Statistical Analysis of Ecophysiology and Mycotoxin Production in Fusarium Species: Key Findings

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Context

<u>Fusarium head blight:</u> Fungal disease → lot of damages (yield / food safety / added value)

Caused by different species of Fusarium → different ecological niche with climate change ?

How will the repartition of the different species of Fusarium evolve with climate change ?

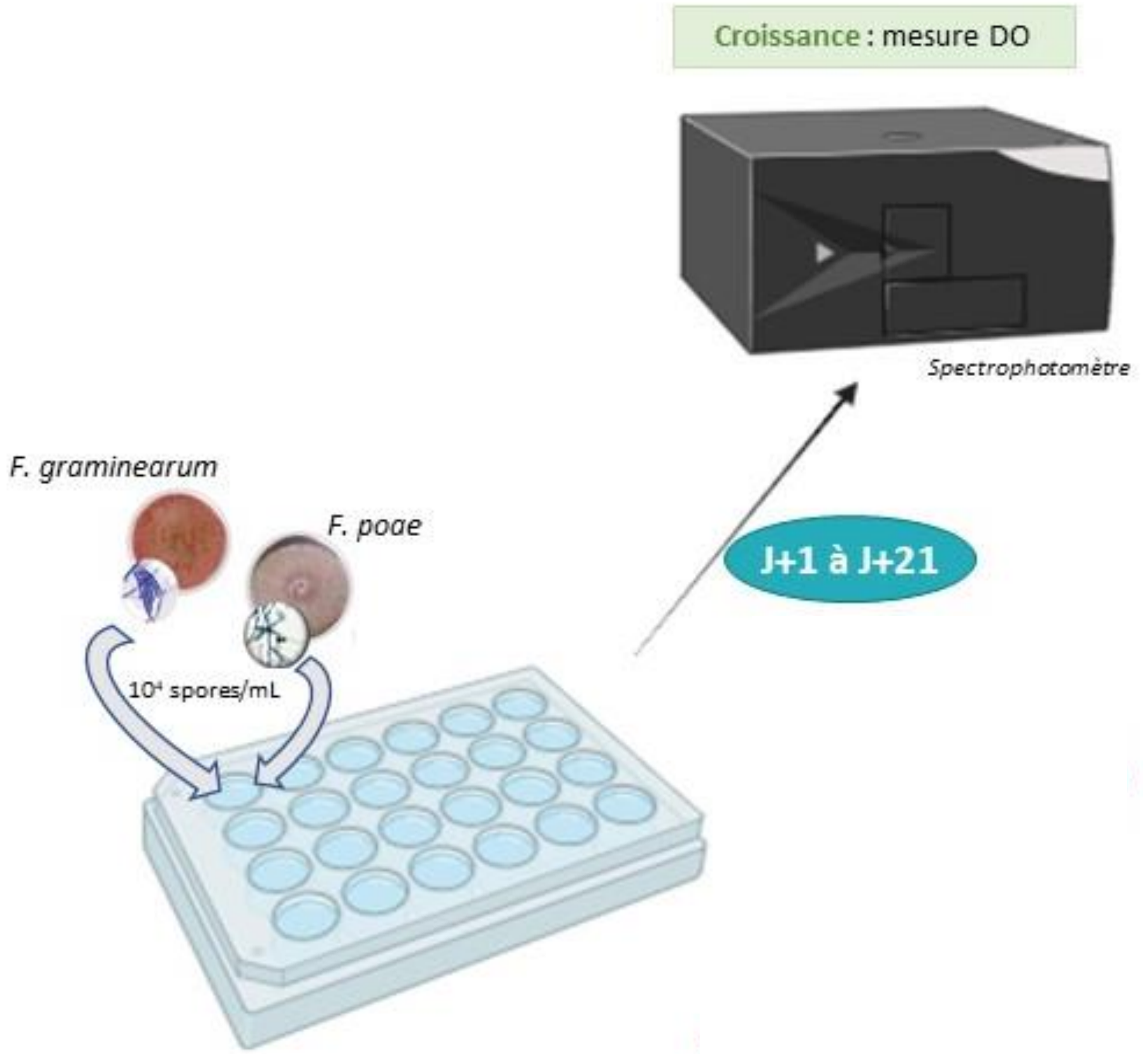
1. **Does it grow ?** Characterize the probability of growth of 25 strains of Fusarium under ≠ T° x aw (Water activity)

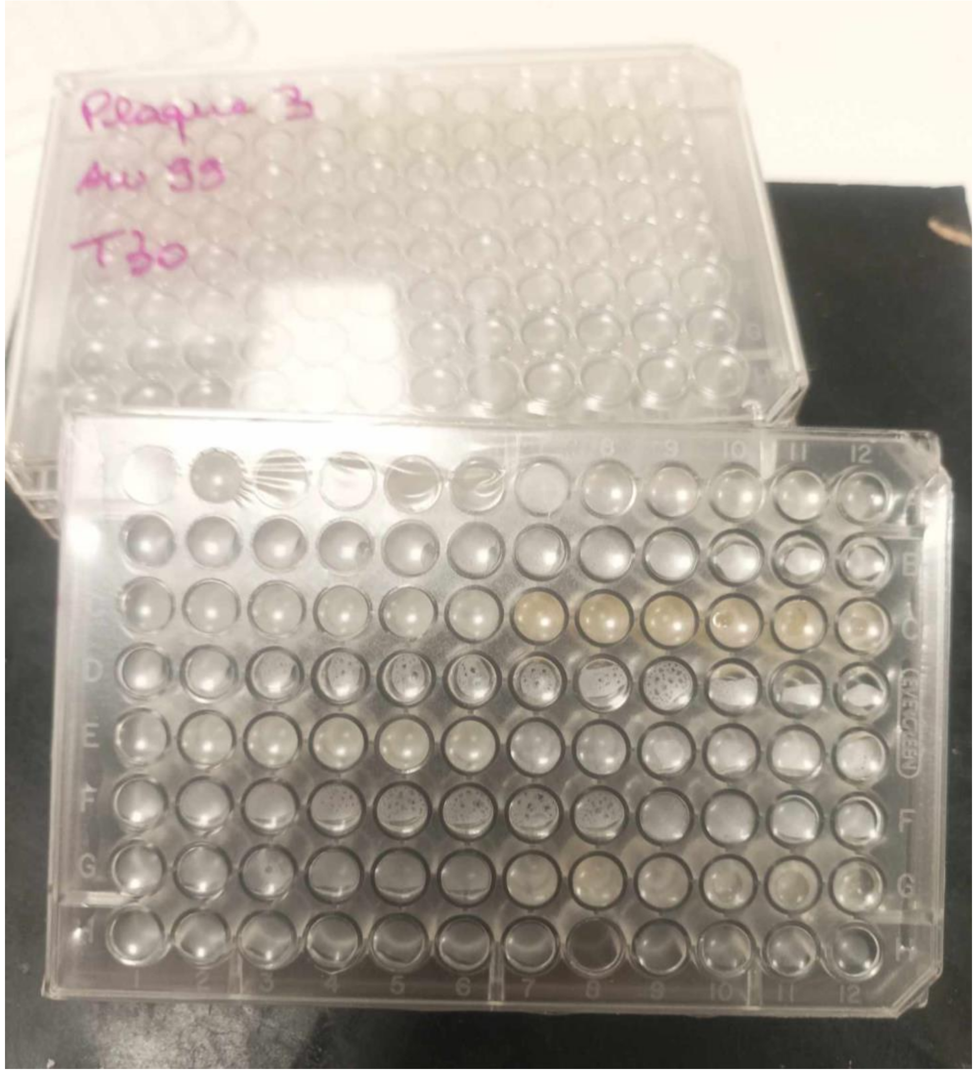
2. **How does it grow ?** Characterize the kinetics of growth of 25 strains of Fusarium under ≠ T° x aw

3. **What happens when it grows ?** Study the mycotoxins emissions ($$$)

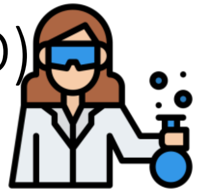
EXPERIMENTAL SETUP

Experimental setup: monitoring growth through optical density measurements (OD)





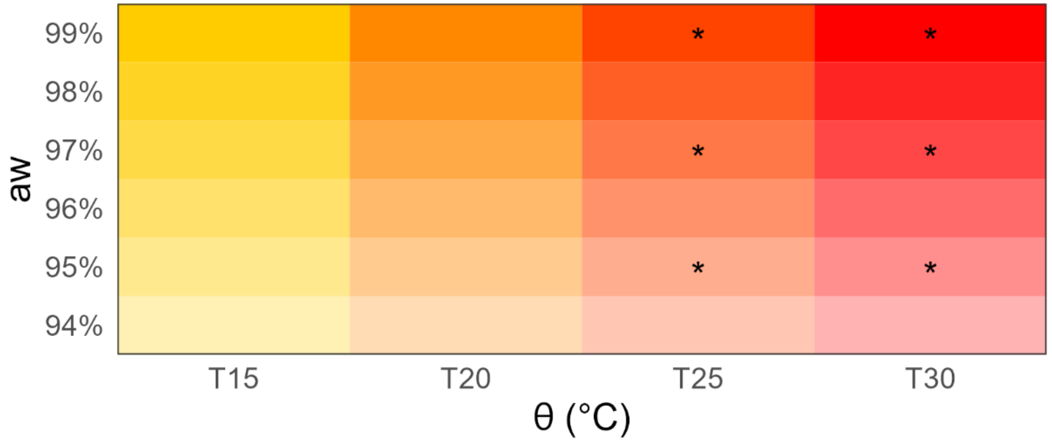
Experimental setup: monitoring growth through optical density measurements (OD)

