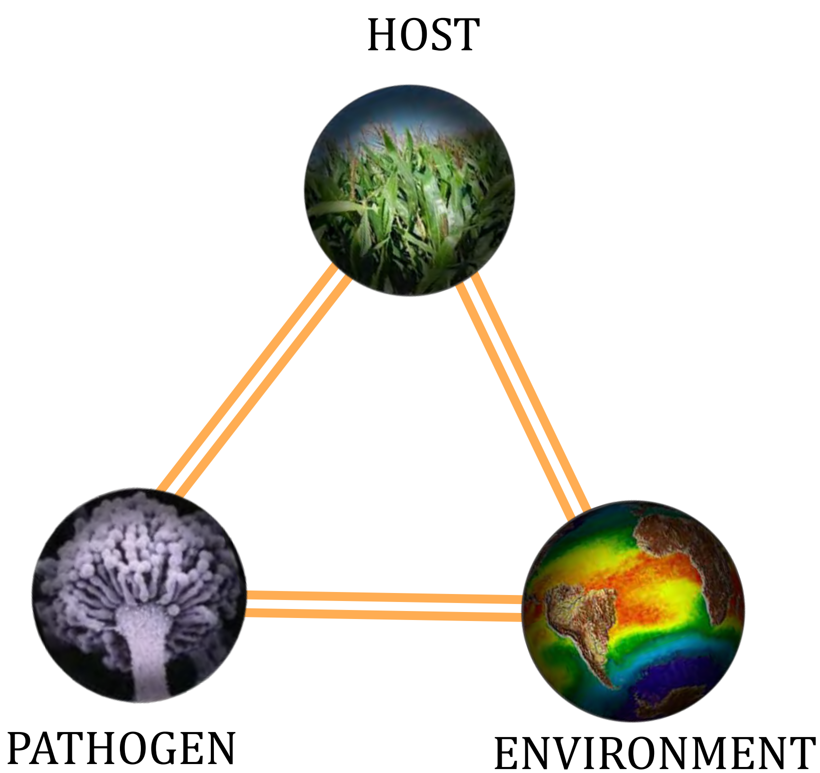
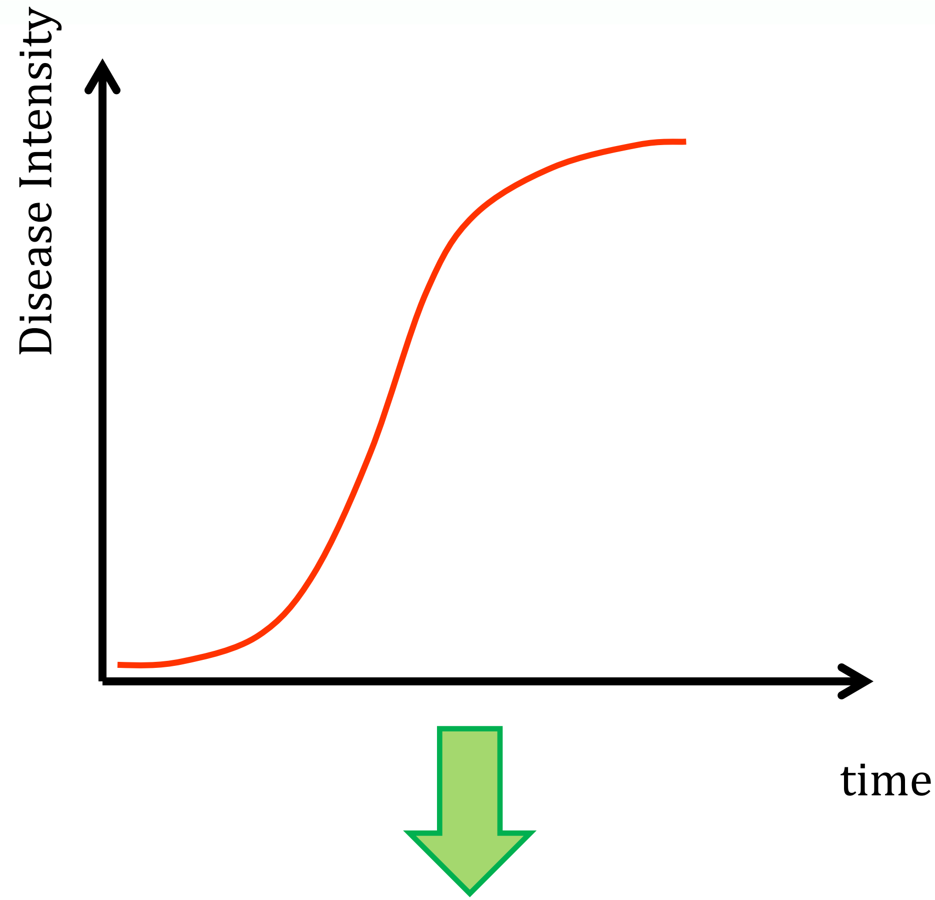
Possiamo prevedere il comportamento delle muffe?

Cenni riguardo ai modelli previsionali per lo sviluppo dei funghi e la produzione di micotossine

Marco CAMARDO LEGGIERI

General Introduction: Epidemiology





MODEL

General Introduction: Model

"A model is a simplified representation of reality."

In fungal epidemiology, possible objectives are:

- Predicting the time and the scale of an event
- Predicting the probability of an event
- Comparing the performance of different management strategies

General Introduction: Model

Modelling approaches

Empirical

Predictor variables → Response variables

STATISTICAL PRINCIPLES

Empiric rule

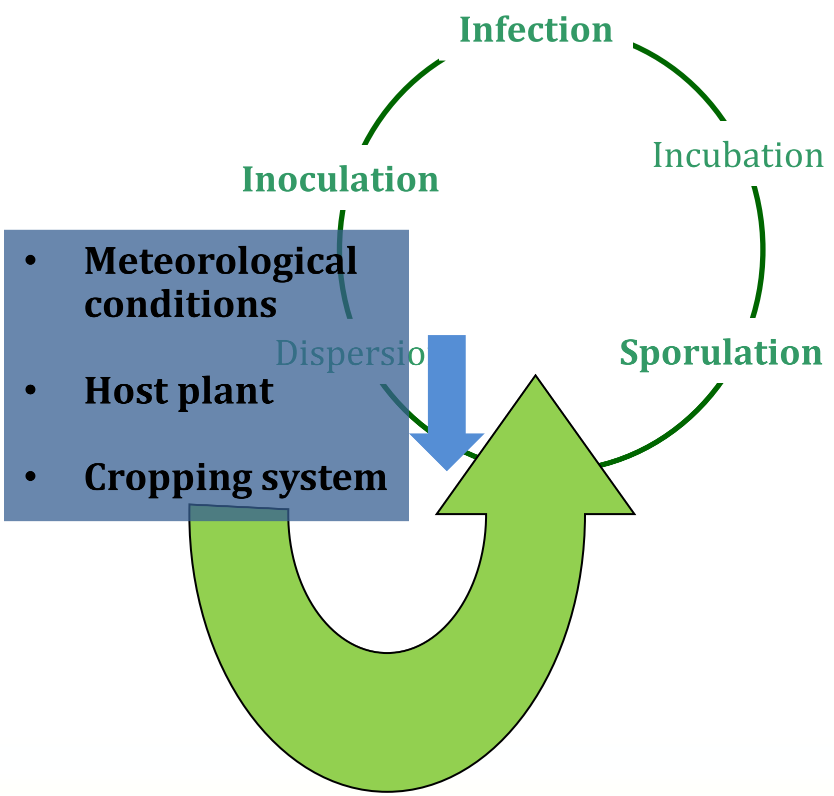
Regression analysis

Non parametric analysis

Stochastic model

Neural network

Mechanistic



Empirical model

***A posteriori* analysis of the variations of epidemics according to changes on the affecting factors.**

Analysis of the quantitative relation which links ***epidemics*** with ***influencing variables***

