Magarey : modèle d'infection pour les maladies foliaires

François Brun (ACTA)

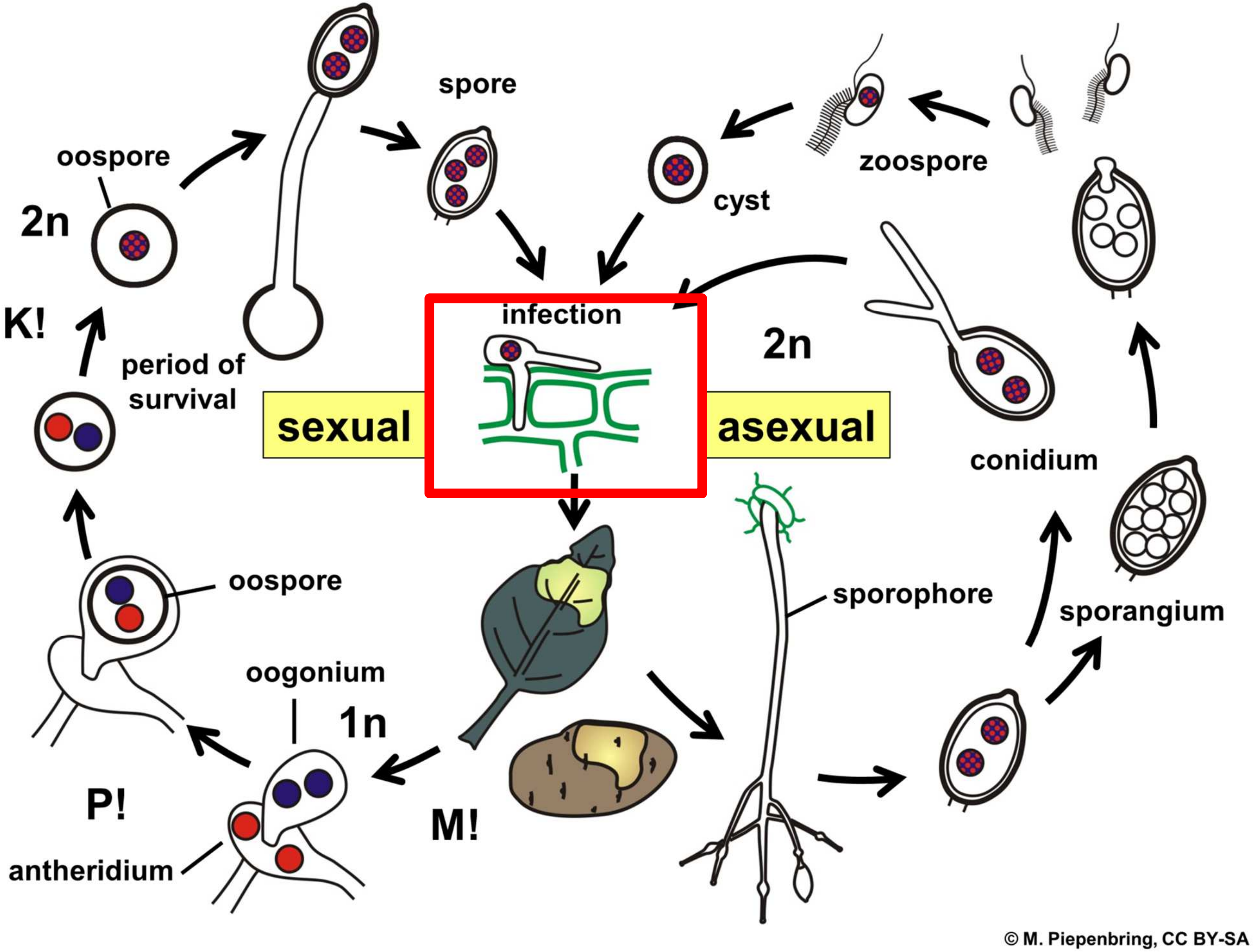
Formation Introduction à la modélisation pour la protection intégrée des cultures.

30 novembre au 4 décembre 2015

Objectifs du cours

- L’infection dans le développement d’une maladie
- Connaissances et expérimentations sur l’infection
- Description du modèle de Magarey
- Utilisation du modèle

exemple de cycle (*P. infestans*)


spore
oospore
2n
K!
period of survival
sexual
infection
asexual
2n
cyst
zoospore
conidium
oospore
sporophore
sporangium
oogonium
1n
P!
M!
antheridium

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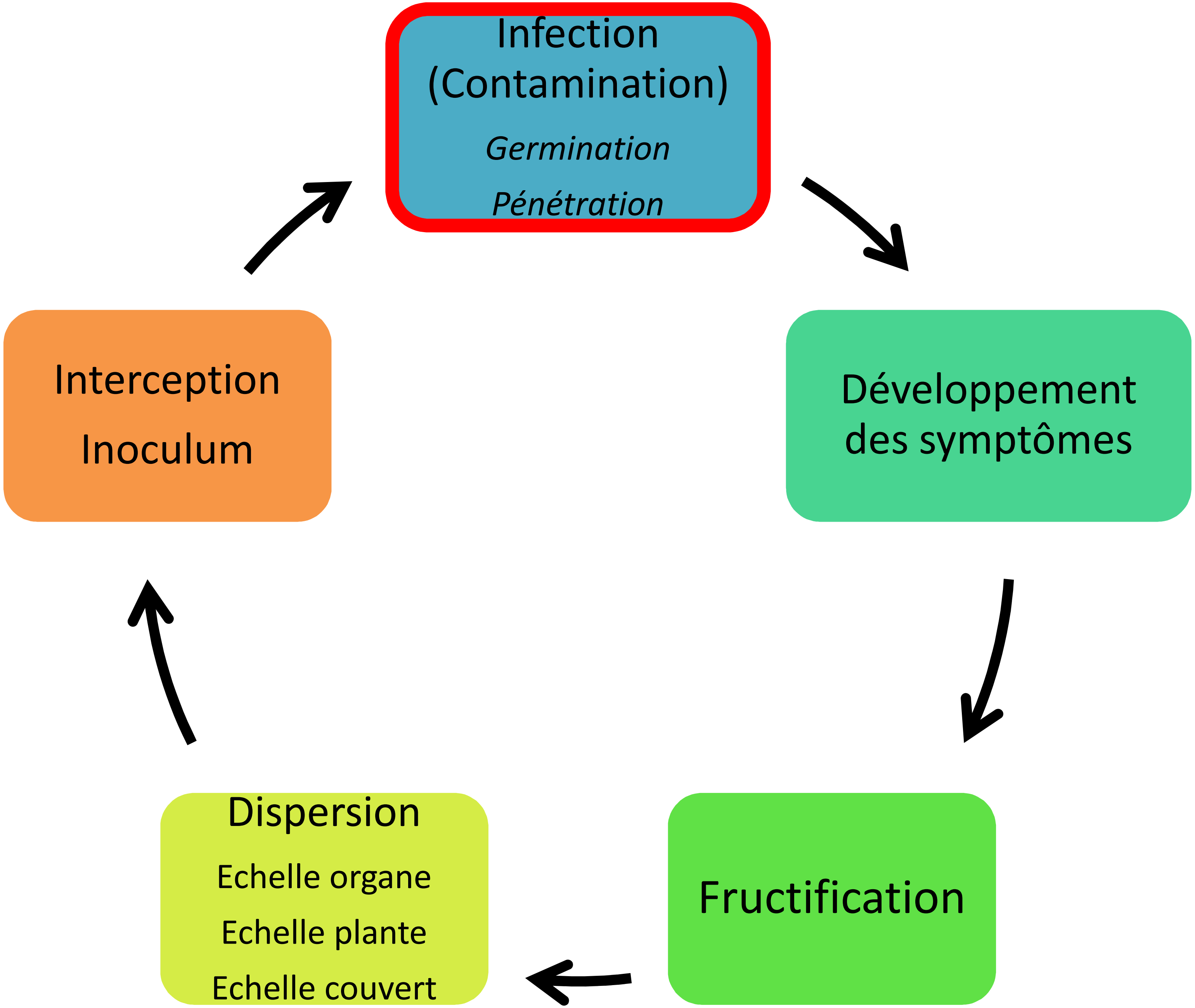
Le cycle de base d’une maladie



Infection
(Contamination)