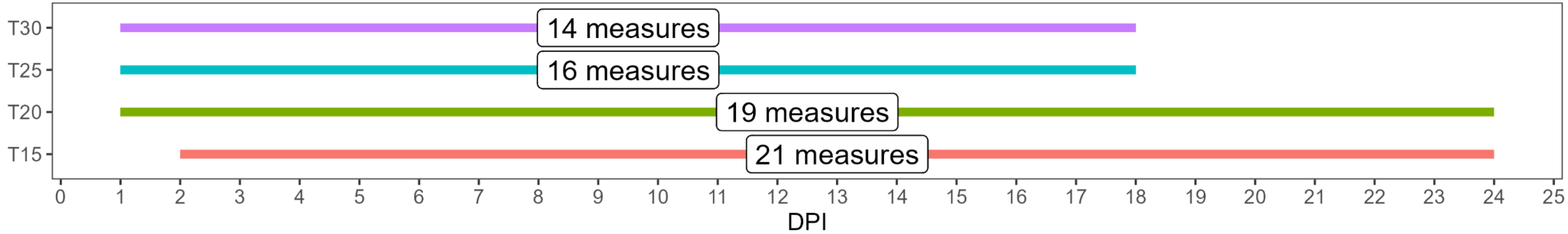


25 strains

F. tricinctum	I104	I106	I524	I526	I86
F. poae	I72	I474	I491	I488	I484
F. langsethiae	I509	I500	I508	I502	I466
F. graminearum	I156	I159	I164	I181	I178
F. avenaceum	I873	I498	I874	I612	I495

4 temperatures and 6 water availabilities



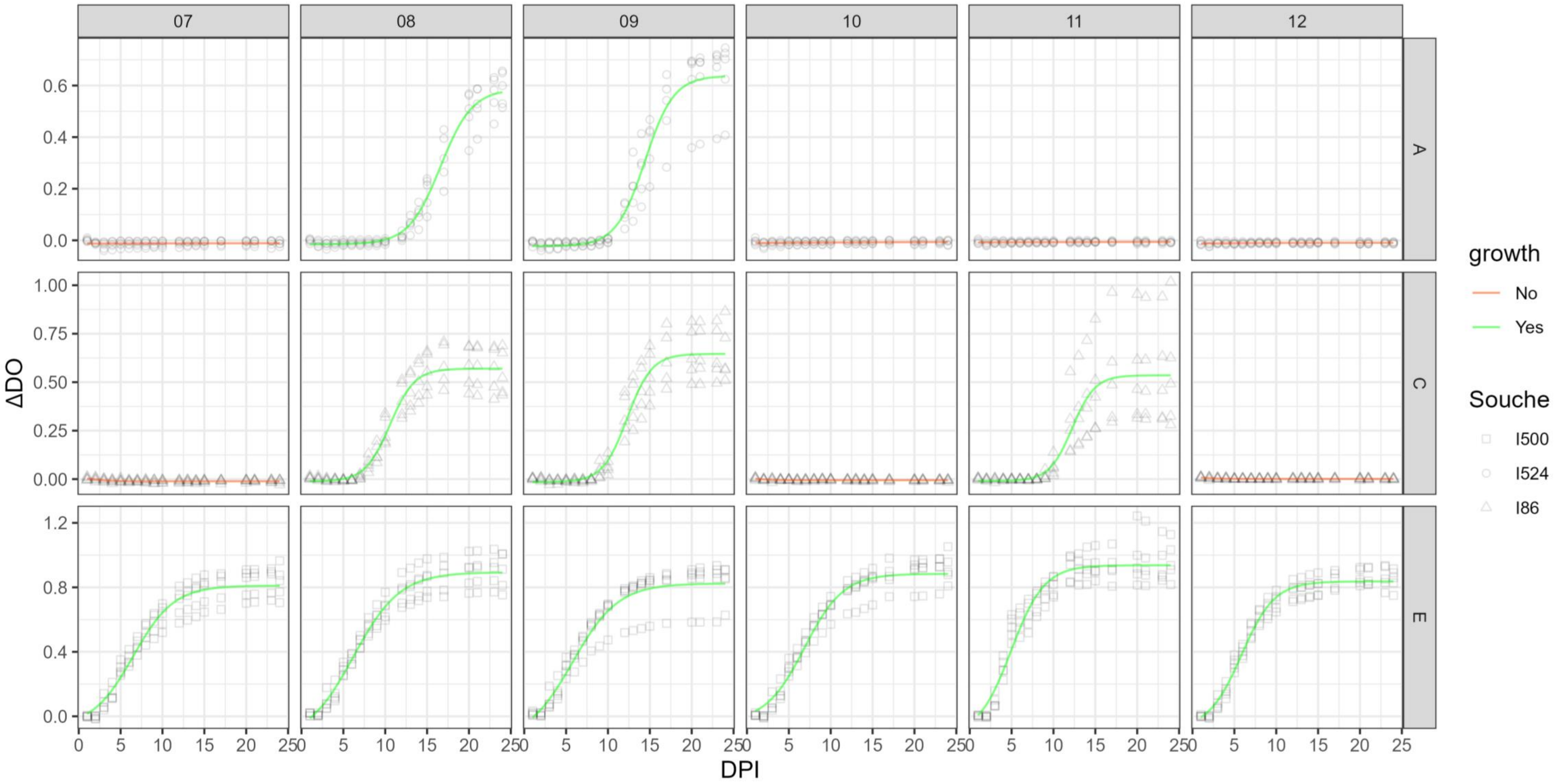


600 treatments, **6** replicates/treatments = **3600** samples (statistical individuals)
120 000 measures of DO

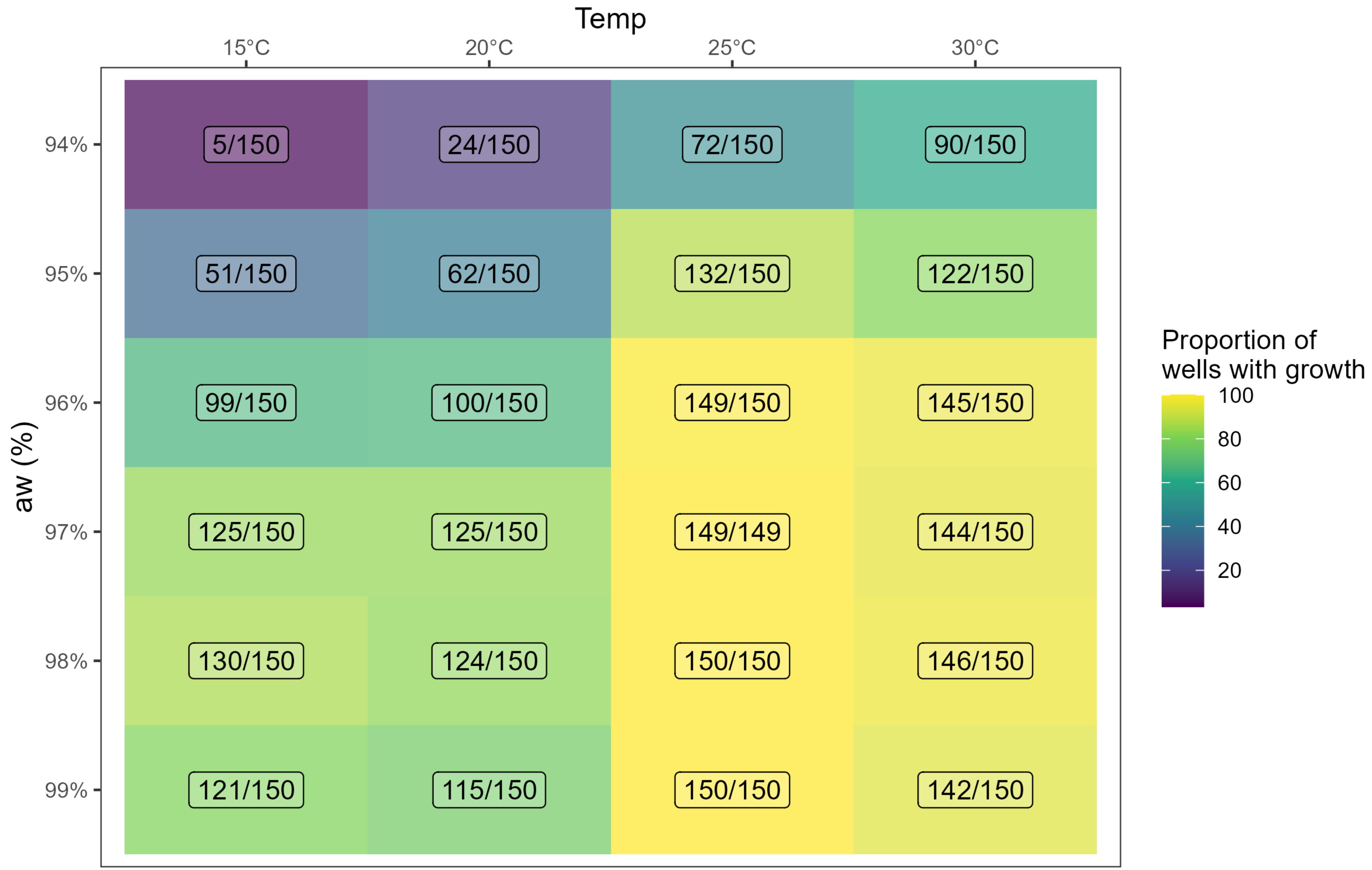
DOES IT GROW ?