According to statistical analyses

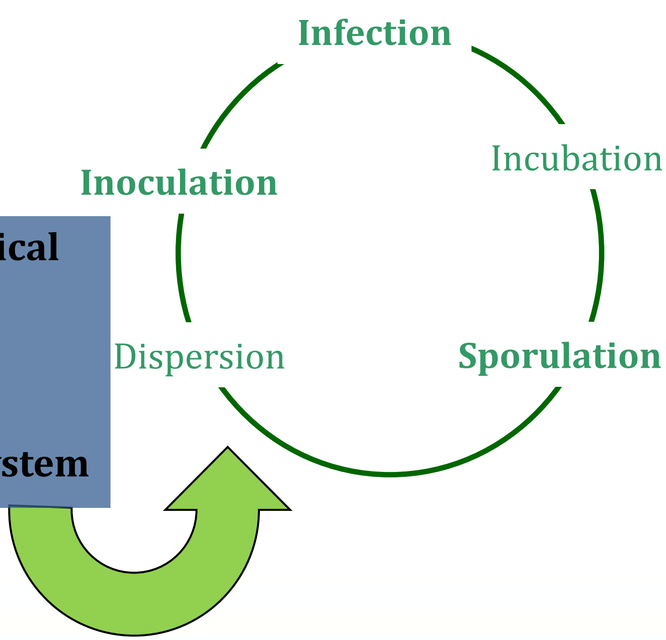
- Empiric rule
- Regression analysis
- Non parametric analysis
- Stochastic model
- Neural network

Mechanistic model

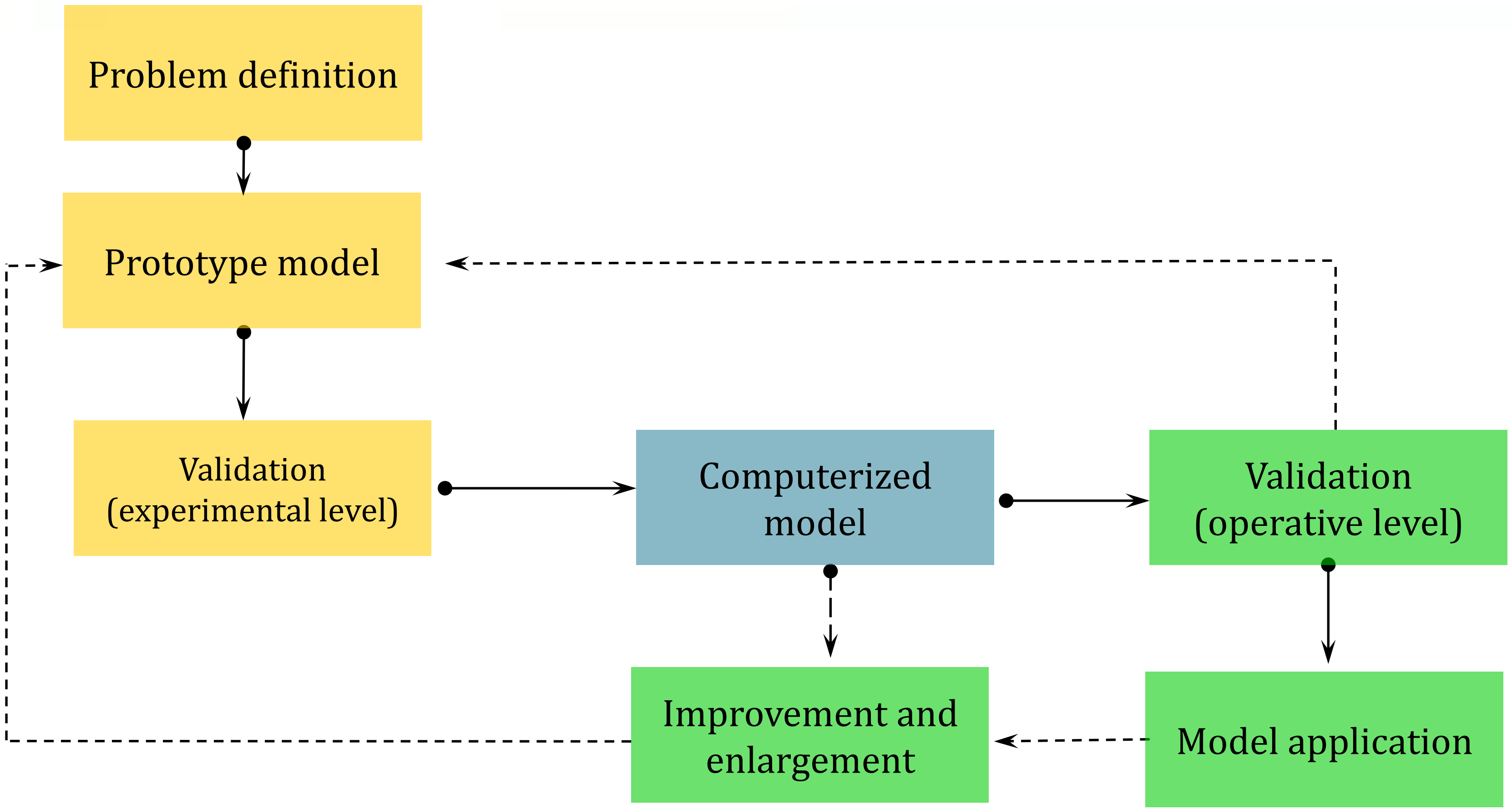
***A priori* analysis of the variations of epidemics according to changes in the affecting factors.**

Analysis of each steps of pathogen infection cycles, influencing variables and change

- **Meteorological conditions**
- **Host plant**
- **Cropping system**



General Introduction: model development



Possiamo prevedere il comportamento delle muffe?

Sviluppo di modelli previsionali, base di dati, elaborazioni matematiche e validazioni dei risultati.

Marco CAMARDO LEGGIERI

Empirical model

A posteriori **analysis of the variations of epidemics according to changes in the factors affecting it**

Analysis of the quantitative relation which links ***epidemics*** with ***influencing variables***

According to statistical analyses

- Empiric rule
- Regression analysis
- Non parametric analysis
- Stochastic model
- Neural network

Steps to built empirical models based on regression analysis

1. Collection of experimental data about disease and biological/meteorological influencing factors
2. Creation of a correlation matrix between variables
3. Elaboration of statistical regression model with the most effective variables
4. Model outputs evaluation

Regression models

$$Y = a + bX1 + cX2 + \ldots + nXn$$

where: Y = level disease

X1 ... Xn = independent variables

Air temperature

Relative humidity

Rain

Leaf wetness

Condition of pathogen

Phenological host stage

Host susceptibility

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Empirical model

Principle drawback:

Based on a numerical relation between collected data in specific experimental condition without any *a priori* defined relation cause-effect between variables

Therefore:

Problems with data out of the experimental range

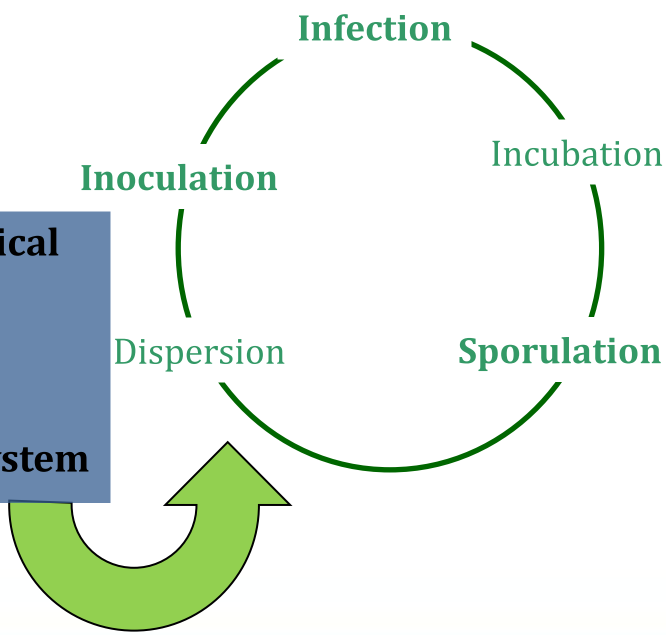
Care validation and re-calibration

Mechanistic model

***A priori* analysis of the variations of epidemics according to changes in the factors affecting it**

Analysis of each steps of pathogen infection cycles, influencing variables and change