Germination

Pénétration

Développement
des symptômes

Fructification

Dispersion

Echelle organe

Echelle plante

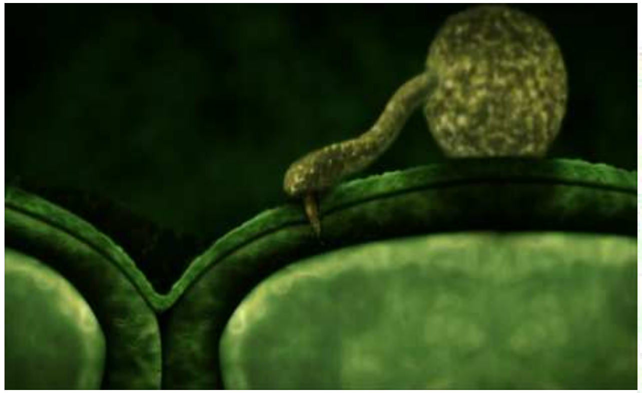
Echelle couvert

Interception

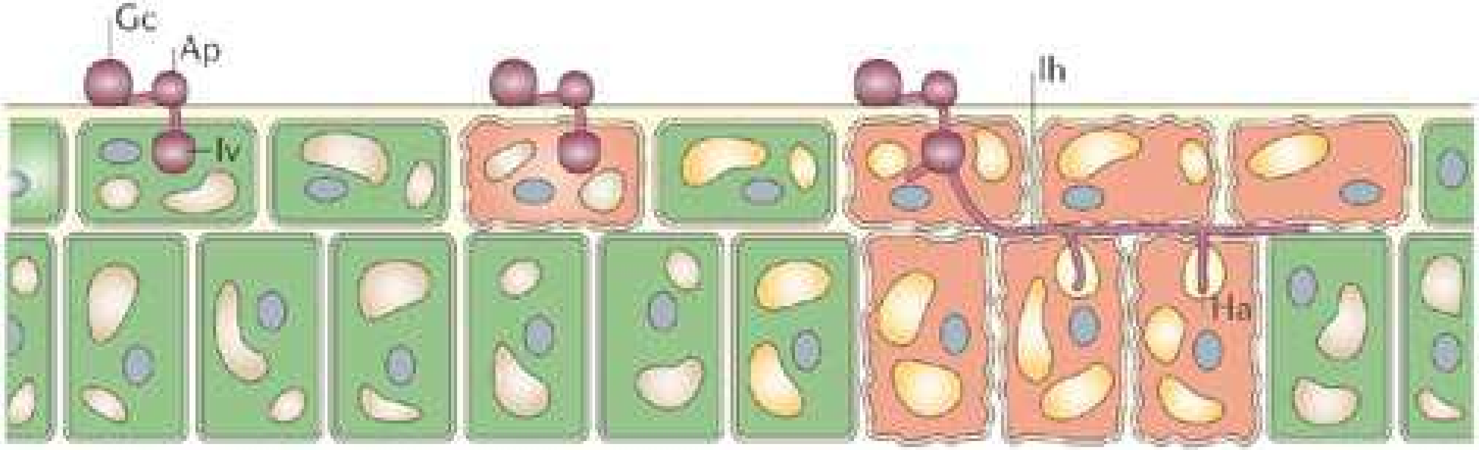
Inoculum

Germination, pénétration et développement

- Illustration (*Phytophthora infestans* sur la pomme de terre)



Phytophthora infestans
Source : Verreet and Klink, 2013



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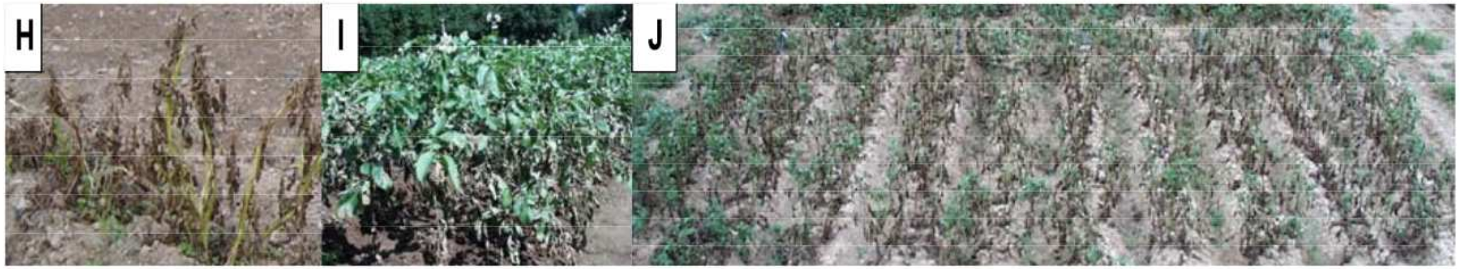
germination pénétration

contamination=infection

développement

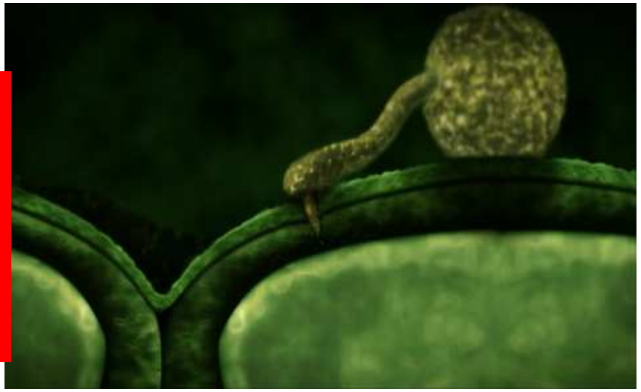


Figures 1.3 H, I, J Symptômes au champ, les plantes attaquées sont noirâtres, comme si elles étaient brûlées (Photographies : R. Corbière – Inra –Le Rheu).

Rakotonindraina, 2012

Infection = fonction de l'environnement

germination
= fonction du Microclimat
- Température
- durée d'humectation



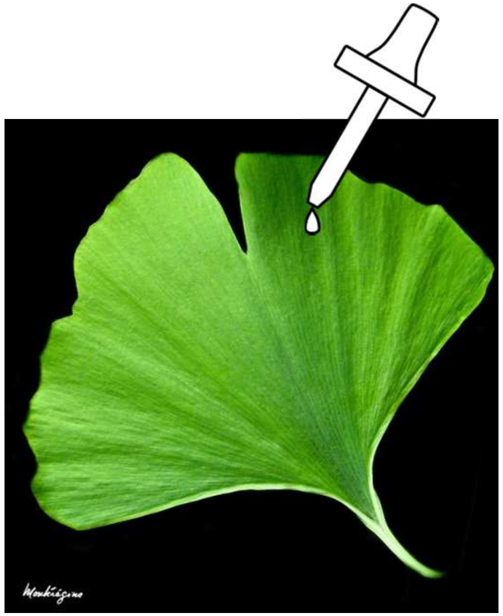
Phytophthora infestans
Source : Verreet and Klink, 2013

Pénétration
- Plante hôte / non hôte
- Signaux plantes,…

Expérimentations sur les conditions d'infections

Enceinte climatique

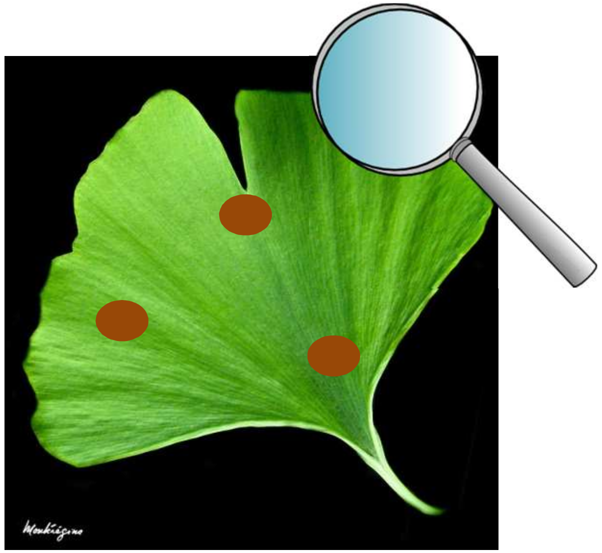
1)Inoculation artificielle à t=0



pour T (température)
et W (durée d'humectation)

Enceinte climatique

2) Observation à t



Estimation de l'infection à différentes combinaisons de température et d'humidité.
avec infection :

- 20% de feuilles symptôme (incidence)
- ou 5% de surface avec symptôme (sévérité)

Expérimentations de la littérature

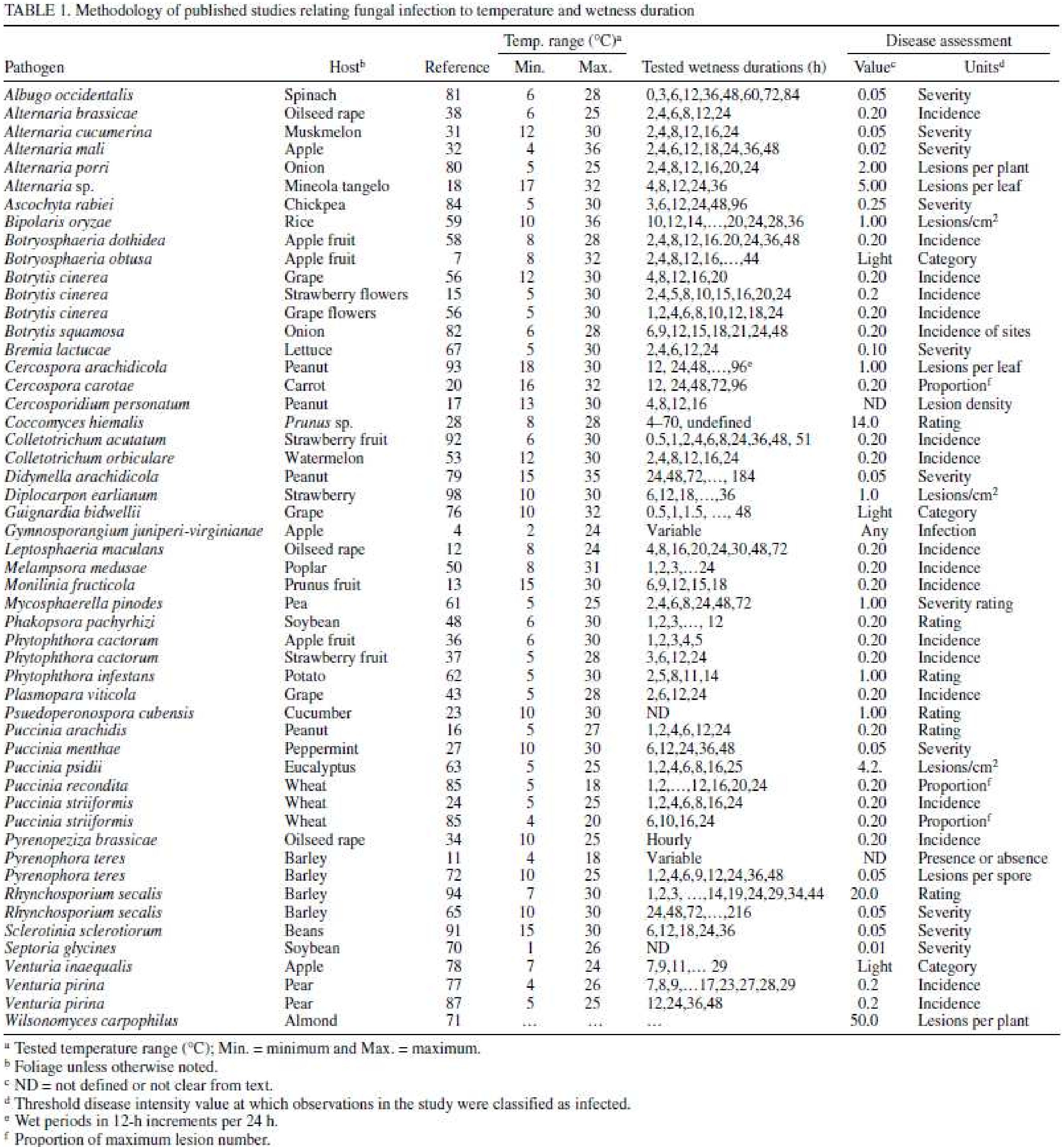


TABLE 1. Methodology of published studies relating fungal infection to temperature and wetness duration