All the samples did not grow

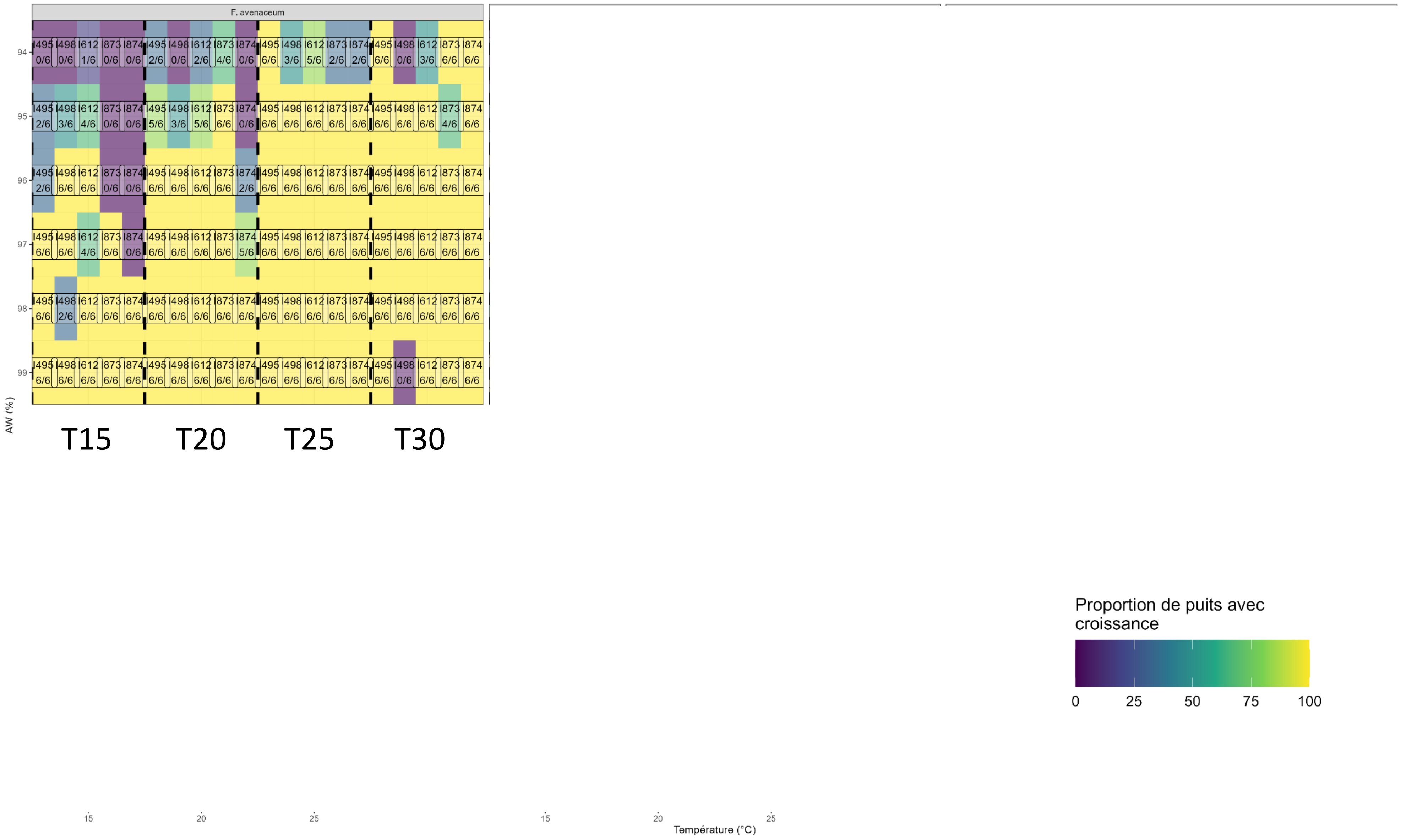
Evolution of OD (20°C, aw = 98%)



Proportion of wells with growth, given temperature and aw

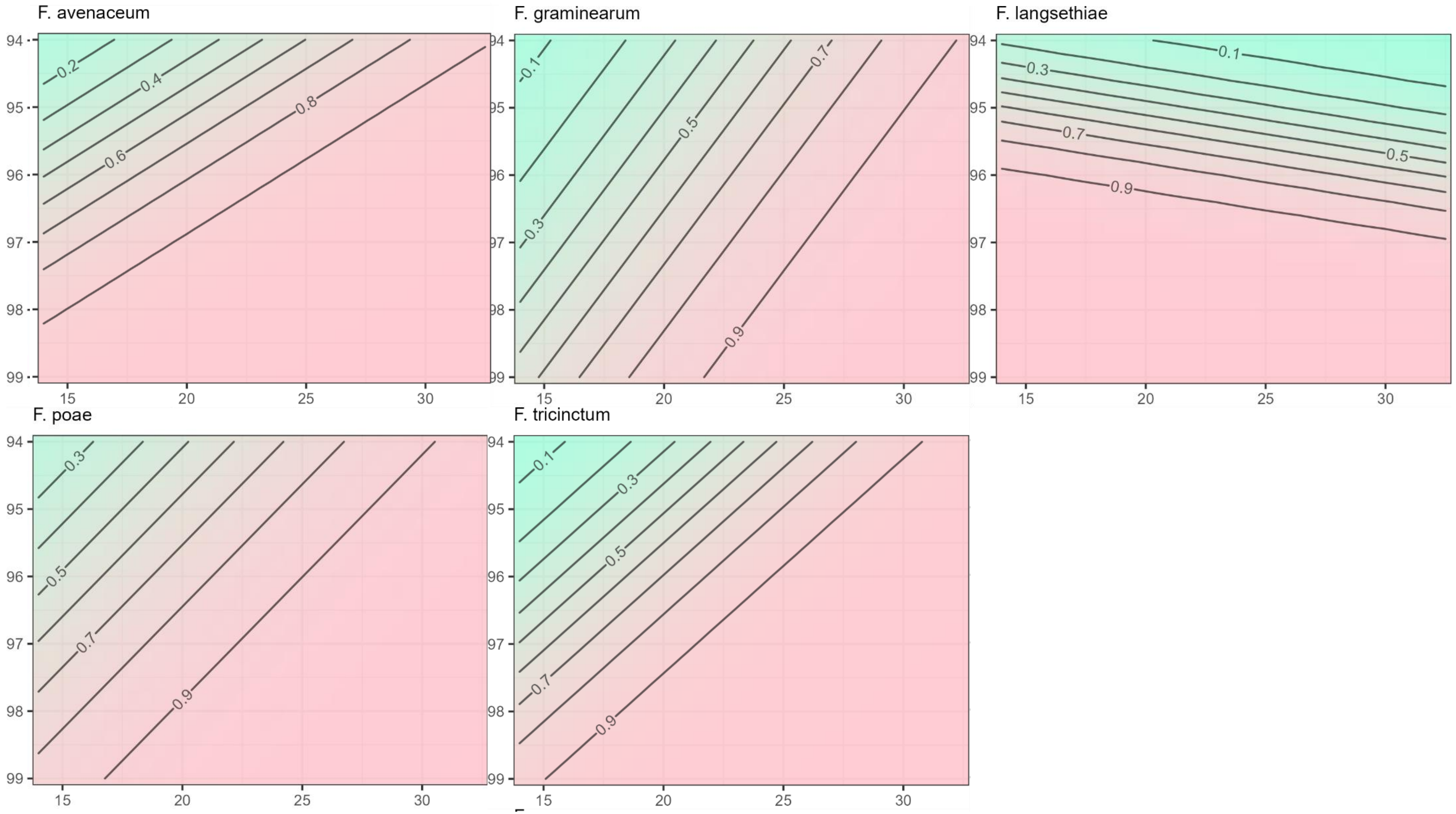


Different behavior depending on the species?



