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Does wind matter in the growth response of beech poles to thinning?

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- Windstorms have a destructive effect on forests (Gardiner et al. 2009)
 - Foresters were recently aware of the role of wind as a growth factor in forest production (Meng et al. 2006, Watt et al. 2010, Dean et al. 2013),
 - For managing a stand, the main foresters' tool is thinning
 - But... wind exposure of a tree is also modified by thinning as light environment, competition for water supply and nutrients
- Which is the importance of natural mechanical stimulations in the increase of growth resulting from thinning ?



Article

Changes in Spruce Growth and Biomass Allocation Following Thinning and Guying Treatments

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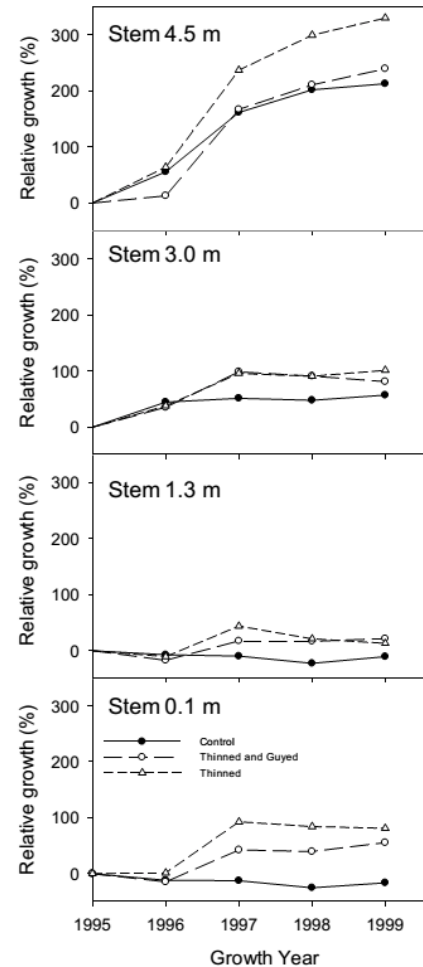
² European Forest Institute, 69, Route d'Arcachon, 33612 Cestas-Pierroton, France

* Correspondence: bruce.nicoll@forestresearch.gov.uk; Tel.: +44-300-067-5584

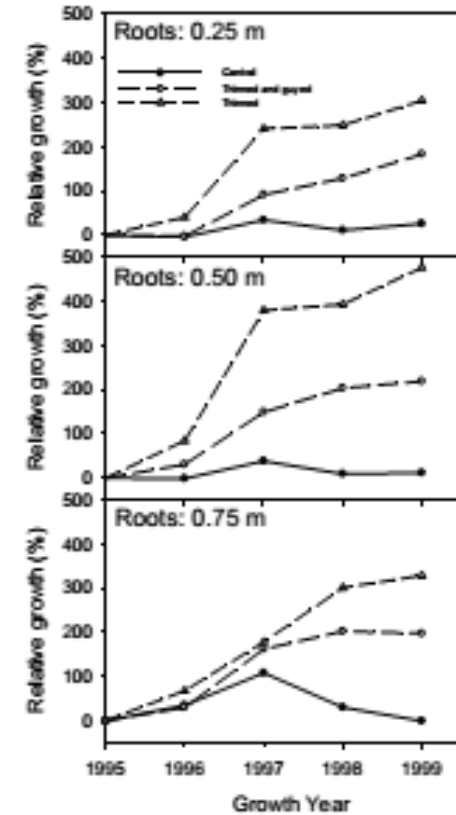
Received: 28 January 2019; Accepted: 8 March 2019; Published: 13 March 2019