			Temp. range (°C)[a]			Disease assessment	
Pathogen	Host[b]	Reference	Min.	Max.	Tested wetness durations (h)	Value[c]	Units[d]
Albugo occidentalis	Spinach	81	6	28	0,3,6,12,36,48,60,72,84	0.05	Severity
Alternaria brassicae	Oilseed rape	38	6	25	2,4,6,8,12,24	0.20	Incidence
Alternaria cucumerina	Muskmelon	31	12	30	2,4,8,12,16,24	0.05	Severity
Alternaria mali	Apple	32	4	36	2,4,6,12,18,24,36,48	0.02	Severity
Alternaria porri	Onion	80	5	25	2,4,8,12,16,20,24	2.00	Lesions per plant
Alternaria sp.	Mineola tangelo	18	17	32	4,8,12,24,36	5.00	Lesions per leaf
Ascochyta rabiei	Chickpea	84	5	30	3,6,12,24,48,96	0.25	Severity
Bipolaris oryzae	Rice	59	10	36	10,12,14,…,20,24,28,36	1.00	Lesions/cm^2
Botryosphaeria dothidea	Apple fruit	58	8	28	2,4,8,12,16.20,24,36,48	0.20	Incidence
Botryosphaeria obtusa	Apple fruit	7	8	32	2,4,8,12,16,…,44	Light	Category
Botrytis cinerea	Grape	56	12	30	4,8,12,16,20	0.20	Incidence
Botrytis cinerea	Strawberry flowers	15	5	30	2,4,5,8,10,15,16,20,24	0.2	Incidence
Botrytis cinerea	Grape flowers	56	5	30	1,2,4,6,8,10,12,18,24	0.20	Incidence
Botrytis squamosa	Onion	82	6	28	6,9,12,15,18,21,24,48	0.20	Incidence of sites
Bremia lactucae	Lettuce	67	5	30	2,4,6,12,24	0.10	Severity
Cercospora arachidicola	Peanut	93	18	30	12, 24,48,…,96[e]	1.00	Lesions per leaf
Cercospora carotae	Carrot	20	16	32	12, 24,48,72,96	0.20	Proportion[f]
Cercosporidium personatum	Peanut	17	13	30	4,8,12,16	ND	Lesion density
Coccomyces hiemalis	*Prunus* sp.	28	8	28	4–70, undefined	14.0	Rating
Colletotrichum acutatum	Strawberry fruit	92	6	30	0.5,1,2,4,6,8,24,36,48, 51	0.20	Incidence
Colletotrichum orbiculare	Watermelon	53	12	30	2,4,8,12,16,24	0.20	Incidence
Didymella arachidicola	Peanut	79	15	35	24,48,72,…, 184	0.05	Severity
Diplocarpon earlianum	Strawberry	98	10	30	6,12,18,…,36	1.0	Lesions/cm^2
Guignardia bidwellii	Grape	76	10	32	0.5,1,1.5, …, 48	Light	Category
Gymnosporangium juniperi-virginianae	Apple	4	2	24	Variable	Any	Infection
Leptosphaeria maculans	Oilseed rape	12	8	24	4,8,16,20,24,30,48,72	0.20	Incidence
Melampsora medusae	Poplar	50	8	31	1,2,3,…24	0.20	Incidence
Monilinia fructicola	Prunus fruit	13	15	30	6,9,12,15,18	0.20	Incidence
Mycosphaerella pinodes	Pea	61	5	25	2,4,6,8,24,48,72	1.00	Severity rating
Phakopsora pachyrhizi	Soybean	48	6	30	1,2,3,…, 12	0.20	Rating
Phytophthora cactorum	Apple fruit	36	6	30	1,2,3,4,5	0.20	Incidence
Phytophthora cactorum	Strawberry fruit	37	5	28	3,6,12,24	0.20	Incidence
Phytophthora infestans	Potato	62	5	30	2,5,8,11,14	1.00	Rating
Plasmopara viticola	Grape	43	5	28	2,6,12,24	0.20	Incidence
Psuedoperonospora cubensis	Cucumber	23	10	30	ND	1.00	Rating
Puccinia arachidis	Peanut	16	5	27	1,2,4,6,12,24	0.20	Rating
Puccinia menthae	Peppermint	27	10	30	6,12,24,36,48	0.05	Severity
Puccinia psidii	Eucalyptus	63	5	25	1,2,4,6,8,16,25	4.2.	Lesions/cm^2
Puccinia recondita	Wheat	85	5	18	1,2,…,12,16,20,24	0.20	Proportion[f]
Puccinia striiformis	Wheat	24	5	25	1,2,4,6,8,16,24	0.20	Incidence
Puccinia striiformis	Wheat	85	4	20	6,10,16,24	0.20	Proportion[f]
Pyrenopeziza brassicae	Oilseed rape	34	10	25	Hourly	0.20	Incidence
Pyrenophora teres	Barley	11	4	18	Variable	ND	Presence or absence
Pyrenophora teres	Barley	72	10	25	1,2,4,6,9,12,24,36,48	0.05	Lesions per spore
Rhynchosporium secalis	Barley	94	7	30	1,2,3, …,14,19,24,29,34,44	20.0	Rating
Rhynchosporium secalis	Barley	65	10	30	24,48,72,…,216	0.05	Severity
Sclerotinia sclerotiorum	Beans	91	15	30	6,12,18,24,36	0.05	Severity
Septoria glycines	Soybean	70	1	26	ND	0.01	Severity
Venturia inaequalis	Apple	78	7	24	7,9,11,… 29	Light	Category
Venturia pirina	Pear	77	4	26	7,8,9,…17,23,27,28,29	0.2	Incidence
Venturia pirina	Pear	87	5	25	12,24,36,48	0.2	Incidence
Wilsonomyces carpophilus	Almond	71	…	…	…	50.0	Lesions per plant

[a] Tested temperature range (°C); Min. = minimum and Max. = maximum.

[b] Foliage unless otherwise noted.

[c] ND = not defined or not clear from text.

[d] Threshold disease intensity value at which observations in the study were classified as infected.

[e] Wet periods in 12-h increments per 24 h.

[f] Proportion of maximum lesion number.

Expérimentations de la littérature

Gramme de T
(température)

Gamme de W
(durée d’humectation)

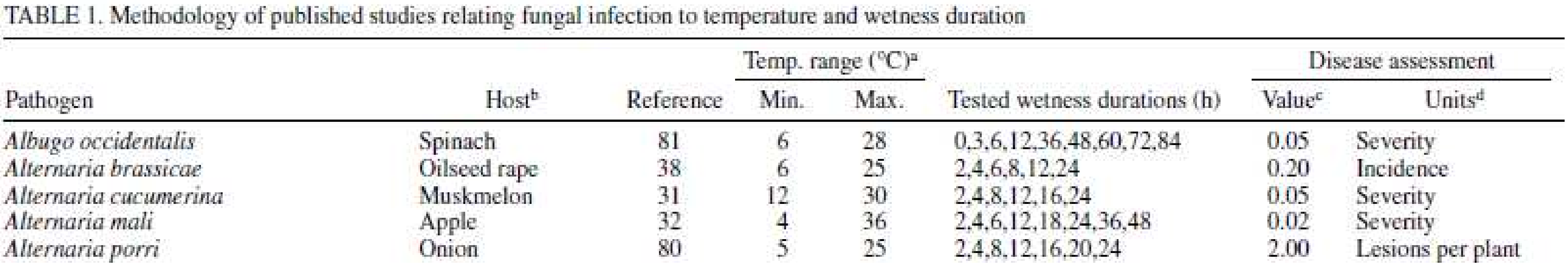


TABLE 1. Methodology of published studies relating fungal infection to temperature and wetness duration