Logistic regression to model the probability of growth

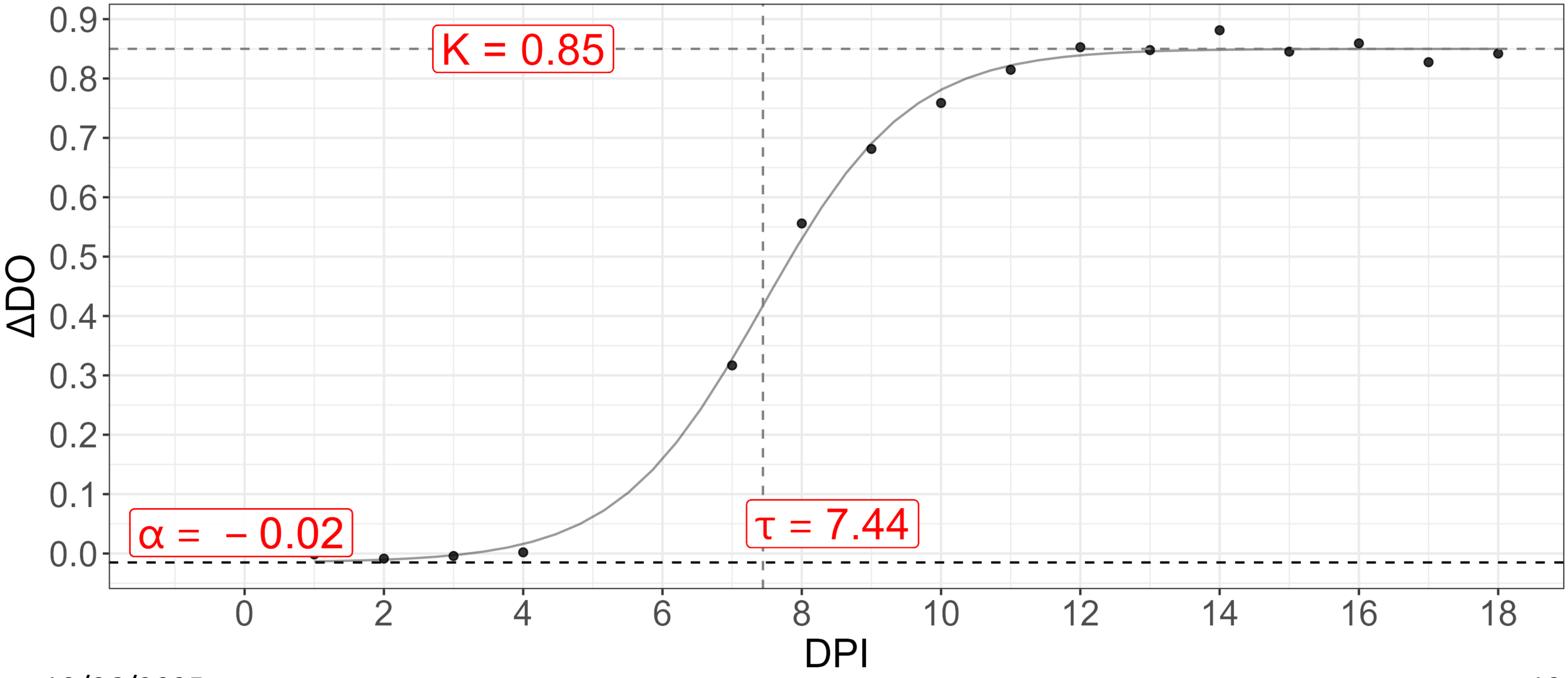
$$logit(P(growth)_i) = \beta_0 + \beta_{1i}Species_i + (\beta_2+\beta_{2i})Temp + (\beta_3+\beta_{3i})aw, i = 1, \ldots, N$$



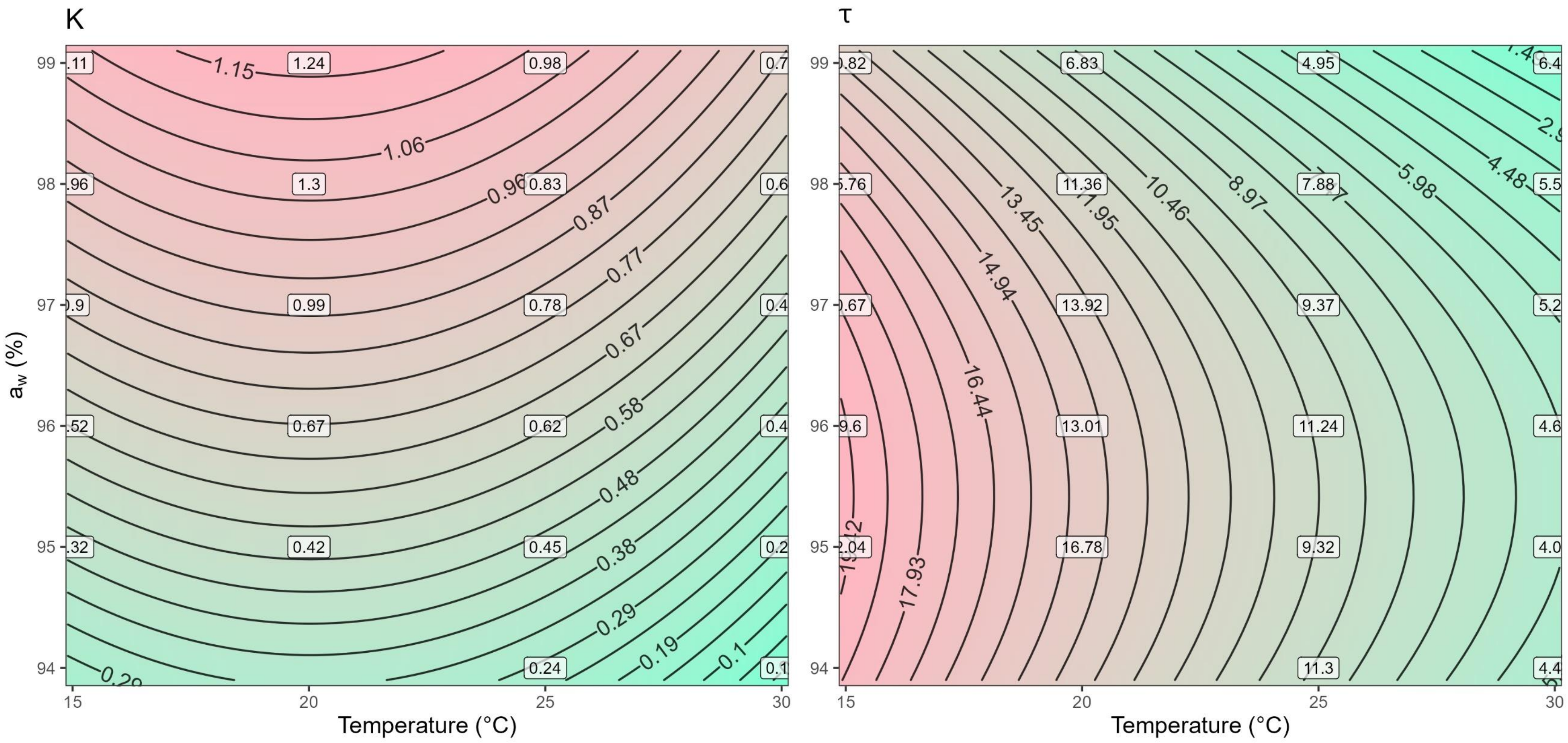
HOW DOES IT GROW ?

Model the kinetics of OD

$$\text{OD(t)} = f_\theta(t) = \alpha + \frac{K}{1+e^{r(\tau-t)}}, where\ \theta = (\alpha, r, \tau, K)$$