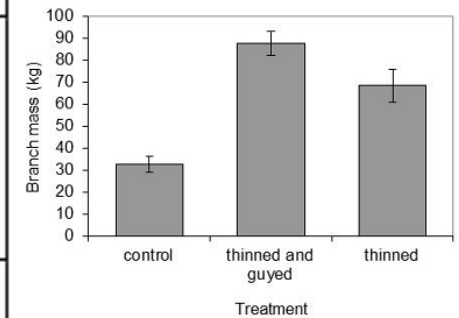
Stem Radial Growth



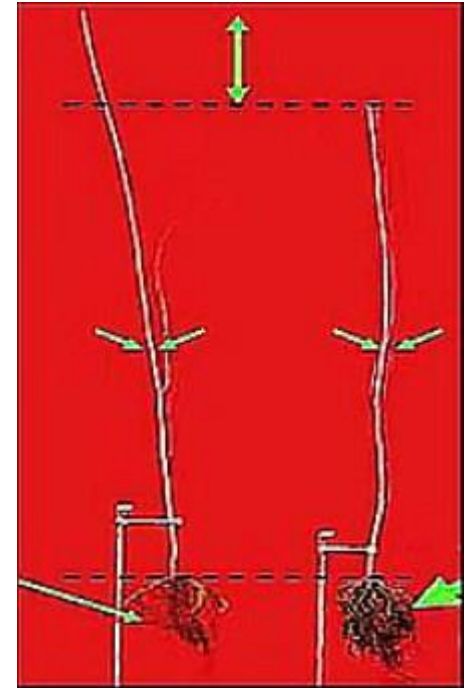
Root Radial Growth



Branch Biomass



- Thigmomorphogenesis has been demonstrated as a powerful mean for acclimation of trees to wind regimes
- Bending strains are the stimuli sensed by plant (Coutand et Moulia 2000) and the S3M model formulates the mechano-perception process (Coutand et Moulia 2000 , Moulia et al., 2011, 2015)
- Most of studies were performed under controlled environment and mainly with seedlings.



Coutand PS 2010

- Can we transpose the gained knowledge in a forestry context for understanding the role of wind in the growth response of trees after thinning ?

The Wind-Thin* Project

- Project began in 2012 within a French project Forwind (2012-2016) in collaboration with PIAF (Clermont-Ferrand) – ONF-RDI (Nancy)
- A stand acclimated to its wind regime (i.e. no silvicultural intervention since 10 years)
- Beech (*Fagus sylvatica* L.)
- Forêt de Haye” ~ 10000 ha close to Nancy mainly broadleaves on a limestone plateau
- Stand used for a 1st study (Bonnesoeur et al . 2016)



The Wind-Thin experiment

- Location : Haye forest close to Nancy (France)

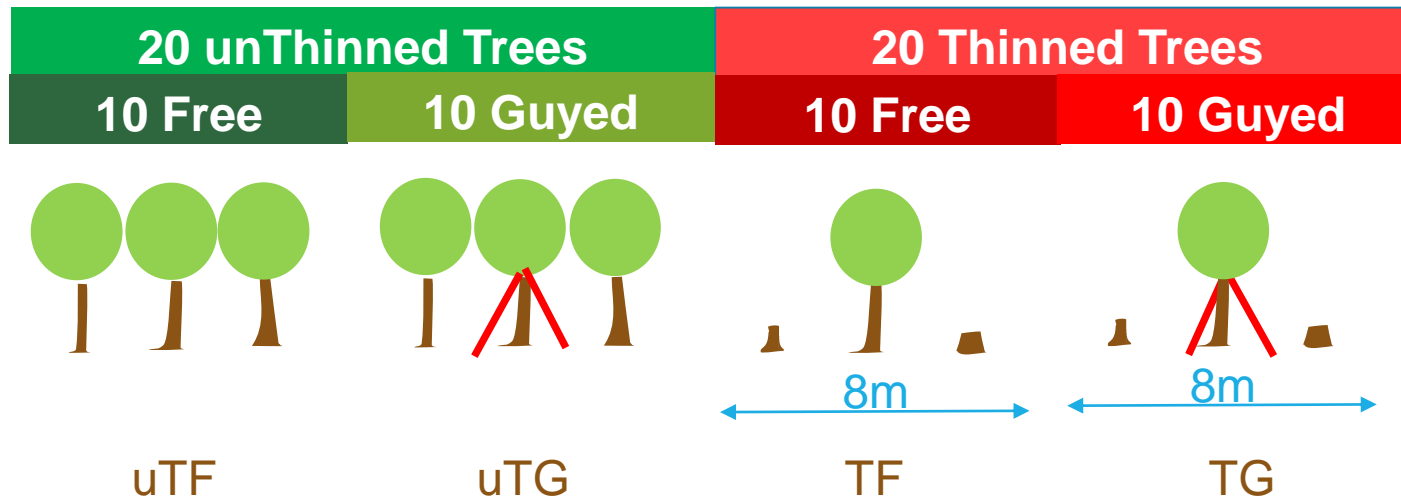
Haye Forest 26th December 1999 after Lothar passed



© Frank Fife/ AFP

The Wind-Thin experiment : Design

- Start in 2015.
- DBH ~13 cm, Ho ~ 13 m, RDI = 0.87, Age ~30 years, Limestone plateau,
- 40 Beech poles divided into 4 treatments
(guyed or free to sway) X (control or thinned trees)
- Each group representing the range of sizes within the stand