			Temp. range (°C)[a]			Disease assessment	
Pathogen	Host[b]	Reference	Min.	Max.	Tested wetness durations (h)	Value[c]	Units[d]
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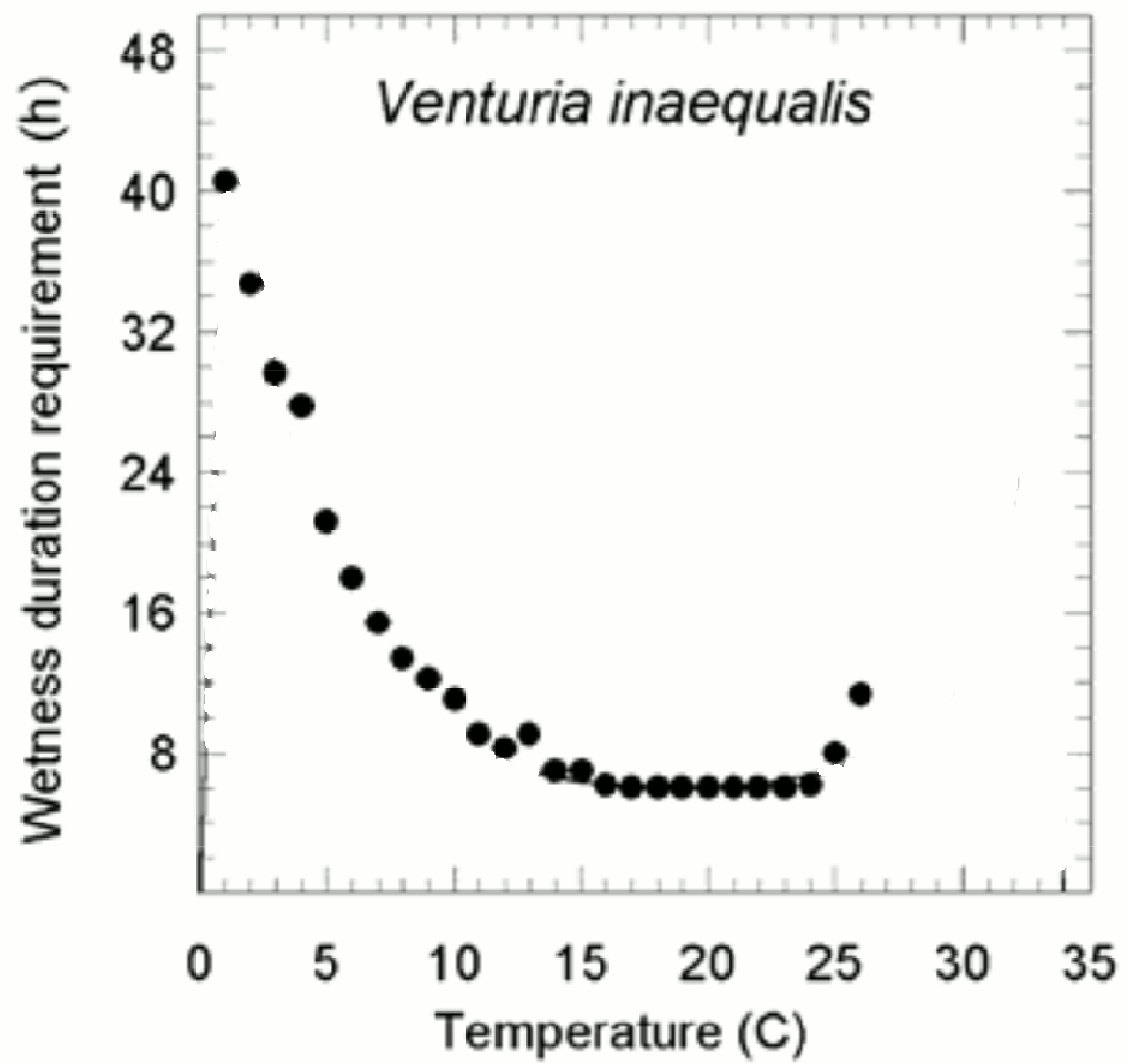
Alternaria brassicae	Oilseed rape	38	6	25	2,4,6,8,12,24	0.20	Incidence
Alternaria cucumerina	Muskmelon	31	12	30	2,4,8,12,16,24	0.05	Severity
Alternaria mali	Apple	32	4	36	2,4,6,12,18,24,36,48	0.02	Severity
Alternaria porri	Onion	80	5	25	2,4,8,12,16,20,24	2.00	Lesions per plant