- **Meteorological conditions**
- **Host plant**
- **Cropping system**



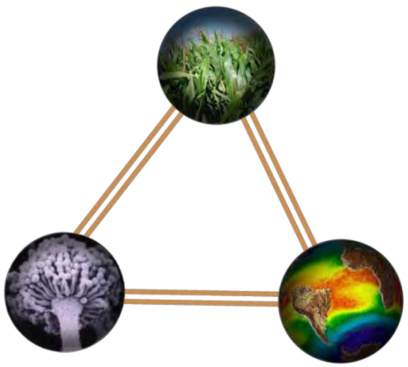
Steps to built a mechanistic model

1. Definition of influencing variables on the patho system, and relations between (logical model)
2. Experimental design to determine quantitative relation between variables /data collection in literature
3. Development of mathematical equation to describe these relations (operative models)

Steps to built a mechanistic model –SYSTEMS ANALYSIS

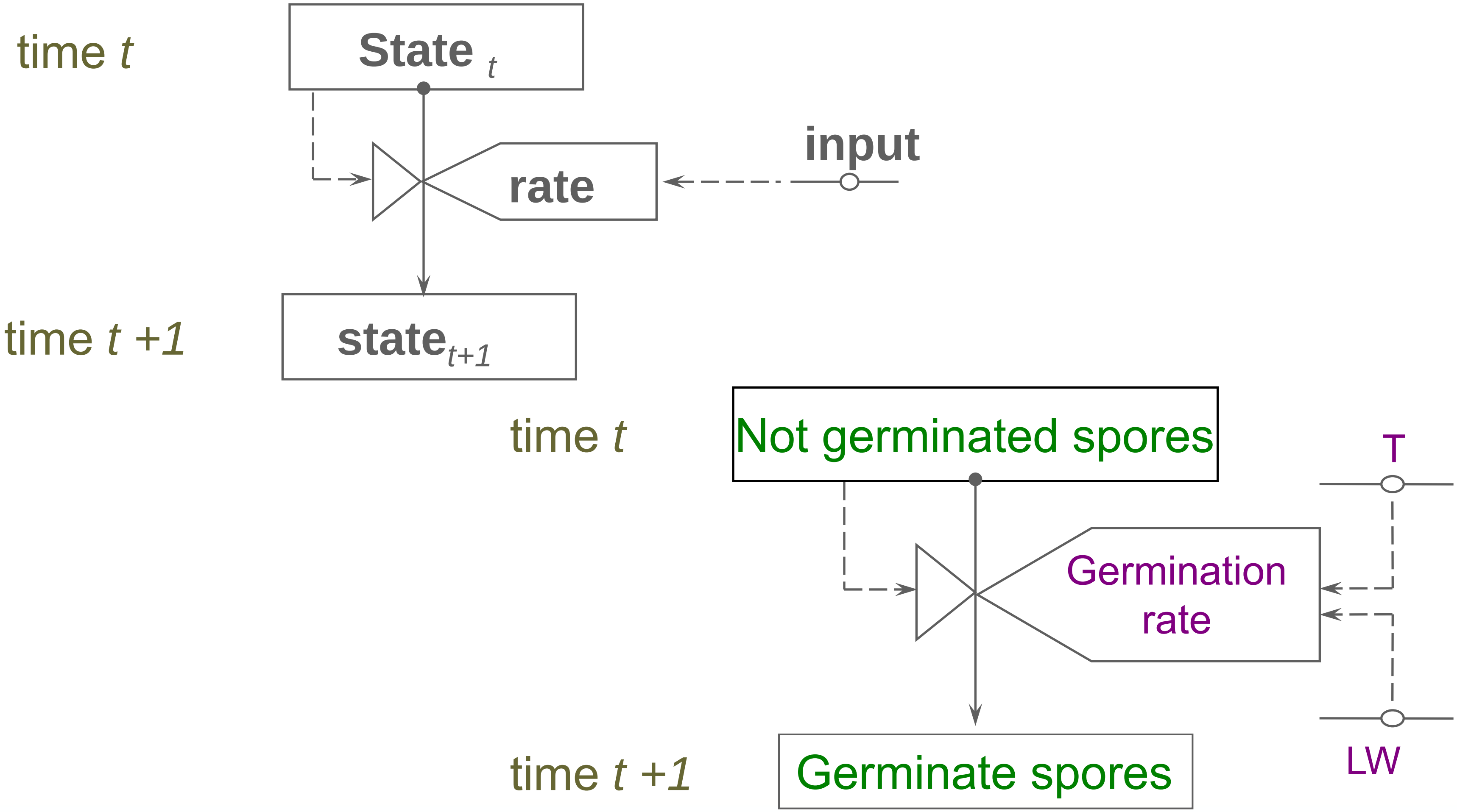
System = limited part of reality which contain element in relation between them (de Wit, 1993)

System's sctructure = all the relation in the system analysed



Patho system

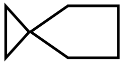
Mechanistic model
RELATIONAL DIAGRAM



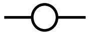
Mechanistic model
RELATIONAL DIAGRAM

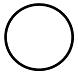
 State variable

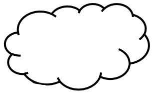
 Direction flow; links two state variables

 Rate; are always mathematical equations

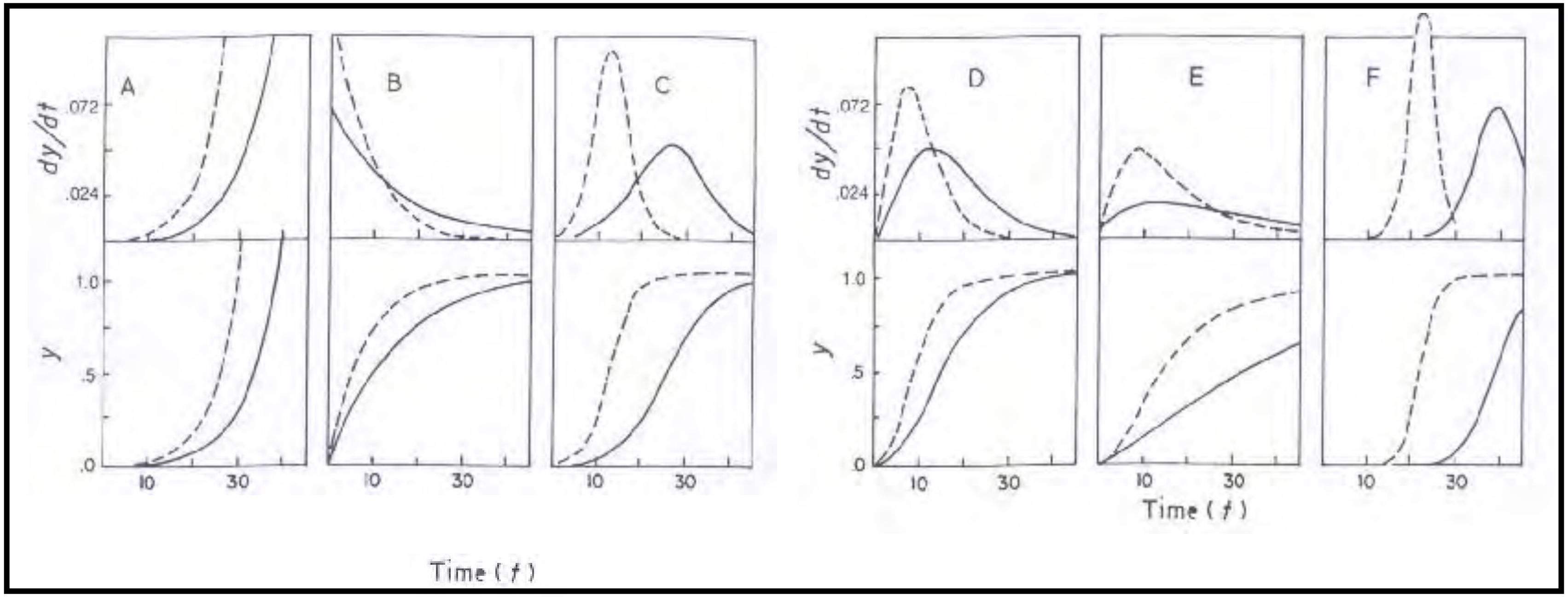
 Information flow

 Constant or parameter (*driving variable*)