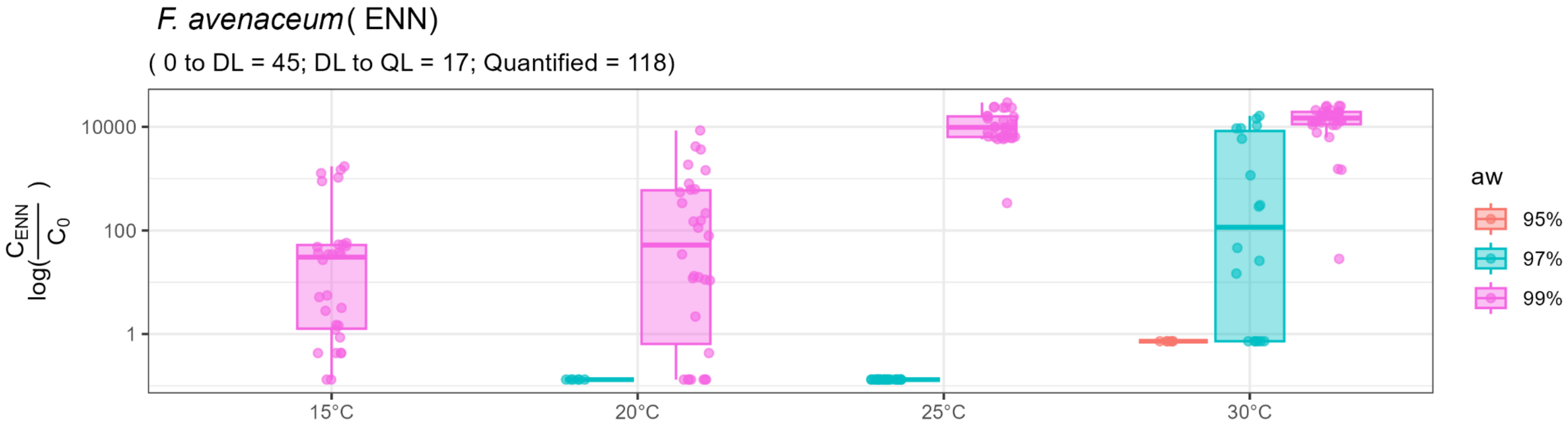


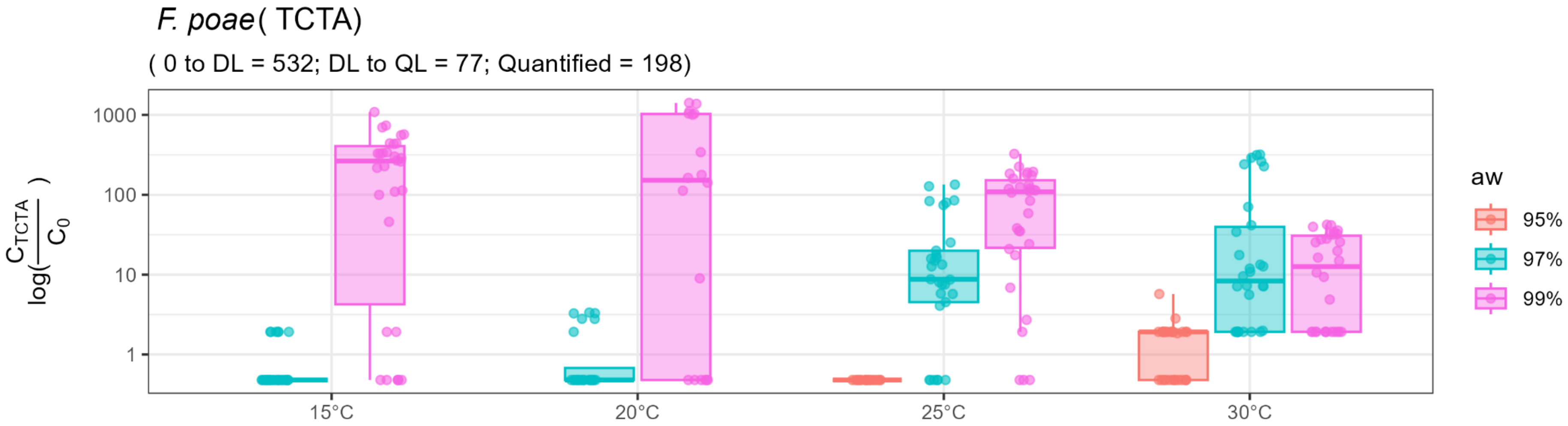
Parameters as a function of T° and aw



Climate & mycotoxins emissions (ongoing work)

Toxins, different behaviour vs Temp x aw

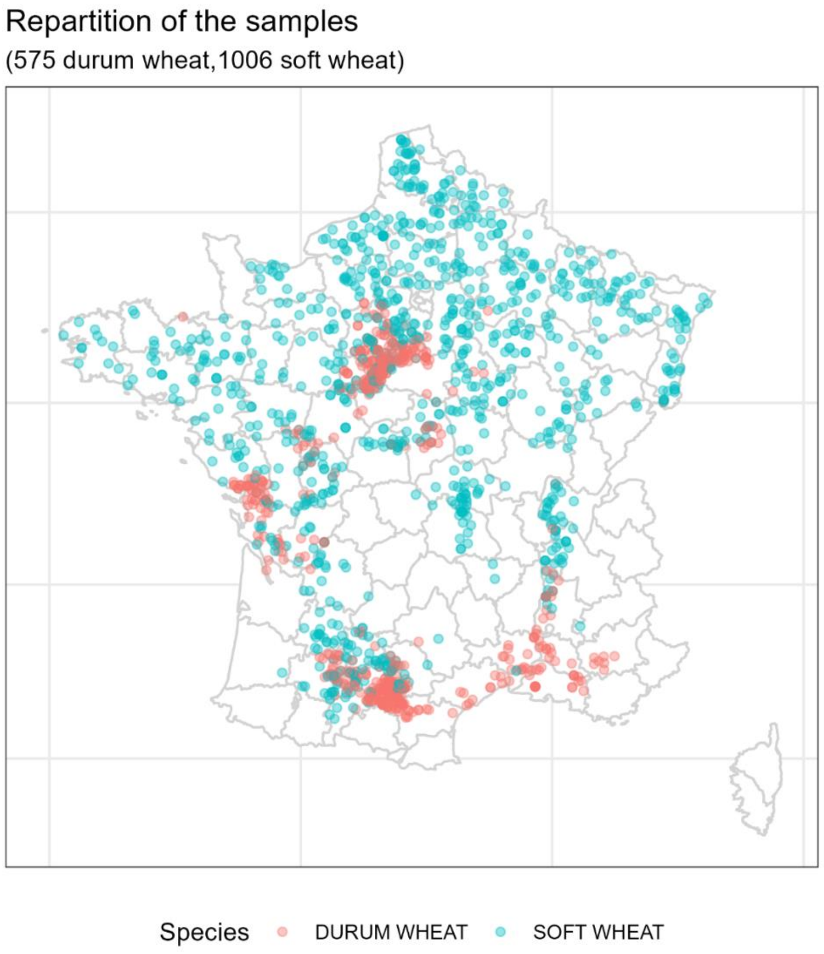


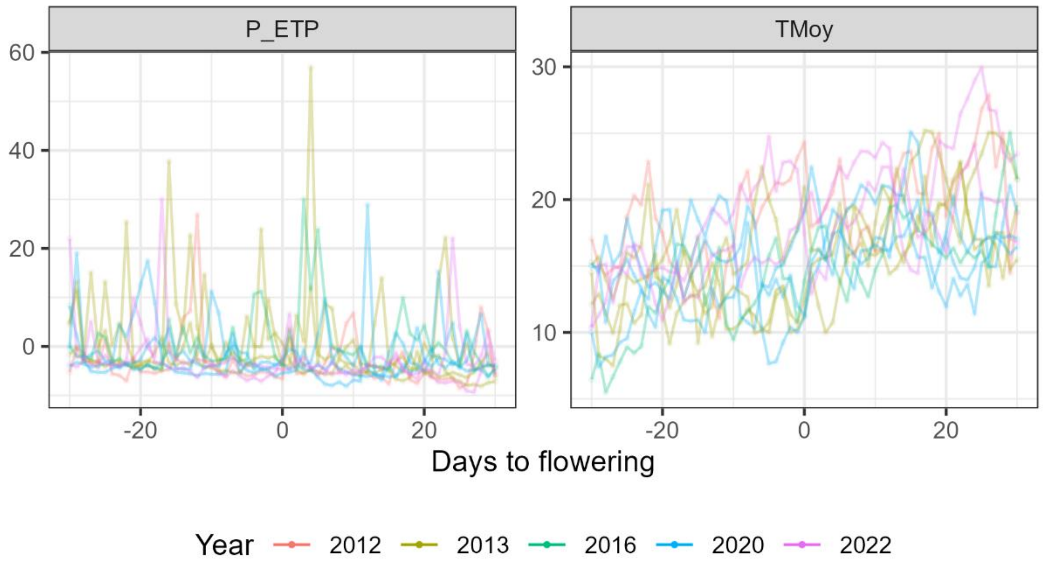


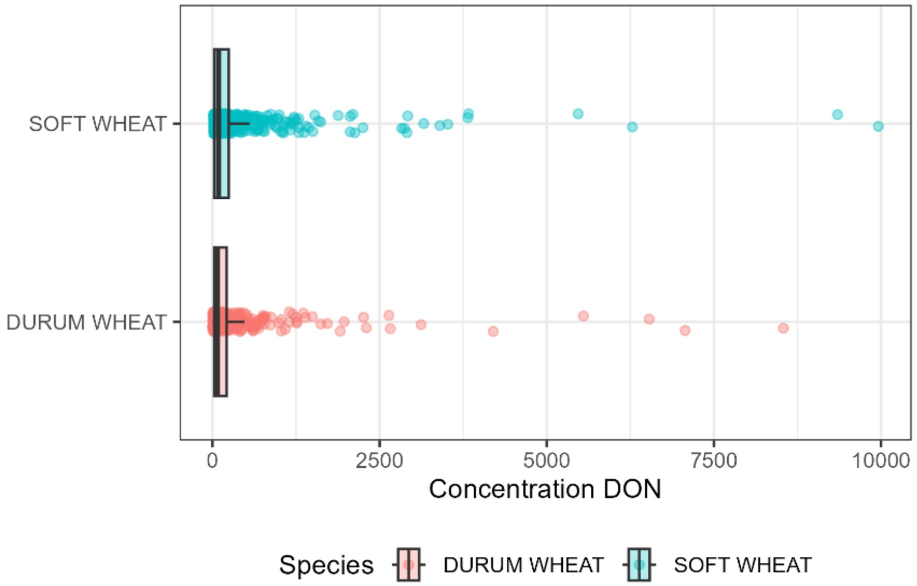
→ *What happens in vivo ?*

ARVALIS

Toxins = f(climate) ?