Variable mesurée
et seuil

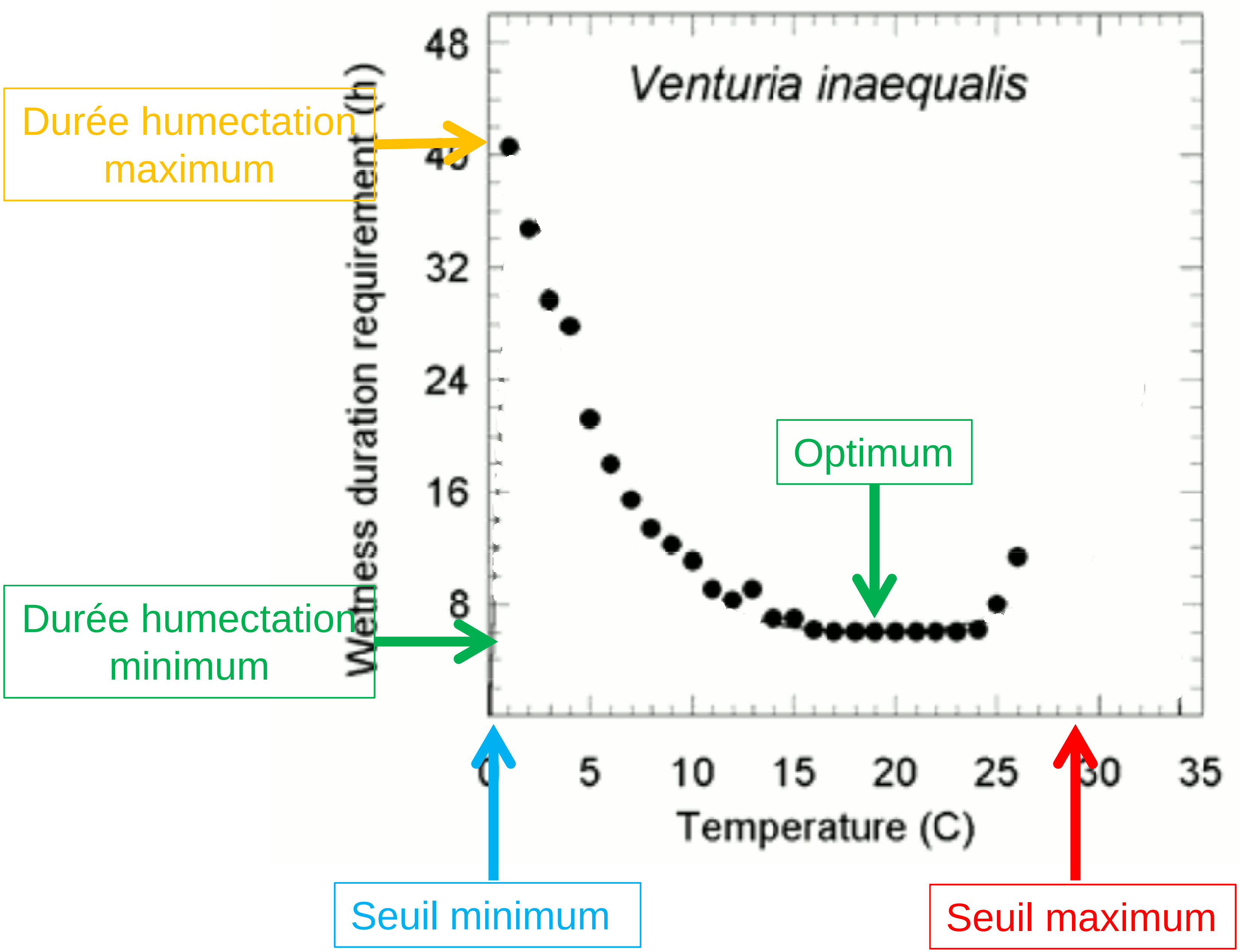
Exemple de données

Tavelure du Pommier
Source : http://www7.inra.fr/hyp3



Source : Magarey, 2005

Interprétation à partir de nos connaissances



Durée humectation maximum

Durée humectation minimum

Optimum

Seuil minimum

Seuil maximum

Source : Magarey, 2005

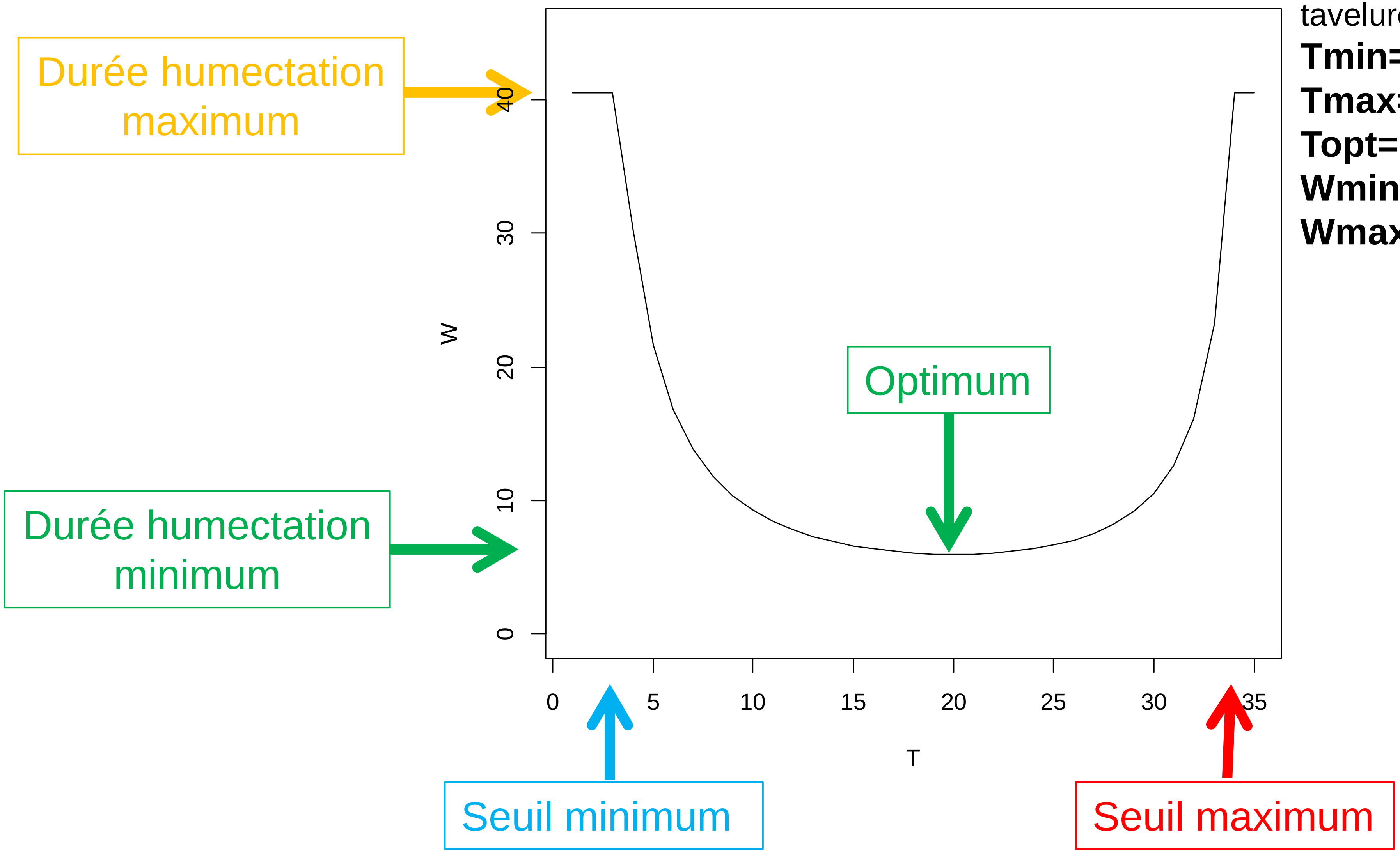
Formalisme proposé par Magarey

$$W = \frac{W_{\min}}{f(T)} \text{ if } T_{\min} \leq T \leq T_{\max} \qquad (1)$$

$$= W_{\max} \text{ otherwise}$$

$$f(T) = \left(\frac{T_{\max} - T}{T_{\max} - T_{opt}}\right)\left(\frac{T - T_{\min}}{T_{opt} - T_{\min}}\right)^{(T_{opt} - T_{\min})/(T_{\max} - T_{opt})} \qquad (2)$$

