Climate effects on the spread of brown rot disease: insights from an epidemiological model

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Brown rot and stone fruit

Brown rot, a fungal disease caused by Monilinia spp.



- Attacking stone fruit (e.g. peach, cherry, plum, etc.)
- Reducing yield in the pre- and post-harvest

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The existing model Bevacqua et al. 2018, Phytopathology



$$\frac{dS}{dt} = -\lambda SI + \eta E$$
$$\frac{dE}{dt} = \lambda SI - \eta E - \sigma(t)E$$
$$\frac{dI}{dt} = \sigma(t)E - \rho I$$

$$\sigma(t) = \begin{cases} 0 & \text{if } w(t) < w_c \\ \gamma w(t) & \text{if } w(t) \ge w_c \end{cases}$$

where

$$w(t) = \frac{w_b w_m}{w_b + (w_m - w_b)e^{-r(t-t_b)}}$$

Param.	Definition
λ	spore exposure
η	spore death
$\sigma(t)$	infection
ρ	fruit death
γ	infection constant
w _b	initial fruit weight
w _m	max. fruit weight
r	fruit growth
t _b	blooming time
t	time

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Model calibration and validation



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Research questions

Do model parameters rely on climate conditions ?

Can a climate corrected model simulate patterns of 2014 and 2015?

Which are the consequences of spatial and temporal variation of climate conditions over the peach-brown rot system ?

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Model parameters and climate conditions

	Constant	Climate corrected
Spore exposure	λ_c	$\lambda(P) = \begin{cases} 0, & \text{if } P = 0\\ \lambda_0, & \text{if } P > 0 \end{cases}$
Fruit infection	γ_c	$\gamma(P) = \begin{cases} 0, & \text{if } P(t-\tau) = 0\\ \gamma_0, & \text{if } P(t-\tau) > 0 \end{cases}$
Spore death	η_c	$\eta(T) = \eta_0 e^{-E_{\eta}/kT}$
Fruit growth	r _c	$r(T) = \frac{r_0 e^{-\frac{E_r}{kT}}}{E_r - \frac{E_r}{kT}}$

where *P* is precipitation, *T* is temperature, τ is a lag time, *k* the Boltzmann factor, *E* is the kinetic energy for a given reaction.

 $2 \times 2 \times 2 \times 2 = 16$ Candidate models of different complexity

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Model selec Akgike Criterion	tion		

Model	λ	γ	η	r	SSE	ΔAIC	WAIC
M1	λ_c	$\gamma(P)$	$\eta(T)$	r _c	2.459	0	0.260
M2	λ_c	$\gamma(P)$	η_c	r(T)	2.460	0.106	0.258
M3	λ_c	$\gamma(P)$	η_c	r _c	2.470	0.116	0.245
M4	λ_c	$\gamma(P)$	$\eta(T)$	r(T)	2.476	0.179	0.237





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The study case: the PACA region







van Gogh - Peach Trees in Blossom, 1889

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Predicted temperature change Reference period 1996-2015



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Predicted precipitation change Reference period 1996-2015



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Predicted yield variation Reference period 1996-2015



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Conclusions

Do model parameters rely on climate conditions?

Yes. Particularly, spore mortality and infection rate

Can a climate corrected model simulate patterns of 2014 and 2015?

Yes

Which are the consequences of spatial and temporal variation of climate conditions over the peach-brown rot system ?

Warmer and drier climates might help controlling brown rot, BUT plant chilling requirement, BUT water availability ...

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Climate conditions as first suspect drivers

Registered temperature and precipitations in 2014 and 2015



Temperature and precipitation indexes Reference period 1996-2015



Predicted Yield The entire region is an orchard



Predicted Yield Actual orchard surface

Actual yield



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