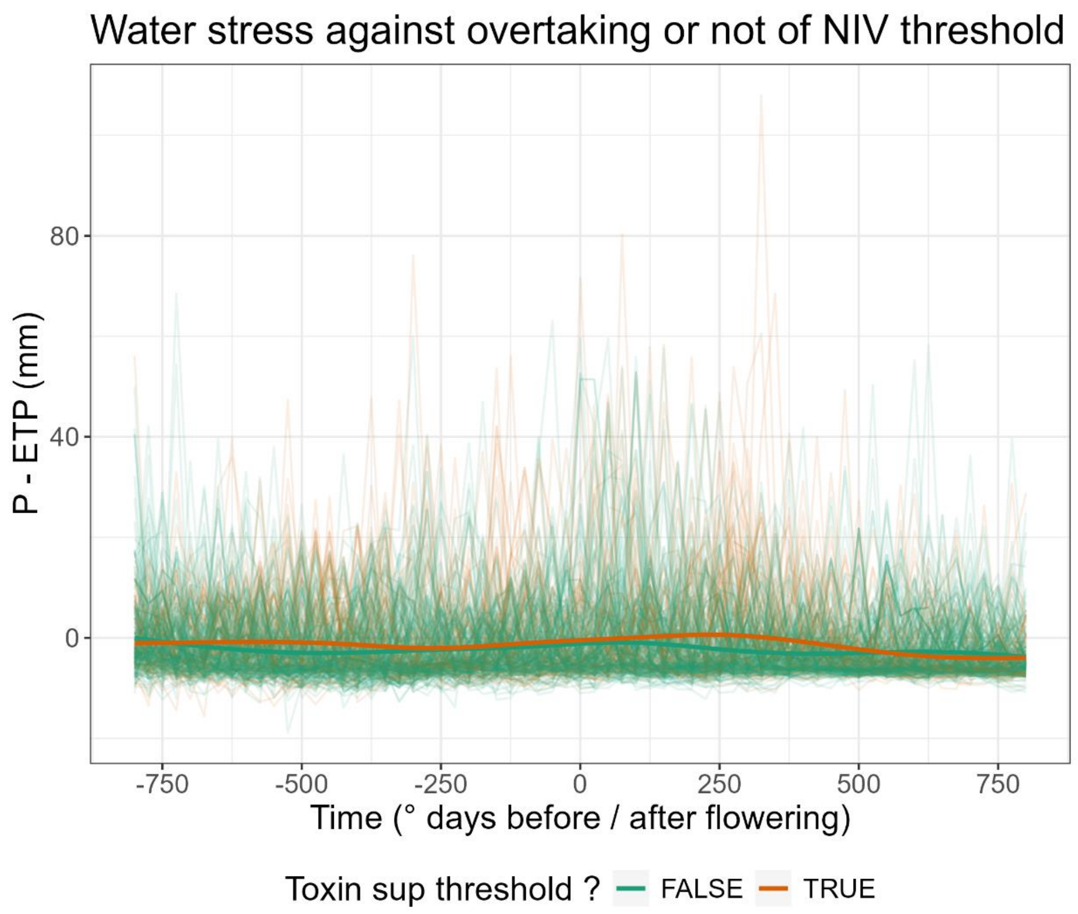


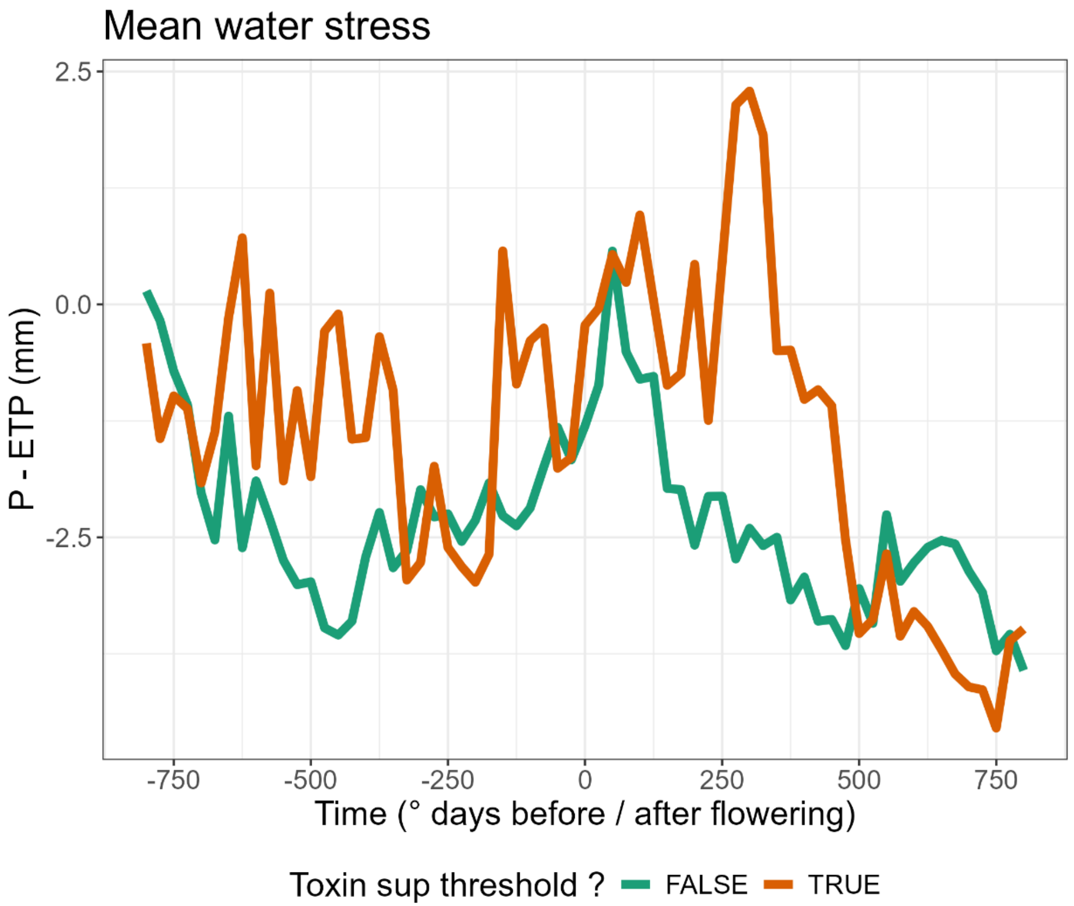




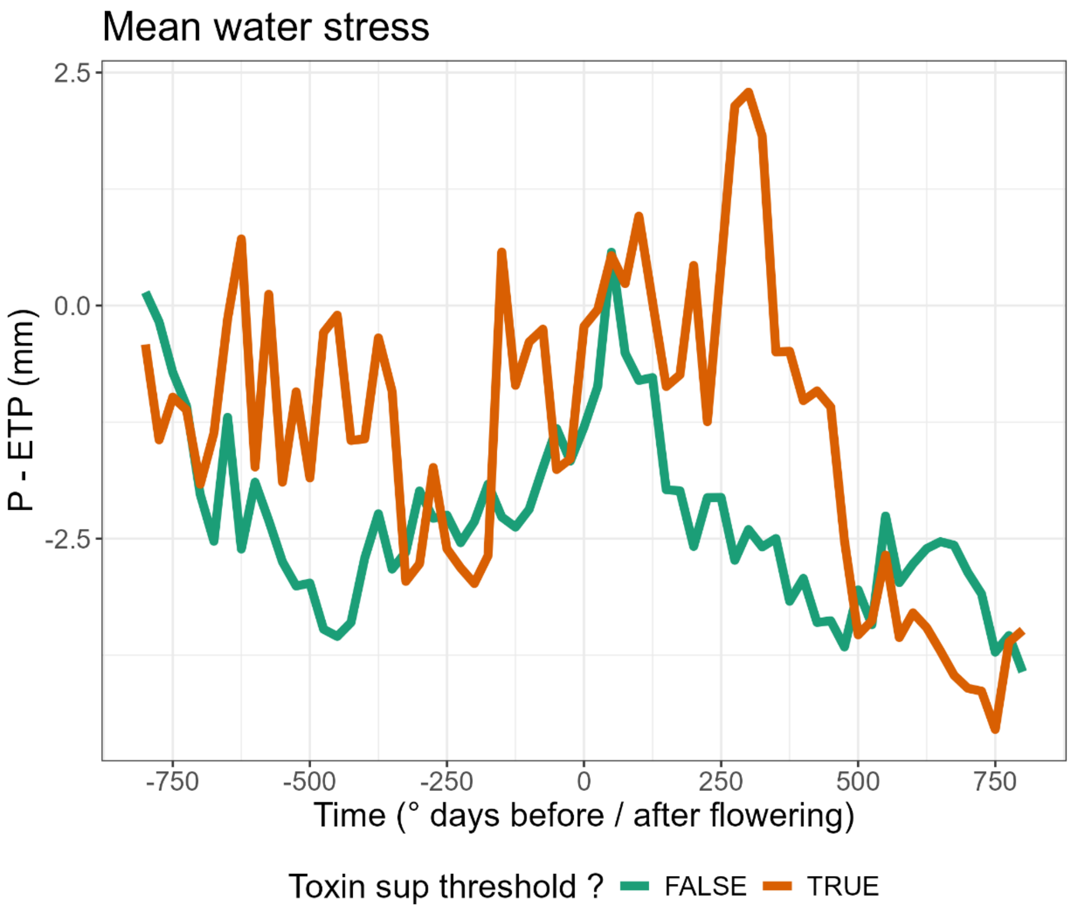
A running example

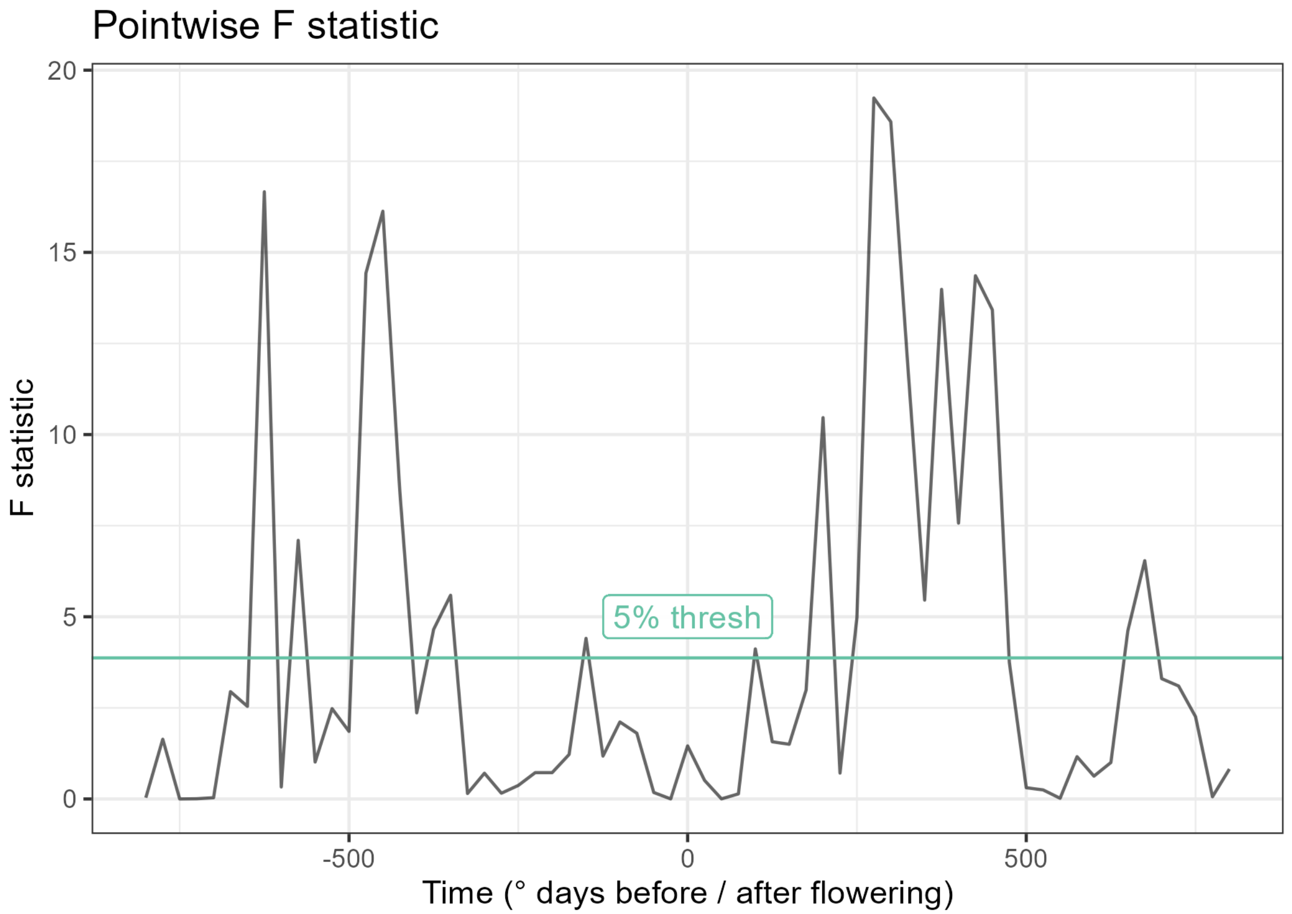
How to find climatic zones related to the overtaking of a given mycotoxin





Pointwise F tests

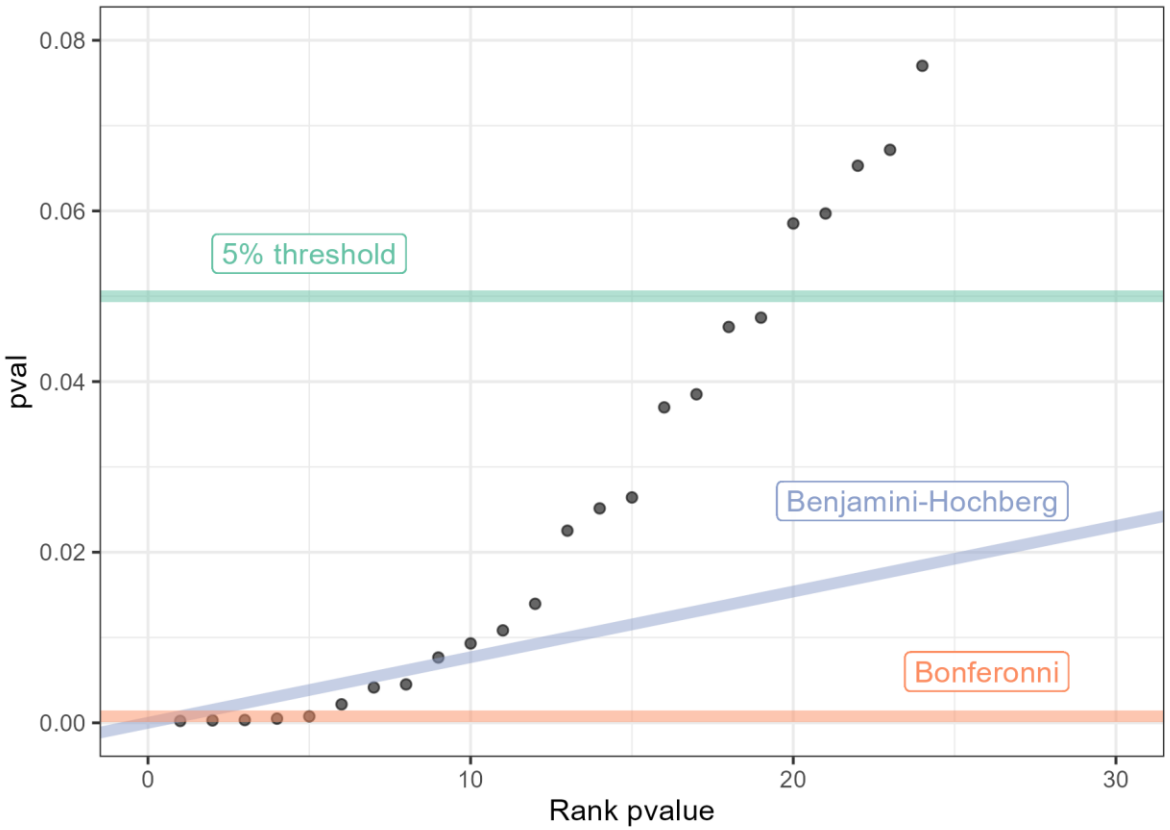




→ *Just a multiple comparison problem ?*

Two possibilities to consider

1) Perform pointwise Ftests and correct the pvalues with a Benjamini-Hochberg procedure



2) Perform a functional ANOVA (Fanova)