Simulation



Durée humectation maximum

Durée humectation minimum

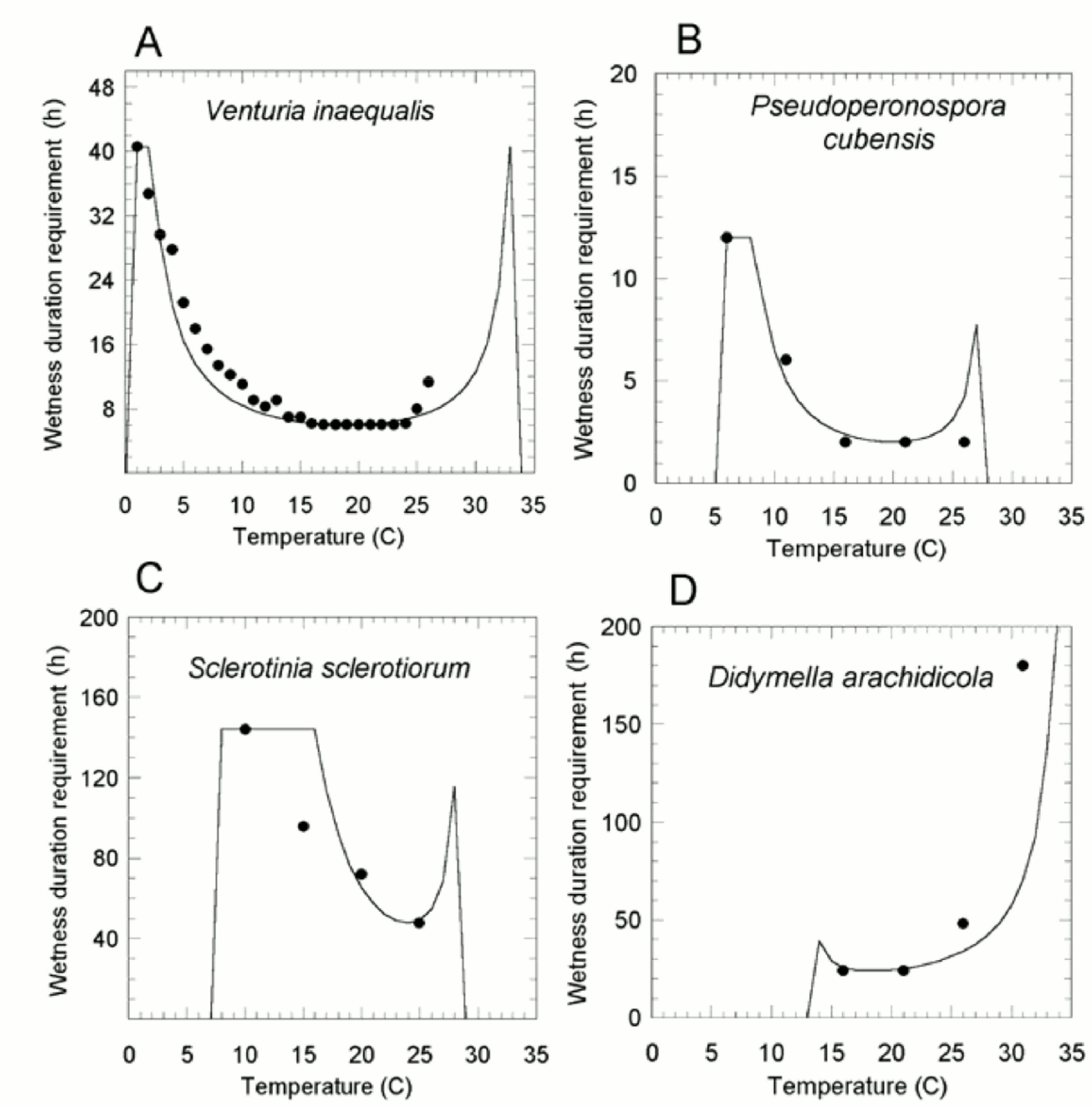
Optimum

Seuil minimum

Seuil maximum

Venturia inaequalis
tavelure pommier
Tmin=1
Tmax=35
Topt= 20
Wmin=6
Wmax=40.5

Estimation des paramètres à partir des données



… pour de nombreuses maladies

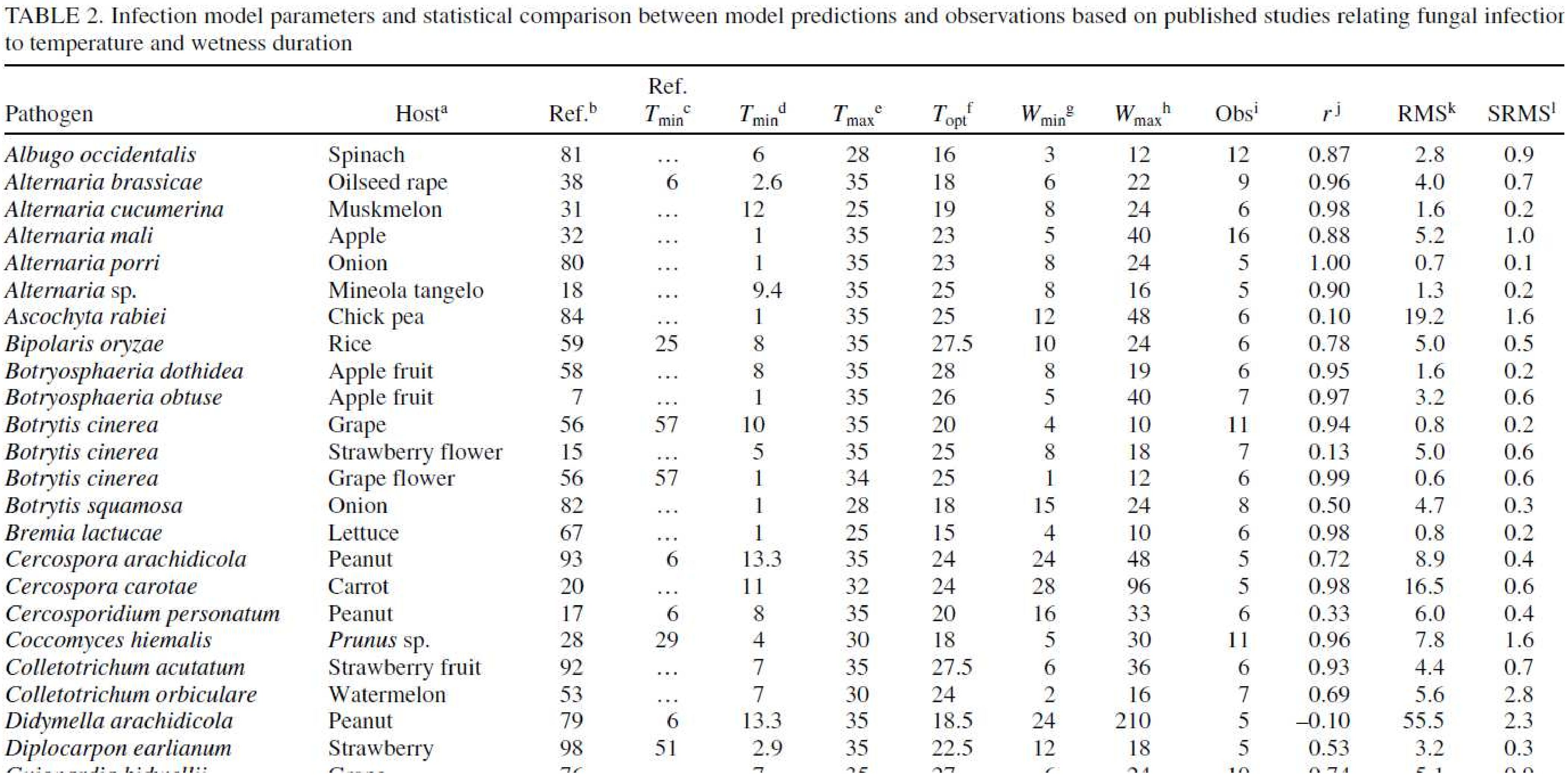
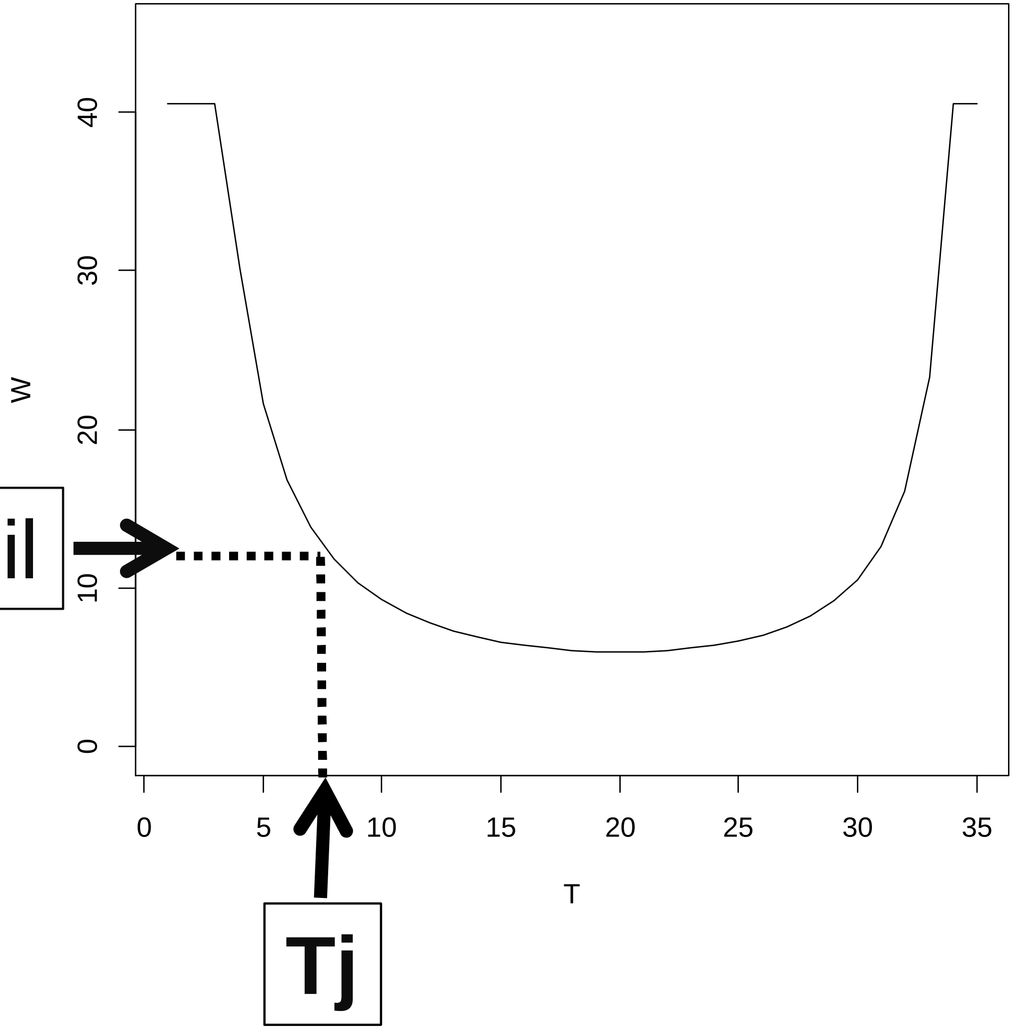


TABLE 2. Infection model parameters and statistical comparison between model predictions and observations based on published studies relating fungal infection to temperature and wetness duration

Pathogen	Host[a]	Ref.[b]	Ref. T_{min}[c]	T_{min}[d]	T_{max}[e]	T_{opt}[f]	W_{min}[g]	W_{max}[h]	Obs[i]	r[j]	RMS[k]	SRMS[l]
Albugo occidentalis	Spinach	81	…	6	28	16	3	12	12	0.87	2.8	0.9
Alternaria brassicae	Oilseed rape	38	6	2.6	35	18	6	22	9	0.96	4.0	0.7
Alternaria cucumerina	Muskmelon	31	…	12	25	19	8	24	6	0.98	1.6	0.2
Alternaria mali	Apple	32	…	1	35	23	5	40	16	0.88	5.2	1.0
Alternaria porri	Onion	80	…	1	35	23	8	24	5	1.00	0.7	0.1
Alternaria sp.	Mineola tangelo	18	…	9.4	35	25	8	16	5	0.90	1.3	0.2
Ascochyta rabiei	Chick pea	84	…	1	35	25	12	48	6	0.10	19.2	1.6
Bipolaris oryzae	Rice	59	25	8	35	27.5	10	24	6	0.78	5.0	0.5
Botryosphaeria dothidea	Apple fruit	58	…	8	35	28	8	19	6	0.95	1.6	0.2
Botryosphaeria obtuse	Apple fruit	7	…	1	35	26	5	40	7	0.97	3.2	0.6
Botrytis cinerea	Grape	56	57	10	35	20	4	10	11	0.94	0.8	0.2
Botrytis cinerea	Strawberry flower	15	…	5	35	25	8	18	7	0.13	5.0	0.6
Botrytis cinerea	Grape flower	56	57	1	34	25	1	12	6	0.99	0.6	0.6
Botrytis squamosa	Onion	82	…	1	28	18	15	24	8	0.50	4.7	0.3
Bremia lactucae	Lettuce	67	…	1	25	15	4	10	6	0.98	0.8	0.2
Cercospora arachidicola	Peanut	93	6	13.3	35	24	24	48	5	0.72	8.9	0.4
Cercospora carotae	Carrot	20	…	11	32	24	28	96	5	0.98	16.5	0.6
Cercosporidium personatum	Peanut	17	6	8	35	20	16	33	6	0.33	6.0	0.4
Coccomyces hiemalis	*Prunus* sp.	28	29	4	30	18	5	30	11	0.96	7.8	1.6
Colletotrichum acutatum	Strawberry fruit	92	…	7	35	27.5	6	36	6	0.93	4.4	0.7
Colletotrichum orbiculare	Watermelon	53	…	7	30	24	2	16	7	0.69	5.6	2.8
Didymella arachidicola	Peanut	79	6	13.3	35	18.5	24	210	5	–0.10	55.5	2.3
Diplocarpon earlianum	Strawberry	98	51	2.9	35	22.5	12	18	5	0.53	3.2	0.3

Utilisation

- Utilisation des données météos pour déterminer si les conditions journalières sont propices à l’infection ou pas.
  - Tj : température du jour
  - Wj : nombre d’heure d’humecation

