshold of 7.78 C (ca. 46 F)	**Dhs (C) during LW periods**	**Dhs (F) during LW periods:**
B. sempervirens (susceptible cultivar):	**89**	**160.2**
B. sempervirens "Suffruticosa" (highly susceptible cultivar):	**31**	**55.8**

IIc. Analysis of results: mature leaves

Temp C	Approx. hrs to 1st infection Buxus sempervirens	Approx. hrs to 1st infection Buxus sempervirens var. Suffruticosa.
6	4000	4000
12	3000	3000
17.6	20	5
22.4	6	2

Temp C	1/Hrs to 1st infect	1/Hrs to 1st infection B.s.var.s.
6		
12	0.000	0.000
17.6	0.050	0.200
22.4	0.167	0.500
slope (b)	0.015805	0.047712
intercept (a)	-0.201655	-0.593585



IId. Proposed model for first infection of mature leaves (x-intercept method):

B. sempervirens (susceptible cultivar):

X-intercept -a/b = 12.7589

Dhs (1/b) 63.2711

Model: above 12.8 C, evidence of first infections in mature foliage occur after 63 DHs during periods of leaf wetness

B. sempervirens "Suffruticosa" (highly susceptible cultivar):

X-intercept -a/b = 12.4410

Dhs (1/b) 20.9591

Model: above 12.4 C, evidence of first infections in mature foliage occur after 21 DHs during periods of leaf wetness

Combined models using a common threshold of 10.56 C (ca. 51 F)	**Dhs during LW periods:**	**Dhs (F) during LW periods:**
B. sempervirens (moderately susceptible cultivar):	**80**	**144**
B. sempervirens "Suffruticosa" (highly susceptible cultivar):	**23**	**41.4**

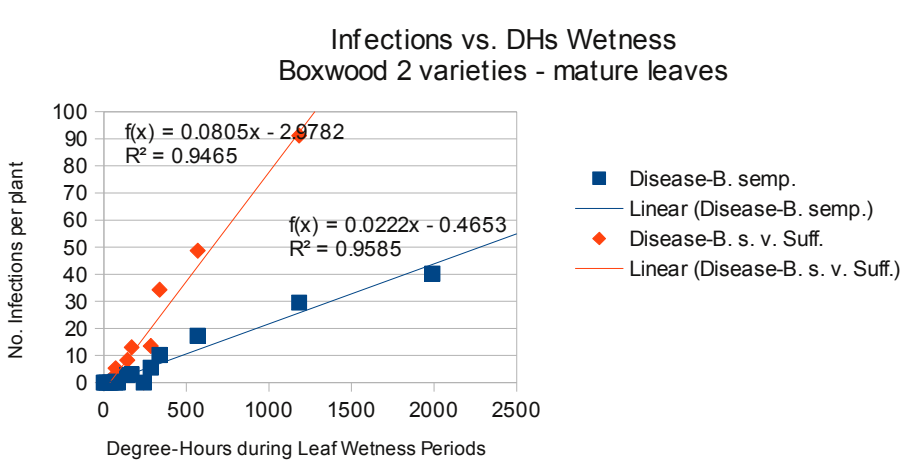
Note: These models were not implemented since the more susceptible young leaves were used for Tlow

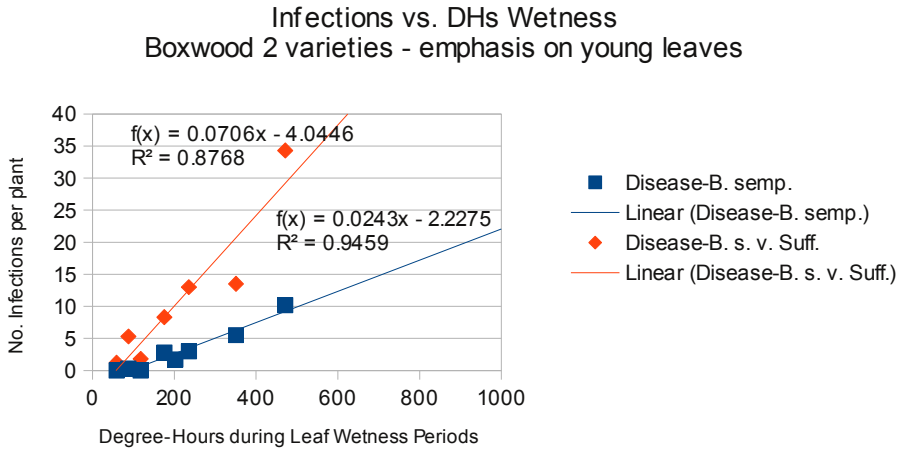
III. Model of degree of infection (no. of lesions as a function of degree-hours during periods of leaf wetness)