 Intermediate variable

 Not quantifiable variable

Suitable library of equation for fitting



A. Exponential

B. Monomolecolar

C. Logistic

D. Gompertz

E. Log-logistic

F. Richards

Suitable library of equation for fitting

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Exponential
$Y = b \cdot \exp(aX)$

Logistic
$Y = c/[1 + a \cdot \exp(-bX)]$

Logarithmic
$Y = \ln(aX^b)$

Monomolecolar
$Y = 1 - b \cdot \exp(-aX)$

Power
$Y = aX^b$

Gompertz
$Y = \exp[-b \cdot \exp(-aX)]$

Asintotic
$Y = a - b \cdot c^X$

Richards
$Y = [1 - b \cdot \exp(-aX)]^{1/(1-c)}$

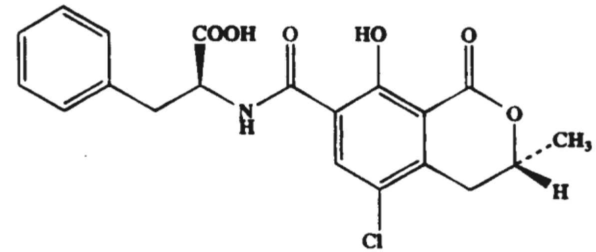
BETE
$Y = [a \cdot X^b \cdot (1-X)]^c$

Weibull
$Y = 1 - \exp\{-[(X-a)/b]^c\}$

Y = dependent variable
X = independent variable
a, b, c = parameters

OTA-Grapes: a prototype model to predict ochratoxin A risk in grapes

Introduction



Grape

PREDICTION

Environment

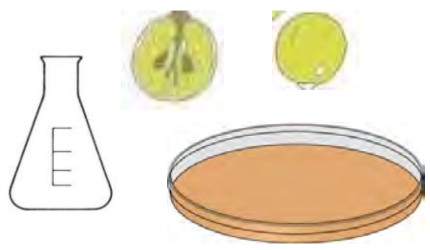
Reg. EC. N 1881/2006

2µg/kg

A. carbonarius

Germination rate

Experimental conditions:
Temperature 15 - 40°C, Relative humidity 85 - 100%, Incubation time 3 - 36hrs



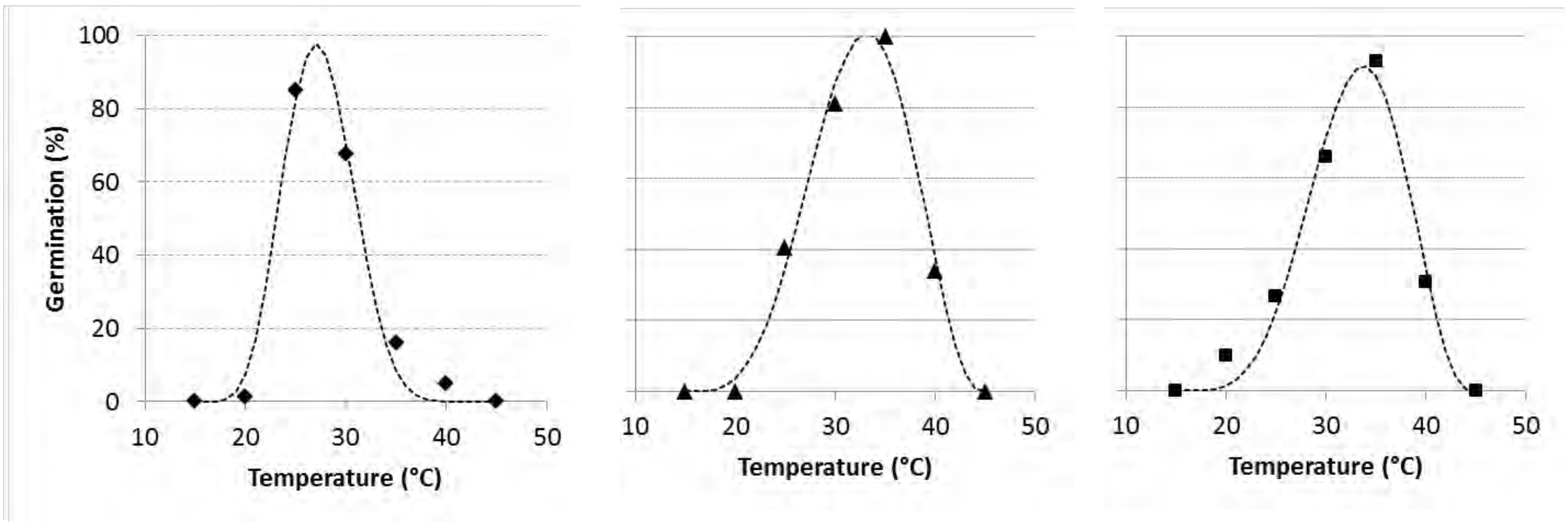
Spore suspension of *A. carbonarius* (10^6 / ml) inoculated onto skin and flesh of berries of white organic grapes and artificial grape juice medium (SGM)

50 single spores were examined (x 3 replicates), temporal observations every 3 hours

Germination rate: non-linear regression models were fitted to the observed data using the statistical package PASW statistics 21

Germination rate: results

SKIN FLESH SGM



The dynamics of spore germination in different T regimes (GeRT) was fitted using a Bete equation (Teq is the equivalent of temperature)

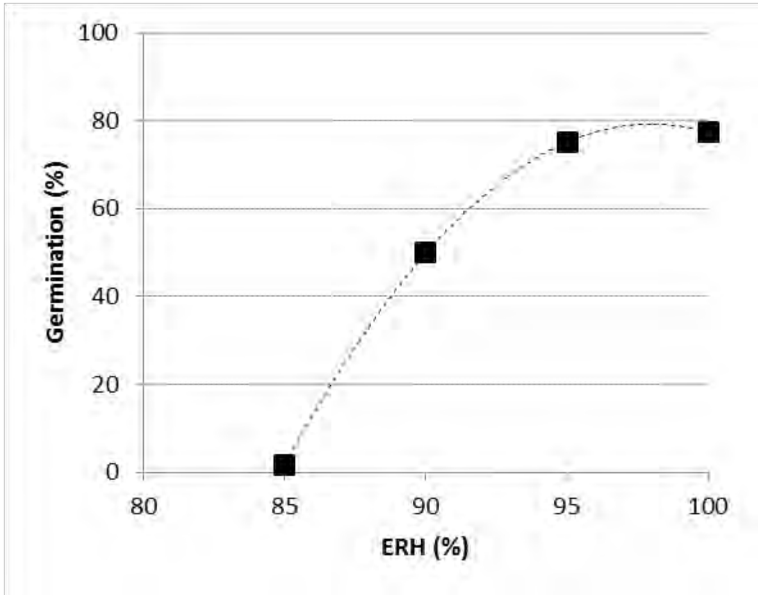
$$\mathrm{GeR_T} = \left(a * (\mathrm{Teq})^b * (1 - \mathrm{Teq})\right)^c$$

$$\mathrm{Teq} = \left(\frac{\mathrm{T-Tmin}}{\mathrm{Tmax-Tmin}}\right)$$

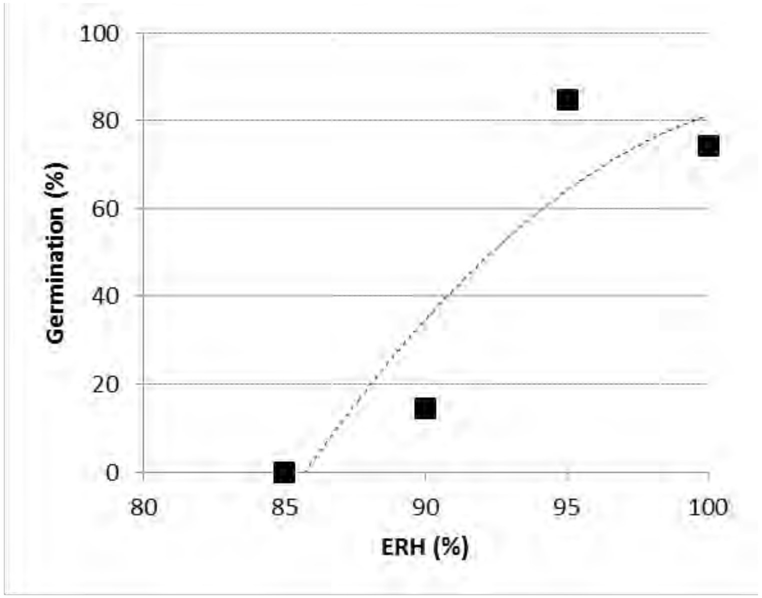
(T is the daily mean temperature, Tmin = 5°C and Tmax = 45°C)