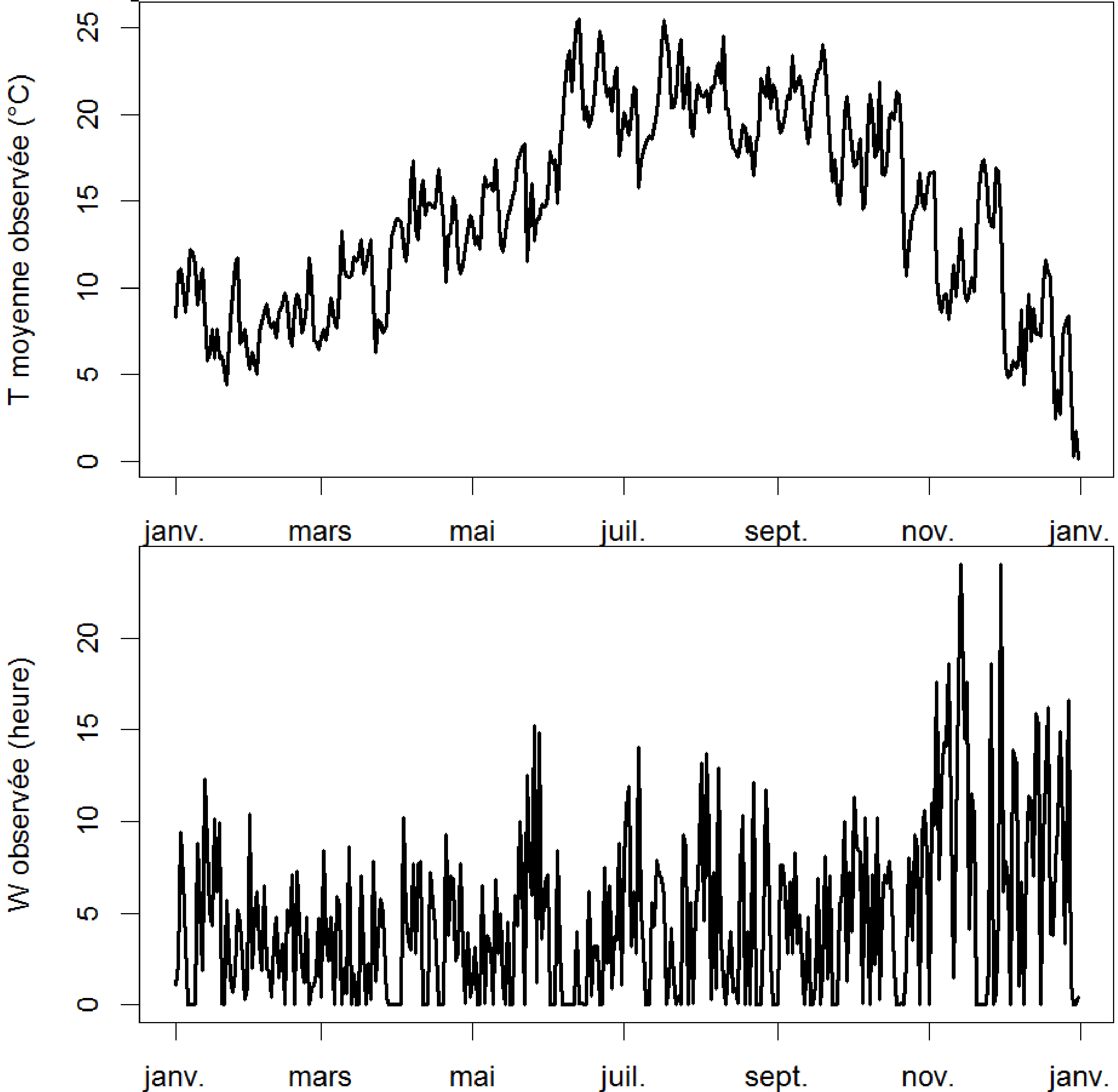


Si Wj >= Wseuil, **infection**

Si Wj < Wseuil, ~~infection~~

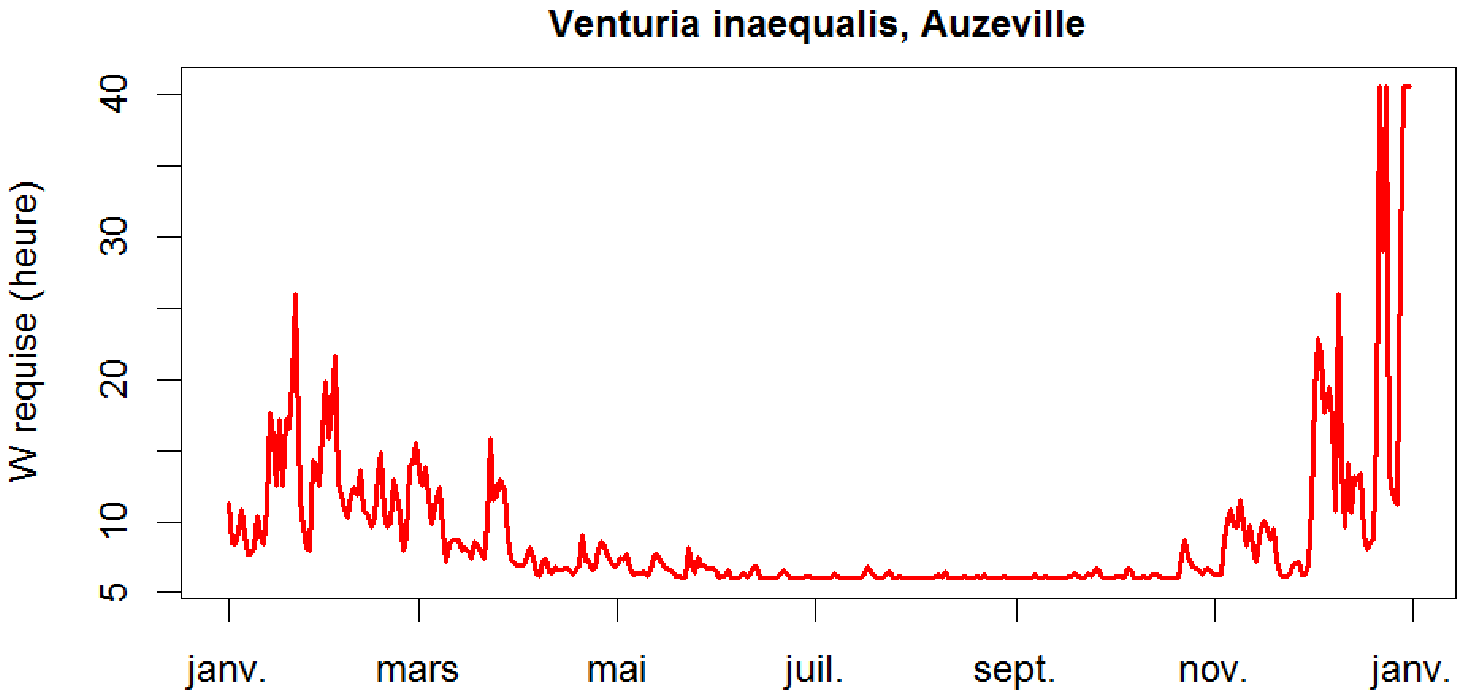
Dynamique des infections

Exemple, station météo avec enregistrement Tmoy et Durée d'humectation



Dynamique des infections

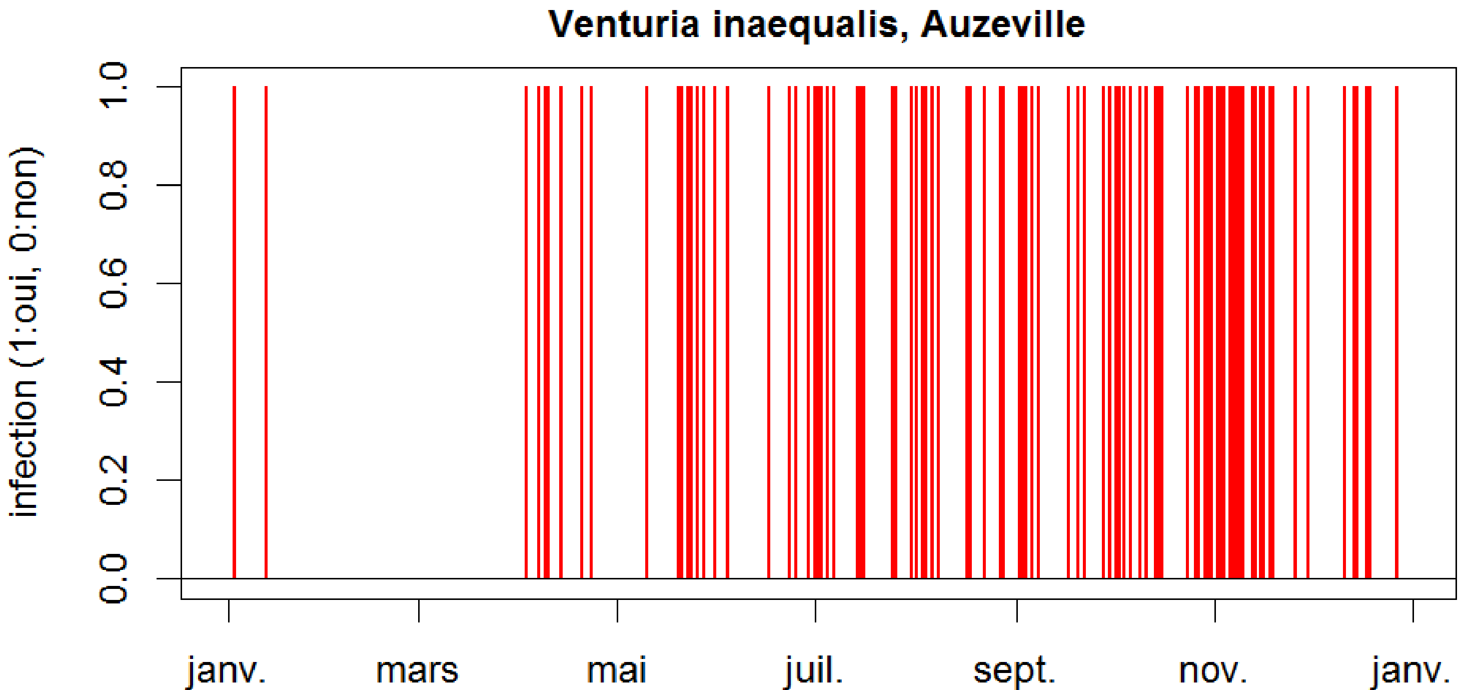
- Simulation des besoins en durée d'humectation