Based on full data set, Gehesquiere et al. 2012

IIIa. Vary Tlow, fit linear model to disease progress vs. degree-hours

	Tlow =		10.56			Tlow=		Modeled Data (outliers and results at greater than 500 DH removed)		Full Data Set	
	B. semp.	Mature only	Number of Lesions				Young	Young+mature		Young+mature	
Temp C	Hrs	Dhs	Disease-B. se	Disease-B. s. v. Suff.			Dhs	Disease-B. se	Disease-B. s. v. Suff.	Disease-B. se	Disease-B. s.
22.4	168	1989.12	40.2				2456.16			40.2	101.8
22.4	48	568.32	17.3	48.7			701.76			17.3	48.7
22.4	24	284.16	5.5	13.5			350.88	5.5	13.5	5.5	13.5
22.4	12	142.08	2.8	8.3			175.44	2.8	8.3	2.8	8.3
22.4	6	71.04	0.3	5.3			87.72	0.3	5.3	0.3	5.3
17.6	168	1182.72	29.5	91.2			1649.76			29.5	91.2
17.6	48	337.92	10.2	34.3			471.36	10.2	34.3	10.2	34.3
17.6	24	168.96	3	13			235.68	3	13	3	13
17.6	12	84.48	0	1.8			117.84	0	1.8	0	1.8
17.6	6	42.24	0	1.2			58.92	0	1.2	0	1.2
12	168	241.92	0	0			708.96			3	0.3
12	48	69.12	0	0			202.56	1.7		1.7	0.7
12	24	34.56	0	0			101.28	0	0	0	0
12	12	17.28	0	0			50.64	0	0	0	0
12	6	8.64	0	0			25.32	0	0	0	0
6	168	0	0	0			0	0	0	0	0
6	48	0	0	0			0	0	0.5	0	0.5
6	24	0	0	0			0	0	0	0	0
6	12	0	0	0			0	0	0	0	0
6	6	0	0	0			0	0	0		



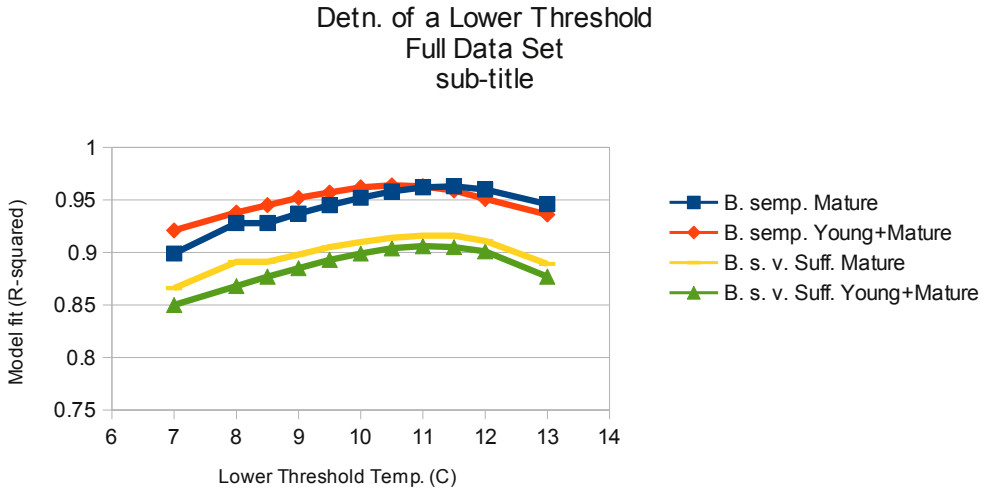


Results: Virtually no difference between exclude young-only leaves and young+mature leaves. See below for determination of Tlow vs. error rates; suggest two options: 1) emphasize young leaves, since they are more susceptible at lower temps (Tlow=7.78C), 2) emphasize mature leaves where threshold fits data a bit better, Tlow=10.56C (51F). Move with a single model option 1 for now

IIIb. Check error rates for varying lower temperature thresholds to determine best value to start with