The Wind-Thin experiment



The Wind-Thin Experiment : monitoring



Band Dendrometers +
Point Dendrometers

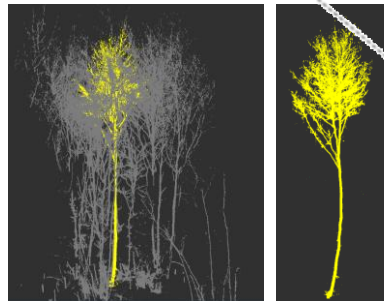
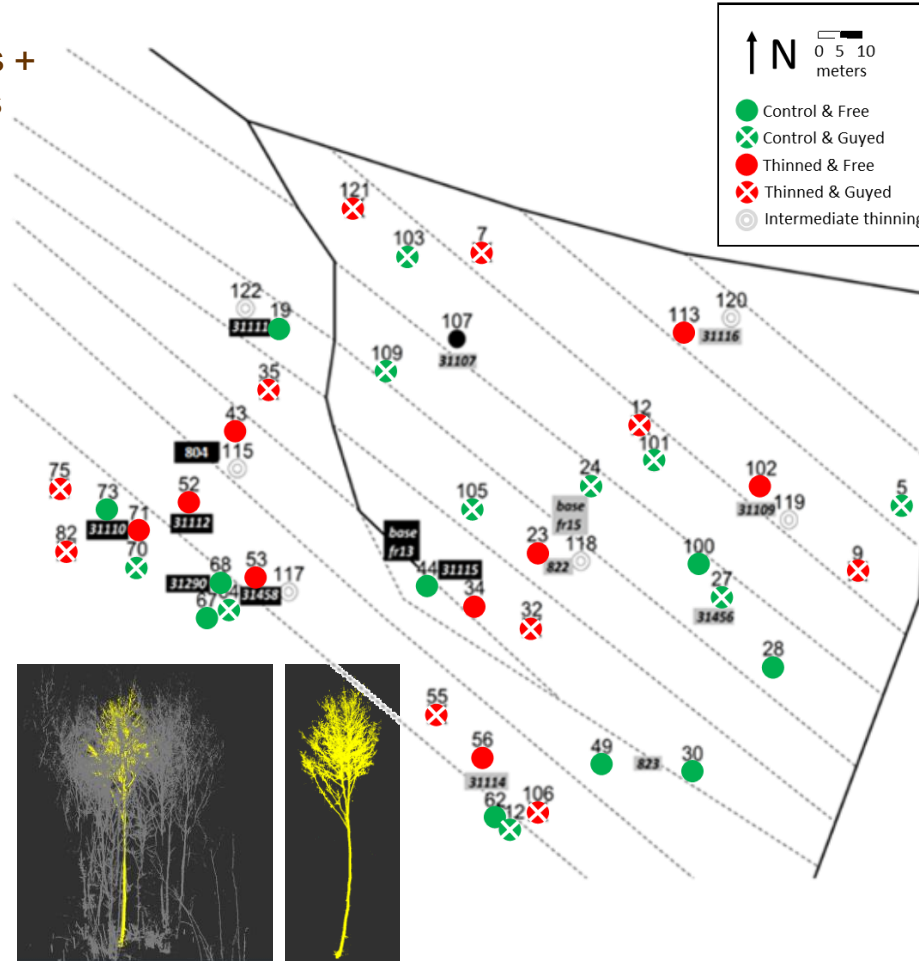