a) Compute pointwise F statistics

b) Aggregate the F statistics (sum for ex.)

c) Distribution of the aggregated F statistics under H0 computed by random permutation technics

***Problems**: Fanova results in a **yes/no** answer, no local information and BH procedure leads to no / noisy results → Need for a compromise*

Local Fanova: a compromise between the two approaches (on going work !)

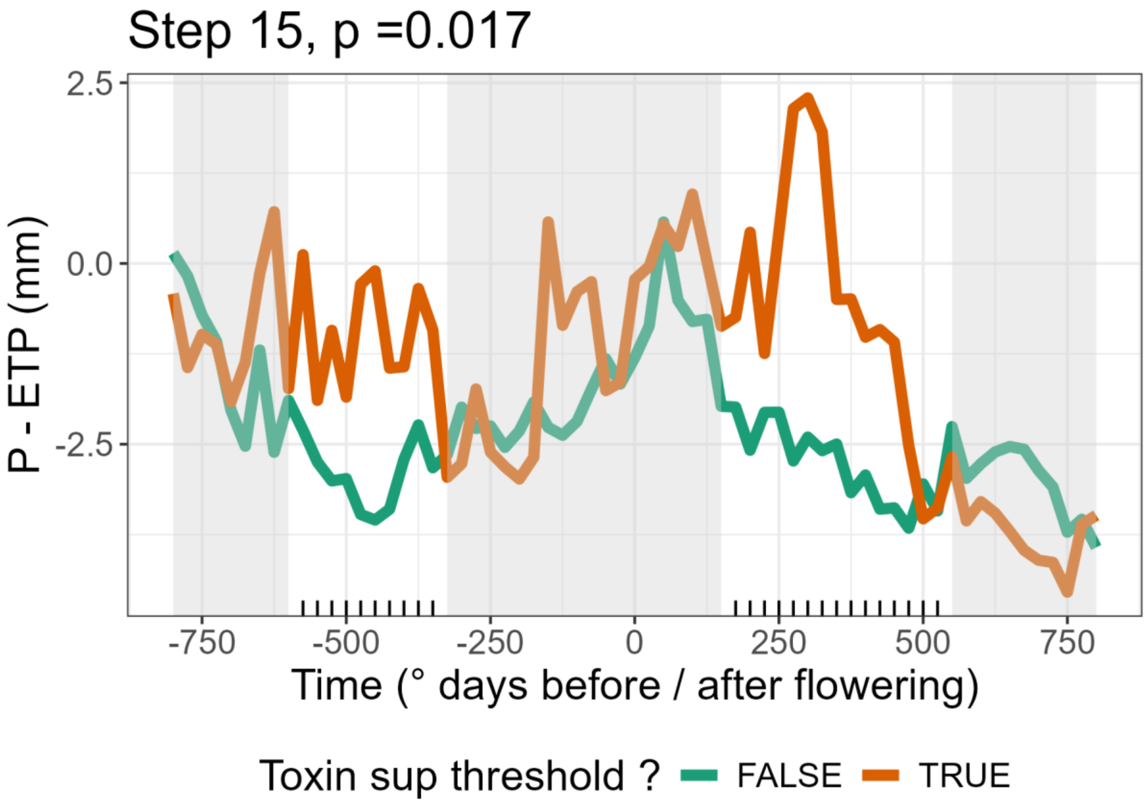
***Idea**: find the largest intervals at which no significant effect can be detected with the functional ANOVA test*