Determination of Tlow – Include all original data

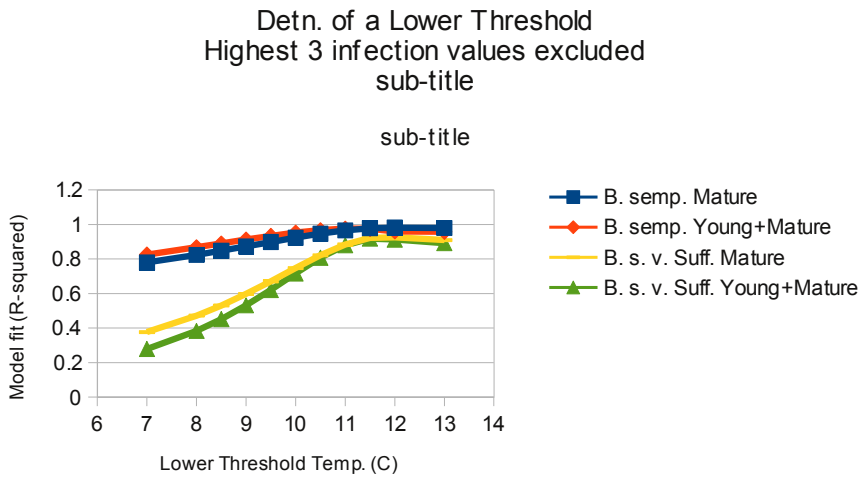
	R-sq values			
Tlow	B. semp. Mature	B. semp. Young+Mature	B. s. v. Suff. Mature	B. s. v. Suff. Young+Mature
13	0.946	0.936	0.889	0.877
12	0.96	0.951	0.911	0.901
11.5	0.963	0.959	0.916	0.905
11	0.962	0.963	0.916	0.906
10.5	0.958	0.964	0.914	0.904
10	0.952	0.962	0.91	0.899
9.5	0.945	0.957	0.905	0.893
9	0.937	0.952	0.898	0.885
8.5	0.928	0.945	0.891	0.877
8	0.928	0.938	0.891	0.868
7	0.899	0.921	0.866	0.85



Results: Highest R2 11.5-12 C for Mature only leaves, 10.5-11 C for Young plus Mature, both vars. Note slow fall-off in R2 showing lack of sensitivity to Tlow.

Determination of Tlow – Exclude Highest 3 data points to focus on X-intercept (and first infections)

Tlow	B. semp. Mature	B. semp. Young+Mature	B. s. v. Suff. Mature	B. s. v. Suff. Young+Mature
13	0.98	0.958	0.91	0.892
12	0.982	0.96	0.926	0.913
11.5	0.979	0.975	0.923	0.918
11	0.966	0.977	0.884	0.88
10.5	0.947	0.968	0.822	0.808
10	0.924	0.953	0.748	0.717
9.5	0.899	0.934	0.671	0.621
9	0.873	0.913	0.598	0.532
8.5	0.848	0.89	0.531	0.452
8	0.824	0.868	0.472	0.384
7	0.78	0.826	0.377	0.279



Results: Highest R2 12 C for Mature only leaves, 11-11.5 C for Young plus Mature, both vars. Note rapidly dropping R2 for the more suscept. Var. Below 11 C.

Interpretation: Two models should be developed: firstly, a model with Tlow=46F for the more susceptible younger leaves, and secondly a model with Tlow=51F for mature leaves. For a first, single model, use the more susceptible younger leaves, and a threshold of 7.78C (46F).

IIIc. Proposed Degree of Infection Models: Based on all data

(modified to exclude data above 500 DH)

Degree of infection as a function of Degree-Hours (Tlow=7.78) during periods of leaf wetness

B. semp. Leaves: infection (#lesions/plant) = 0.0243 x DH – 2.2275
R2 = 0.946

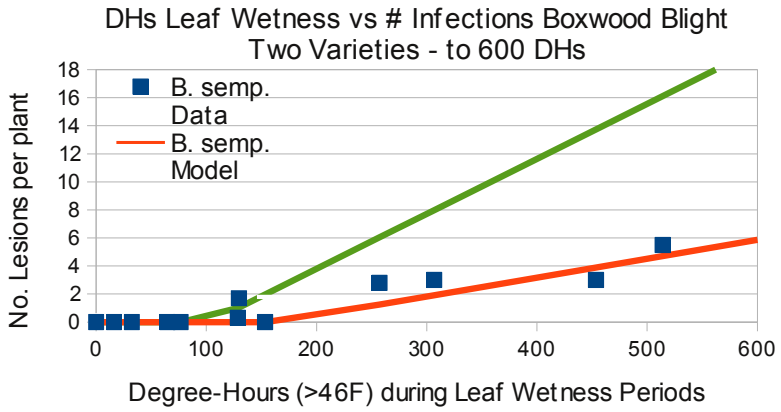
B. s. v. Suff. Leaves: infection (#lesions/plant) = 0.0706 x DH – 4.0446
R2 = 0.877