Germination rate: results

SKIN



SGM



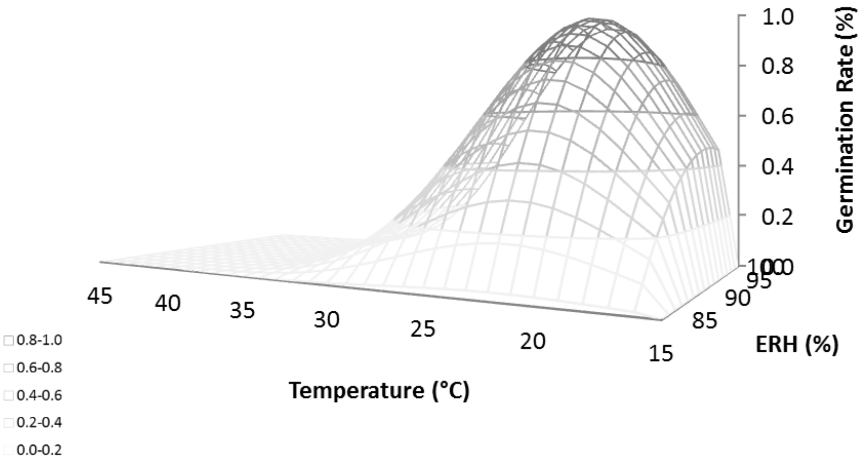
The dynamics of spore germination in different RH regimes (GeRRH) was fitted using a polynomial equation detailed below:

$$GeR_{RH} = a * RH^2 + b * RH + c$$

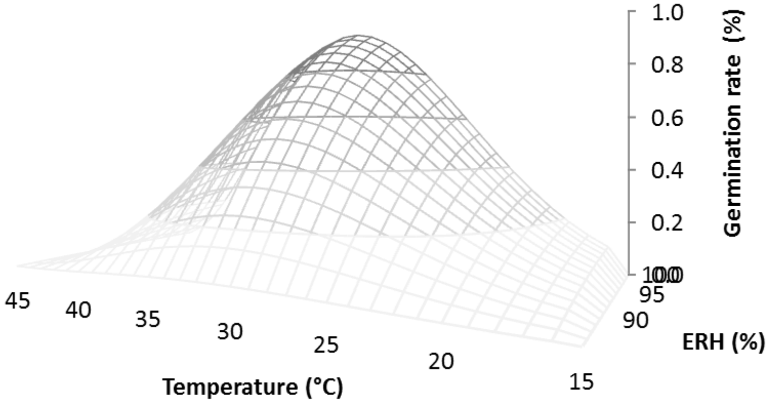
Where RH is the daily mean value.