Inputs:
k = window size
n = number of intervals to consider

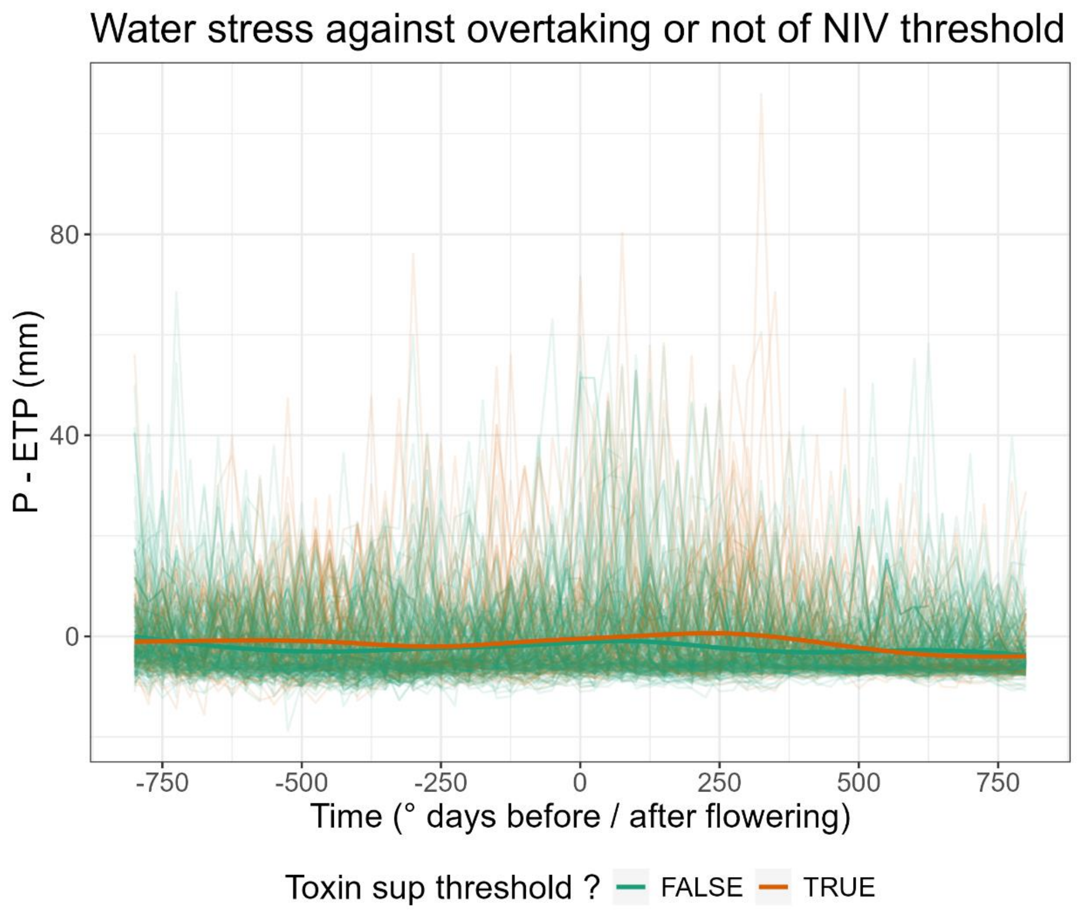
Algorithm:
1. For each interval i in 1 to n:
   a. Define a time frame centered on interval i with a window size k
   b. Perform a Fanova on these time frames

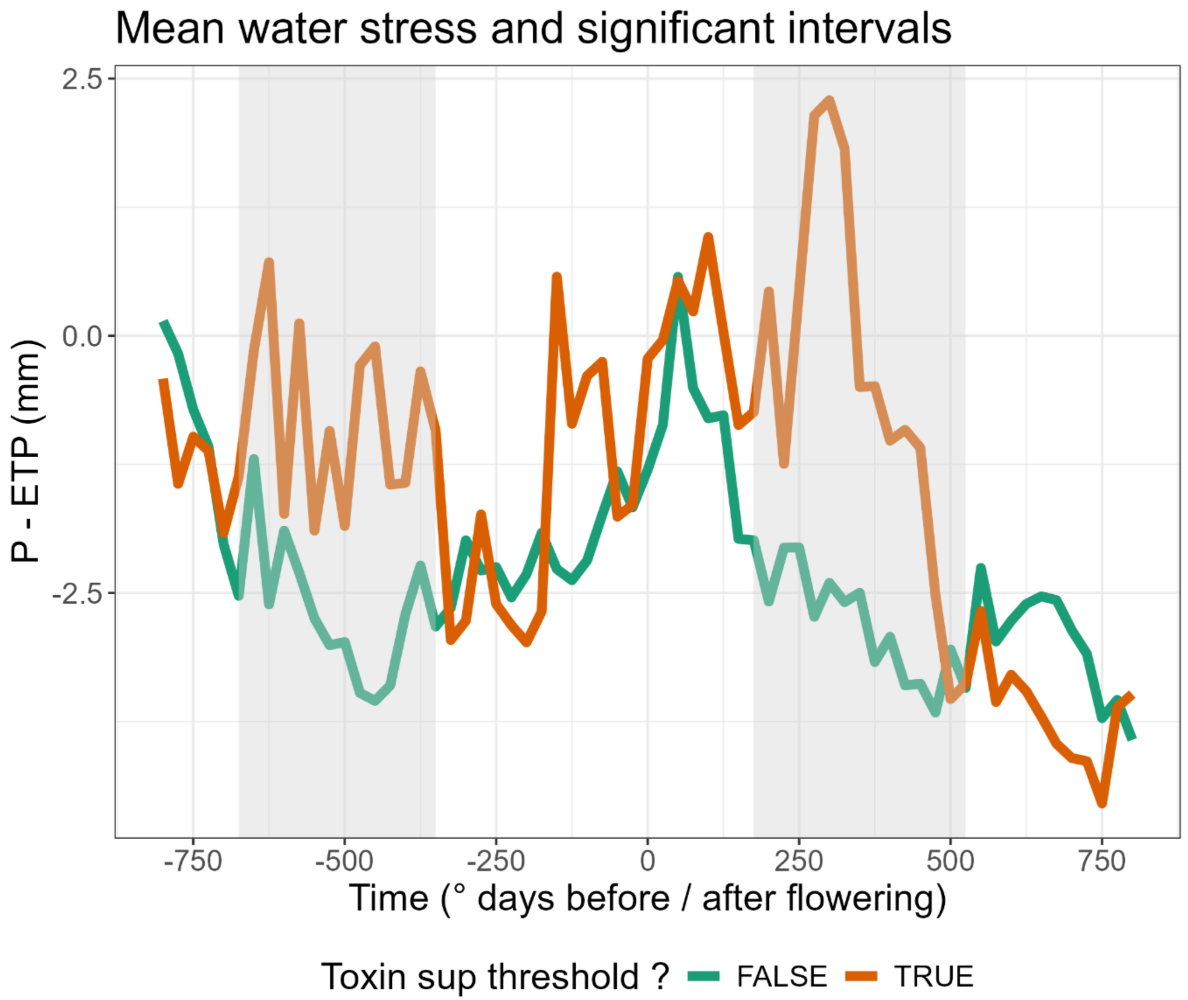
2. Remove all intervals from the time frame that are significant.

3. While the Fanova on the remaining whole time frame is not significant:
   a. Add more intervals to the time frame
   b. Perform a Fanova
   c. Stop when the largest possible interval is found for which the test is not significant



Results


Water stress against overtaking or not of NIV threshold
P - ETP (mm)
80
40
0
-750
-500
-250
0
250
500
750
Time (° days before / after flowering)
Toxin sup threshold ? FALSE TRUE


Mean water stress and significant intervals
P - ETP (mm)
2.5
0.0
-2.5
-750
-500
-250
0
250
500
750
Time (° days before / after flowering)
Toxin sup threshold ? FALSE TRUE

Perspectives

- How to set hyperparameters (window size, number of intervals) ?
- Comparison with other methods (Servien et al. 2019 (SISIR/SFCB), Grollemund et al. 2018 (BLISS) : function-on-scalar regression)
- Simulation study
- Link with in vitro results ?

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