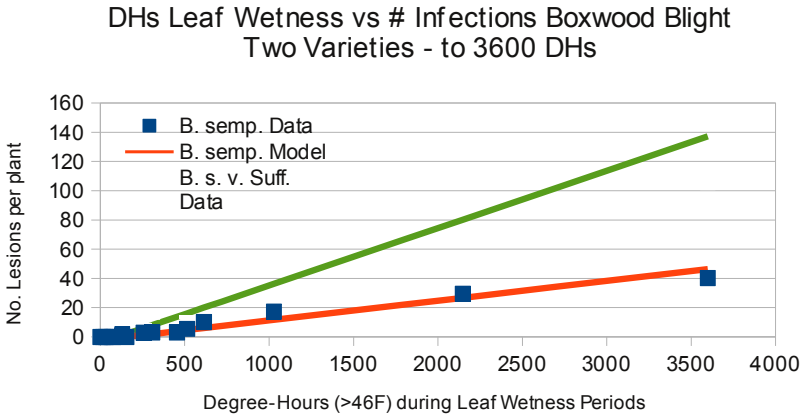
	No. of lesions per plant			
	B. semp.	B. s. v. Suff.		
DH (>7.78C)	Young+Mature	Young+Mature	DH(>46F)	Events to consider using in models:
0	0.0	0.0	0.0	
40	0.0	0.0	72.0	
90	0.0	2.3	162.0	
139	1.2	5.8	250.2	← event: at 250DH (F), 1-6 lesions/plant predicted
167	1.8	7.7	300.6	← event: at 300DH (F), 2-8 lesions/plant predicted
178	2.1	8.5	320.4	← event: at 320DH (F), 2-9 lesions/plant predicted
223	3.2	11.7	401.4	← event: at 400DH (F), 3-12 lesions/plant predicted
250	3.8	13.6	450.0	← event: at 450DH (F), 3-12 lesions/plant predicted
306	5.2	17.6	550.8	← event: at 550DH (F), 5-18 lesions/plant predicted
334	5.9	19.5	601.2	
445	8.6	27.4	801.0	
500	9.9	31.3	900.0	
600	12.4	38.3	1080.0	
700	14.8	45.4	1260.0	
834	18.0	54.8	1501.2	
1000	22.1	66.6	1800.0	

IIId. Degree of infection (no. lesions/plant) models vs. data for plots

Dhs (C)	DHs (F)	B. semp. Data	B. semp. Mod	B. s. v. Suff. D	B. s. v. Suff. Model
0	0	0	0.00	0	0.00
0	0	0	0.00	0.5	0.00
9	16.2	0	0.00	0	0.00
18	32.4	0	0.00	0	0.00
36	64.8	0	0.00	0	0.00
42.6	76.68	0	0.00	1.2	0.00
71.4	128.52	0.3	0.00	5.3	1.00
72	129.6	1.7	0.00	0.7	1.04
85.2	153.36	0	0.00	1.8	1.97
142.8	257.04	2.8	1.24	8.3	6.04
170.4	306.72	3	1.91	13	7.99
252	453.6	3	3.90	0.3	13.75
285.6	514.08	5.5	4.71	13.5	16.12
340.8	613.44	10.2	6.05	34.3	20.02
400	720		7.49		24.20
571.2	1028.16	17.3	11.65	48.7	36.28
1000	1800		22.07		66.56
1192.8	2147.04	29.5	26.76	91.2	80.17
1500	2700		34.22		101.86
1999.2	3598.56	40.2	46.35	101.8	137.10

Results: note that the model remains fairly linear even out to 3600 DH (lower plot), even though it was modified to be based on the lower range of DH values (upper plot)





IV. Summary of model parameters for implementation at uspest.org/risk/models:

Name of model:	Boxwood blight infection risk
Model type:	Degree-hours (DHs) accumulated during periods of leaf wetness
Lower temperature threshold:	46 F (7.78C)
Upper temperature threshold:	85 F (29.4 C)
No. of dry hours to stop the infection cycle:	more than 8.0
DHs to first infection of young leaves (highly susc. Var.)	56.00
DHs to first infection of young leaves (susc. Var.)	160.00
DHs for level of infection: 6 lesions, highly susc. Var., 1 lesion, susc. Var	250
DHs for level of infection: 12 lesions, highly susc. Var., 3 lesions, susc. Var	400
DHs for level of infection: 18 lesions, highly susc. Var., 5 lesions, susc. Var	550
Model assumptions:	1. Spores from microsclerotia generally require rainfall to initiate the infection process, thus the model conservatively does not require rainfall events, as spores may also be present from existing lesions. 2. The model should reflect a range of infection conditions most likely to occur in typical N. American climates; it was adjusted to reflect needs in the humid mid-latitudes (such as NC, VA, WV, PA, and MD). 3. These results reflect work performed on one highly susceptible (English boxwood) and one susceptible (American boxwood) variety; lower infection risk levels would be expected for less susceptible varieties.

List of needs for improvement in the model(s):	1. More varieties should be tested; a very wide range of susceptibility/tolerance is already known. 2. The models are weak with respect to lower temperatures; the lower temperature threshold may change once more data are available. 3. The upper temperature threshold and no. dry hours to stop an infection cycle also could be better resolved with more research; for now these values are somewhat conservative.