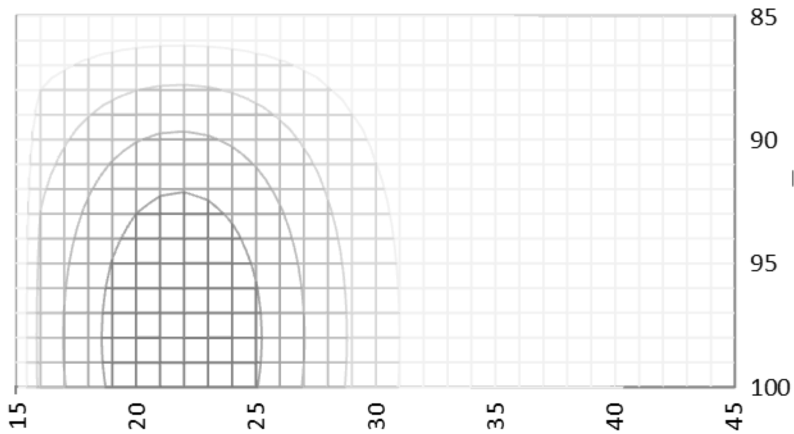
Germination rate: results

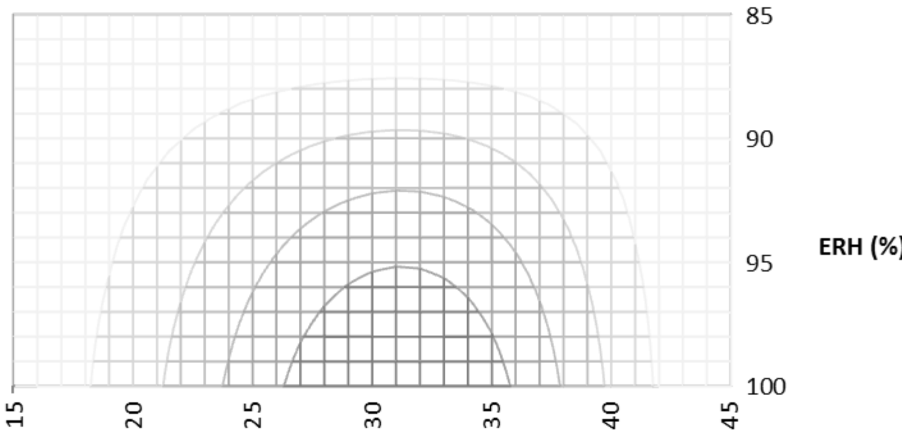
SKIN



SGM

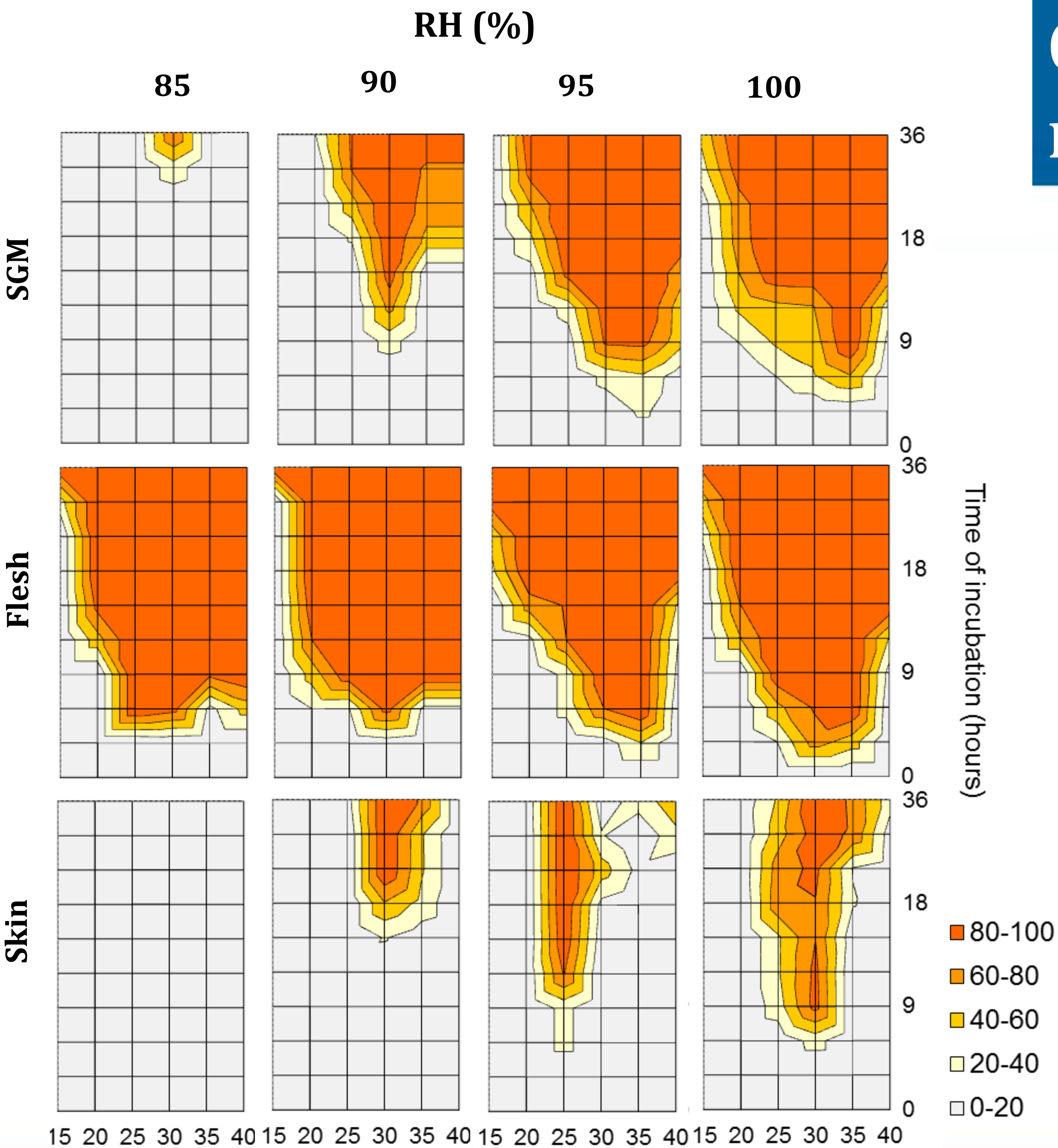






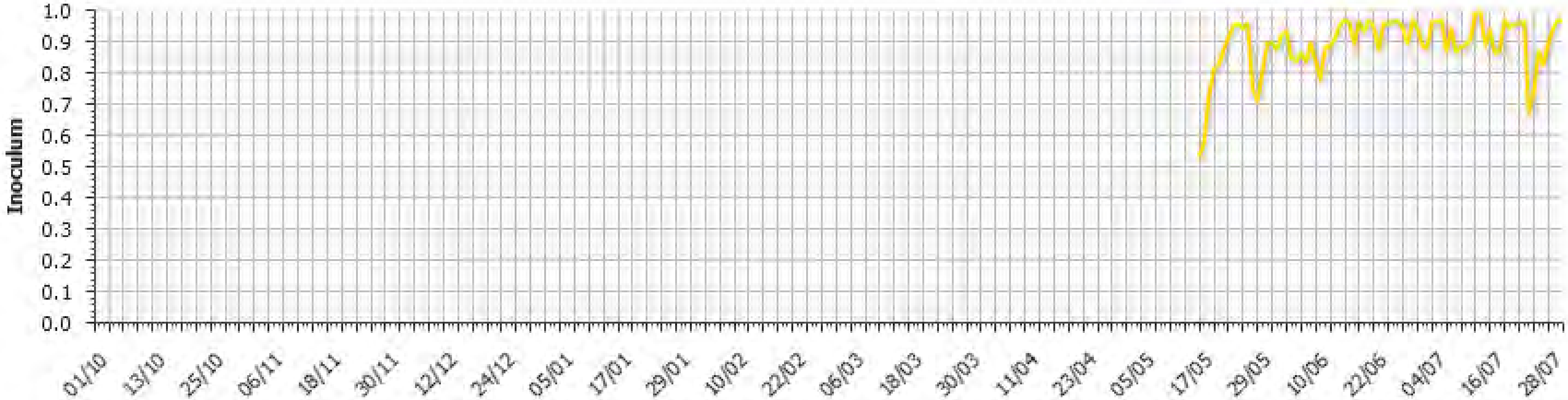
Temperature (°C)

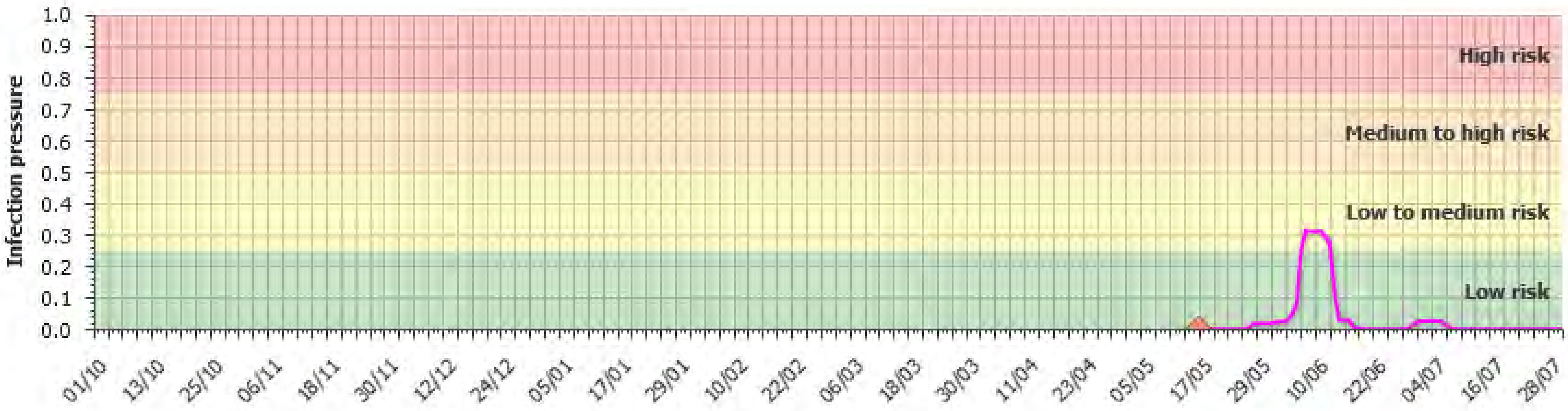
Germination rate: result



100% germination can occur much more rapidly on grape flesh (6 hrs) followed by SGM medium (9 hrs) and then grape skin (24 hrs) under optimal condition of **30-35°C** and **100% RH**