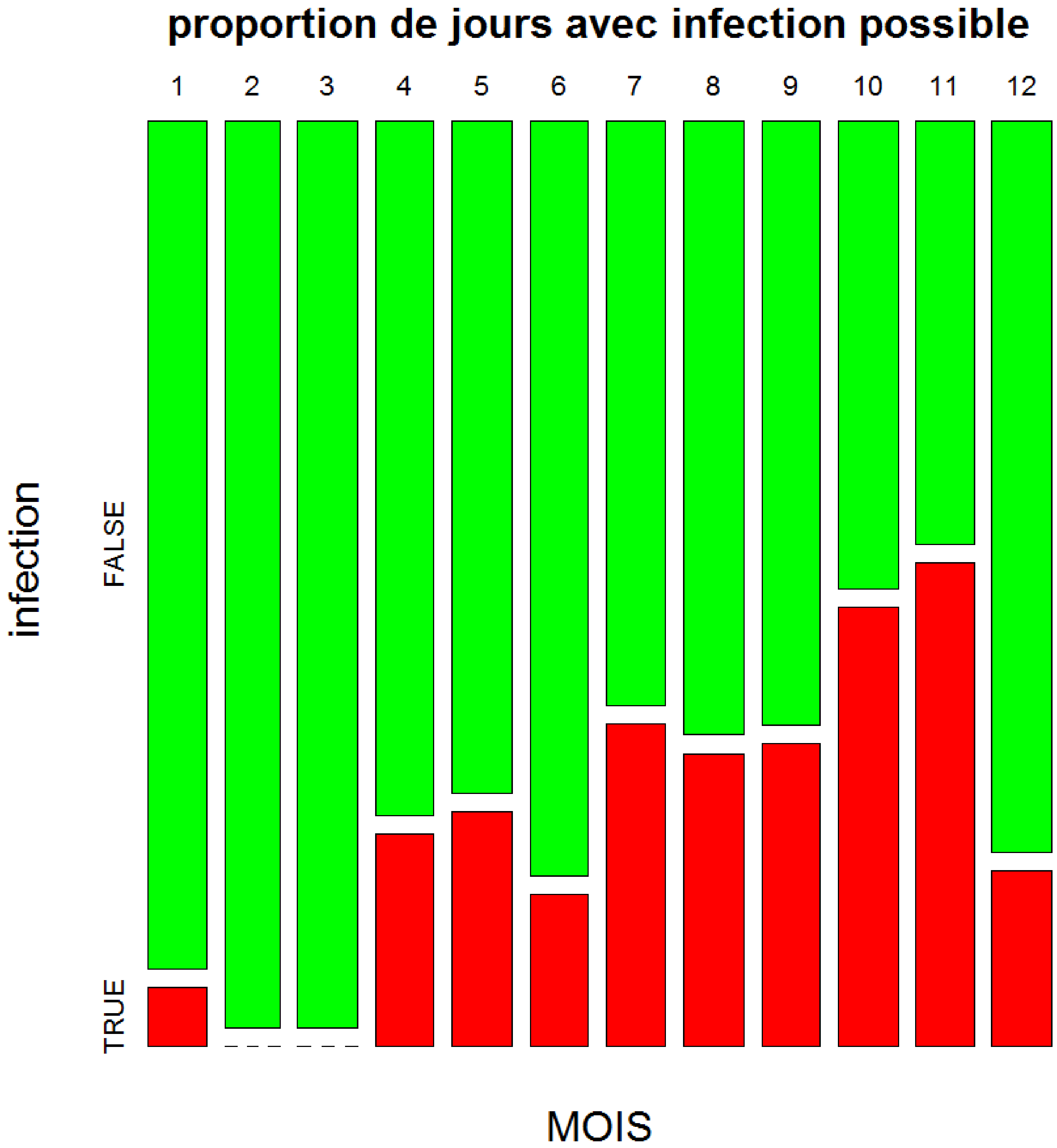
Venturia inaequalis, Auzeville

- jours propices à l'infection

besoin<observation



Venturia inaequalis, Auzeville



proportion de jours avec infection possible

Utilisation pour analyse de risque

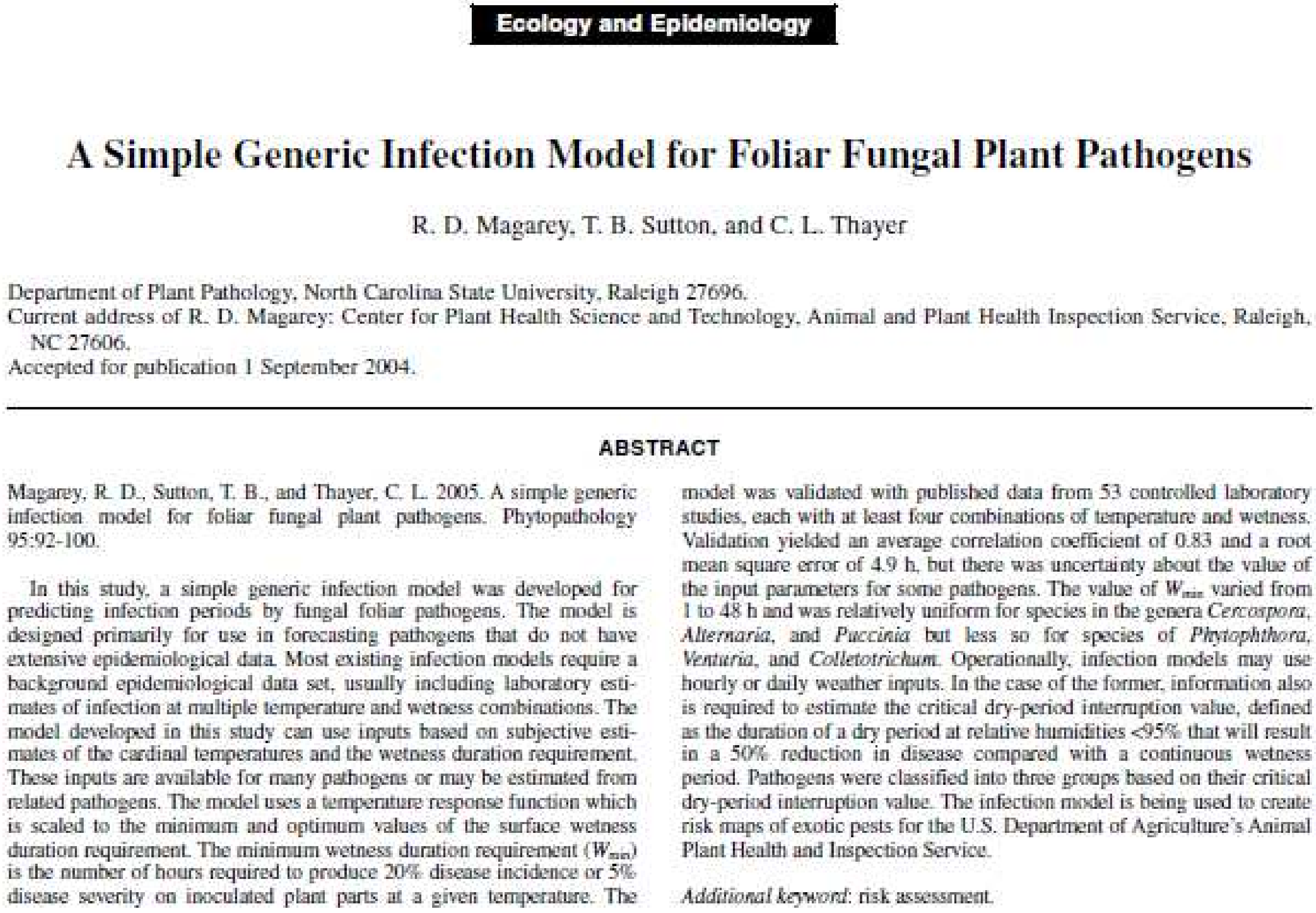
- Risque invasif : est-ce que les conditions météorologiques d’un endroit permettent l’infection d’une maladie pas encore présente ?

Conclusion

- Connaissances et données
  - Formulation d’une équation ayant un sens biologique
  - utilisation de données pour calibrer la relation
- Utilisations
  - Pour déterminer les jours propices à l’infection
  - Pour l’analyse de risque (invasif)
  - Combiné à d’autres formalismes dans des modèles plus complets
- Voir les exposés
  - Analyse des risques d’invasions biologiques et place de l'expertise.
  - Analyse d'incertitude et de sensibilité.

référence

Magarey, R. D., Sutton, T. B., and Thayer, C. L. 2005. A simple generic infection model for foliar fungal plant pathogens. Phytopathology. 95:92-100.



Ecology and Epidemiology

A Simple Generic Infection Model for Foliar Fungal Plant Pathogens

R. D. Magarey, T. B. Sutton, and C. L. Thayer

Department of Plant Pathology, North Carolina State University, Raleigh 27696.
Current address of R. D. Magarey: Center for Plant Health Science and Technology, Animal and Plant Health Inspection Service, Raleigh, NC 27606.

Accepted for publication 1 September 2004.

ABSTRACT

Magarey, R. D., Sutton, T. B., and Thayer, C. L. 2005. A simple generic infection model for foliar fungal plant pathogens. Phytopathology 95:92-100.

In this study, a simple generic infection model was developed for predicting infection periods by fungal foliar pathogens. The model is designed primarily for use in forecasting pathogens that do not have extensive epidemiological data. Most existing infection models require a background epidemiological data set, usually including laboratory estimates of infection at multiple temperature and wetness combinations. The model developed in this study can use inputs based on subjective estimates of the cardinal temperatures and the wetness duration requirement. These inputs are available for many pathogens or may be estimated from related pathogens. The model uses a temperature response function which is scaled to the minimum and optimum values of the surface wetness duration requirement. The minimum wetness duration requirement (W_{min}) is the number of hours required to produce 20% disease incidence or 5% disease severity on inoculated plant parts at a given temperature. The model was validated with published data from 53 controlled laboratory studies, each with at least four combinations of temperature and wetness. Validation yielded an average correlation coefficient of 0.83 and a root mean square error of 4.9 h, but there was uncertainty about the value of the input parameters for some pathogens. The value of W_{min} varied from 1 to 48 h and was relatively uniform for species in the genera *Cercospora*, *Alternaria*, and *Puccinia* but less so for species of *Phytophthora*, *Venturia*, and *Colletotrichum*. Operationally, infection models may use hourly or daily weather inputs. In the case of the former, information also is required to estimate the critical dry-period interruption value, defined as the duration of a dry period at relative humidities <95% that will result in a 50% reduction in disease compared with a continuous wetness period. Pathogens were classified into three groups based on their critical dry-period interruption value. The infection model is being used to create risk maps of exotic pests for the U.S. Department of Agriculture's Animal Plant Health and Inspection Service.

Additional keyword: risk assessment.