Examples of model output: FHB-model





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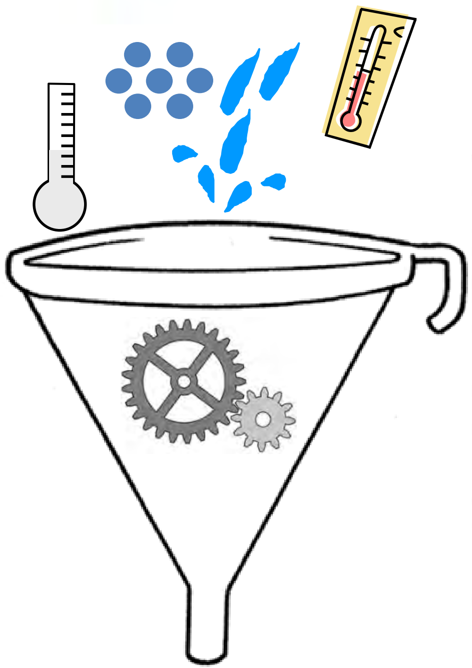
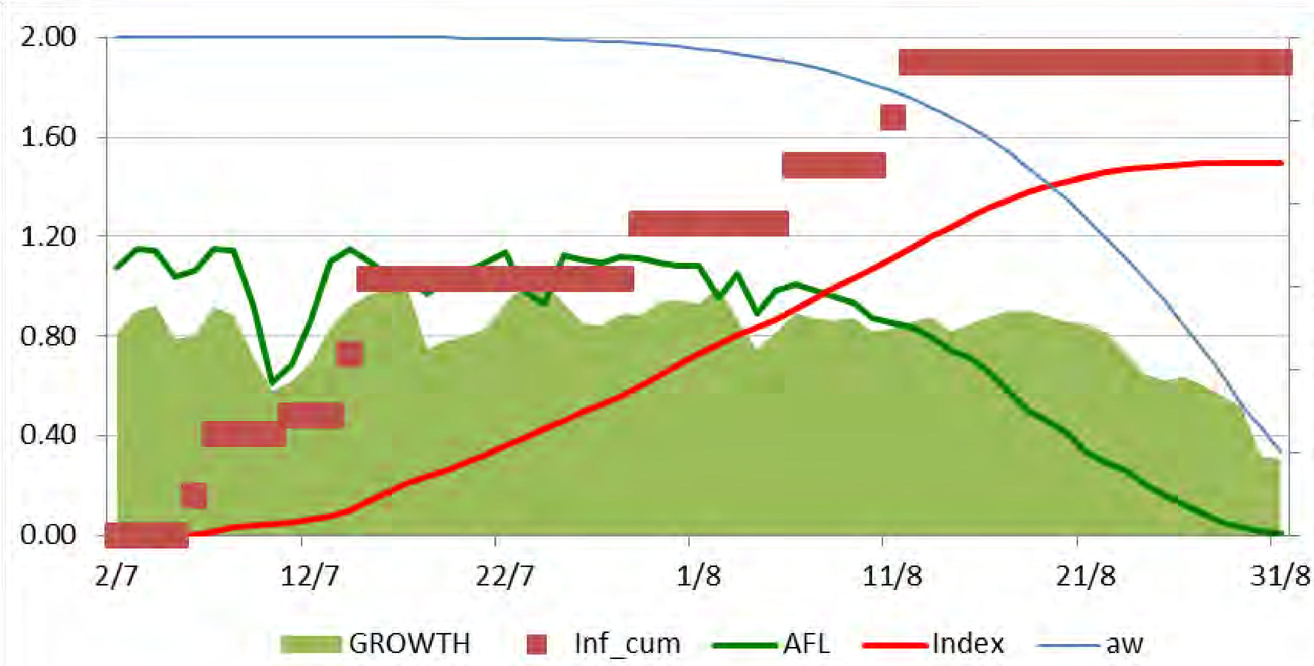
Examples of model output: AFLA model



Aflatoxin Index



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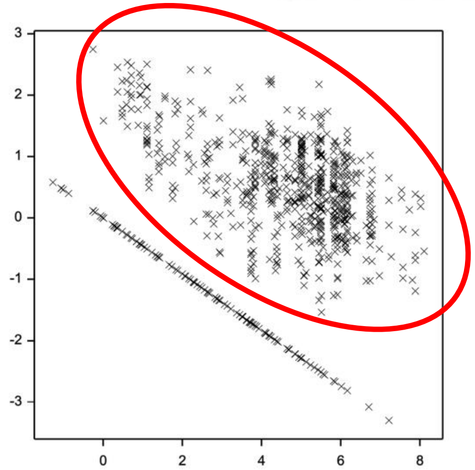
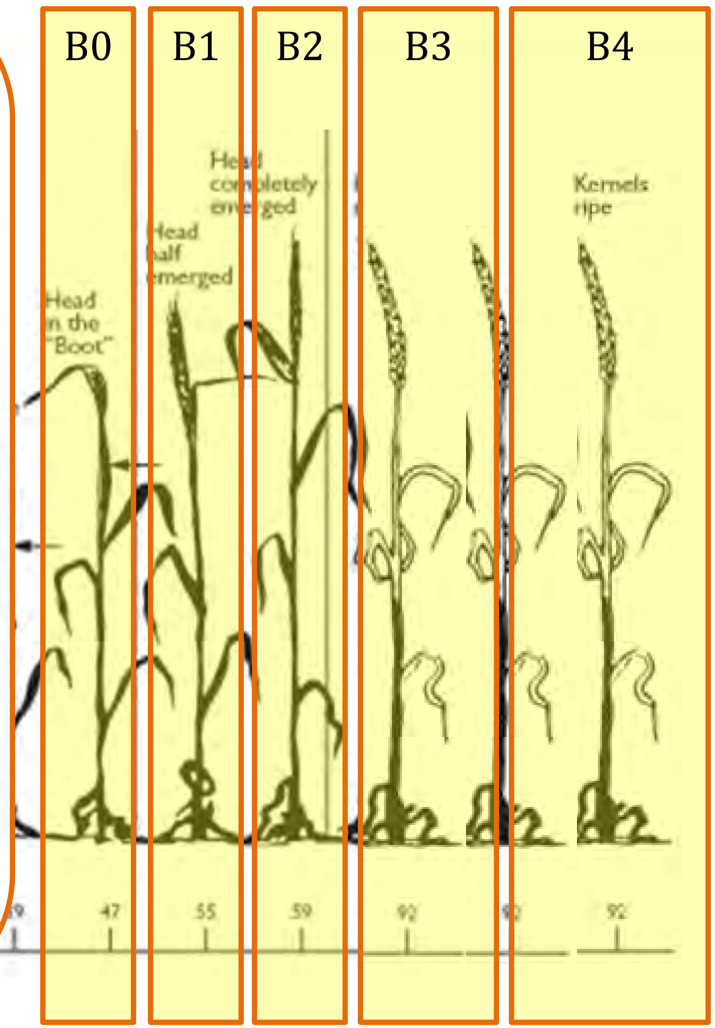
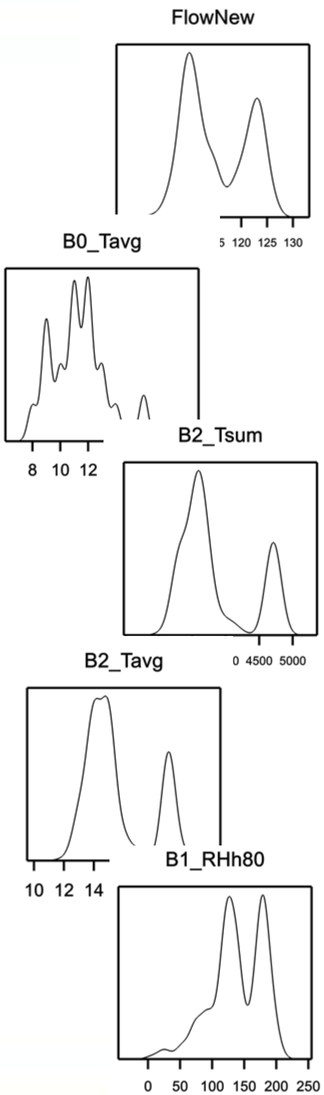
Empirical model for DON in wheat

Parameters calculated in each block:

- T sum
- T avg
- Th 25
- Sum_Rain
- RHh80

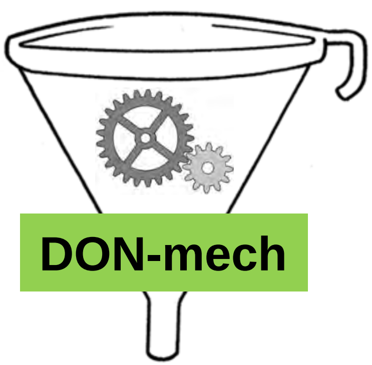


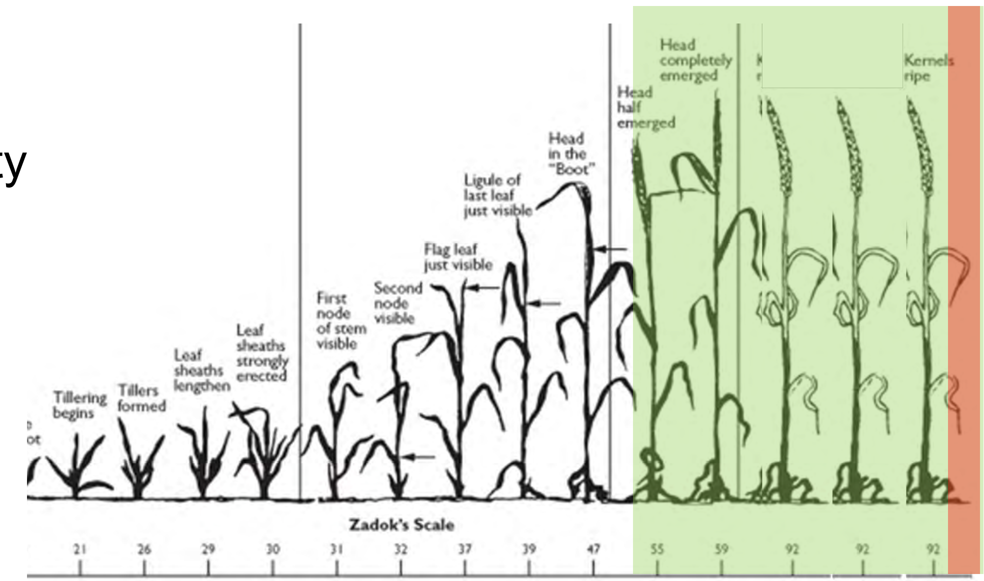




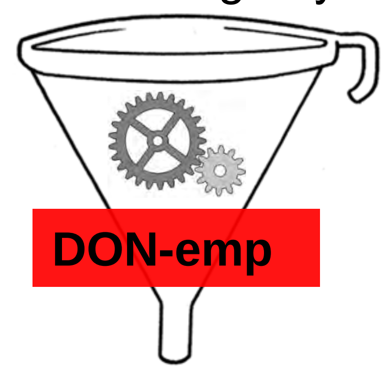
Models input – output variables

Hourly:
Temperature
Relative**H**umidity
Rain





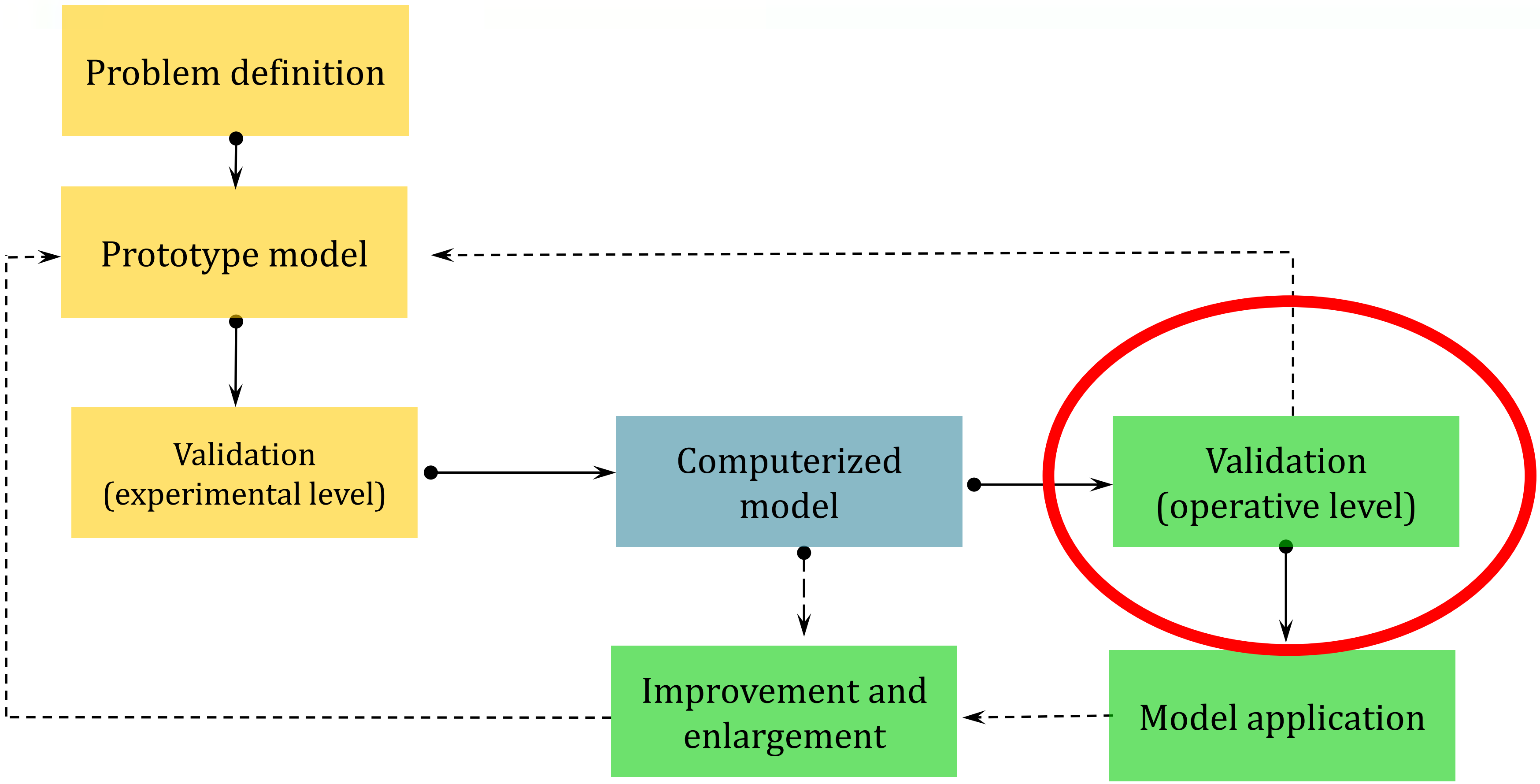
B0_**T**avg
B0_**T**h25
B0_**R**ain
B1_**T**h25
B1_**RH**h80
B2_**T**avg
B2_**T**h25
LenFH
Flowering day



- **FHB Index**
- **DON Index**

- **DON Index**

Last step: Model Validation



Last step: Model Validation

Comparing model output and real observations in different epidemiological conditions (year, location, …)

Italian data

PREDICTED

OBSERVED

	0	1
0	74	19
1	0	7

Dutch data

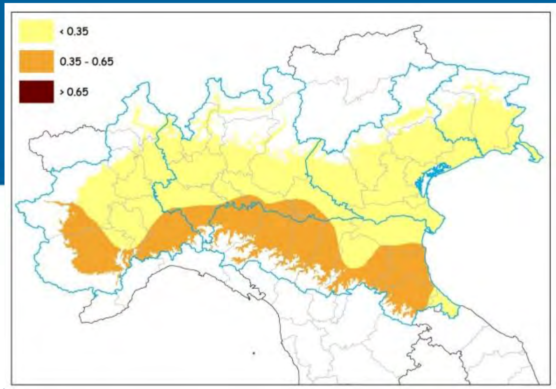
PREDICTED

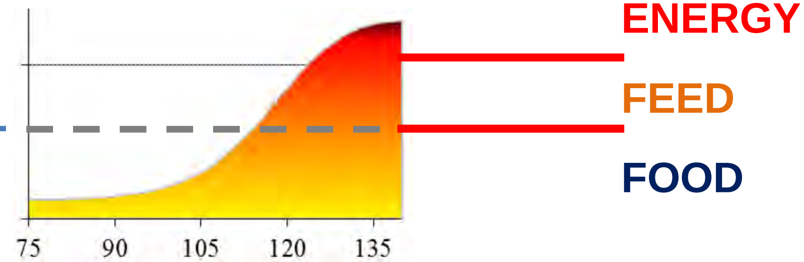
	0	1
0	89	5
1	5	1

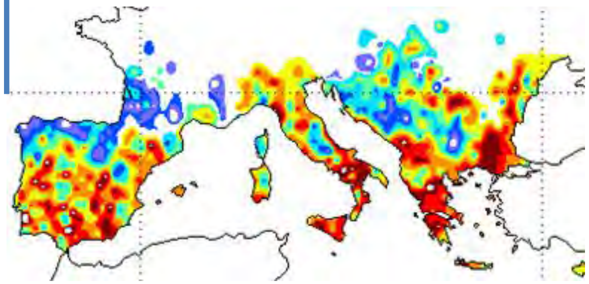
Historic data

Actual data

Predicted data







Thank you for your attention!