Strain Sensors

Close to breast height

2014 / 2016 / 2018
3D T-Lidar data
and

spatialized inventory of the neighbours



20m Meteorological Mast



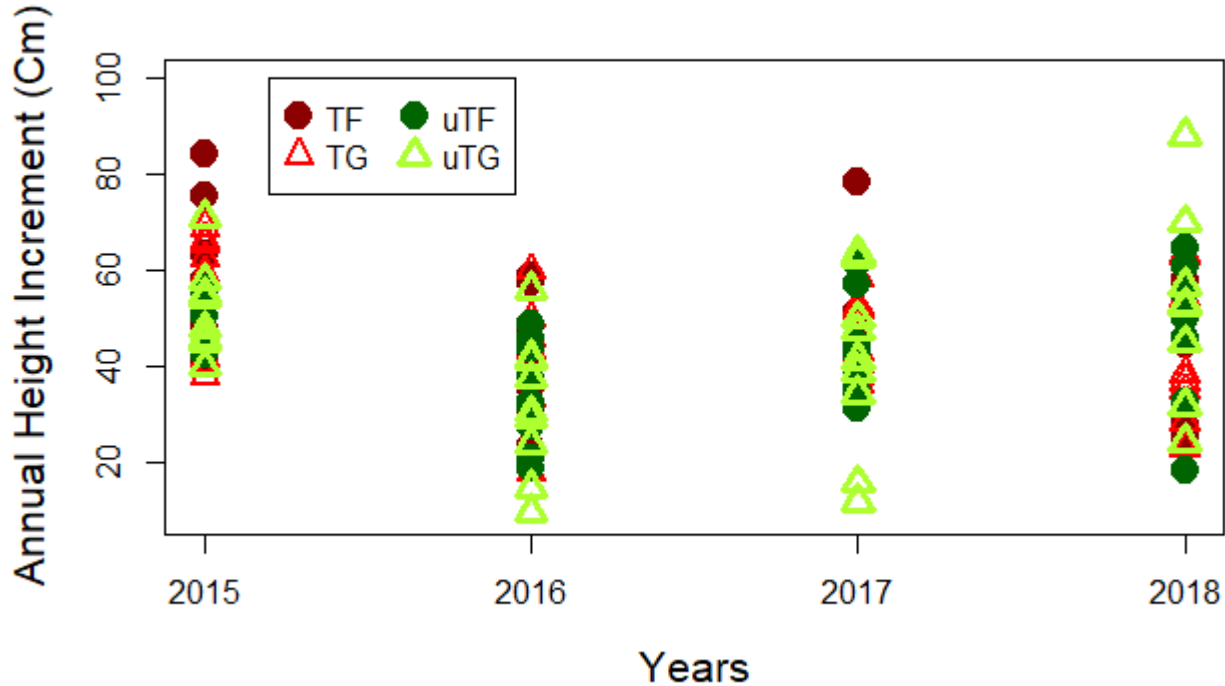
Annual LAI measurements and
soil characterization to calculate water-balance

The Wind-Thin Experiment : final characterization

- T-Lidar measurements
- Biomass distribution
- Pulling tests (Cf. Joel's presentation)
- Root systems and soil characterizations
- Wood samples
 - Mechanical properties, density, MFA
 - Stem analysis
 - Grain angle
 - refined analysis of radial growth anisotropy

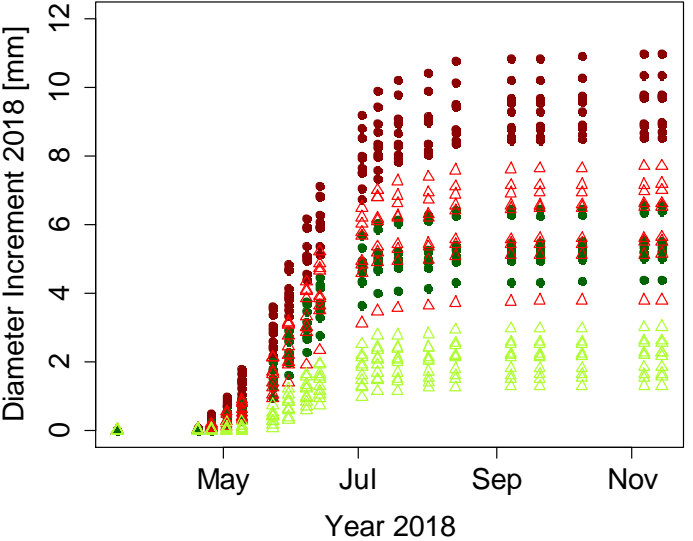
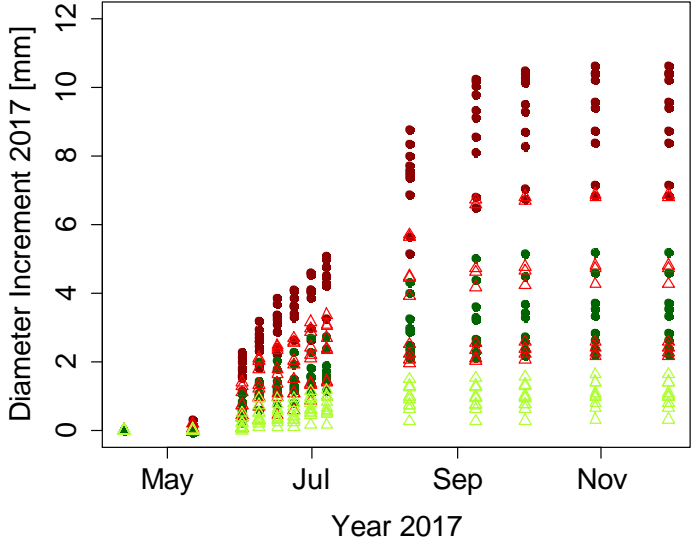
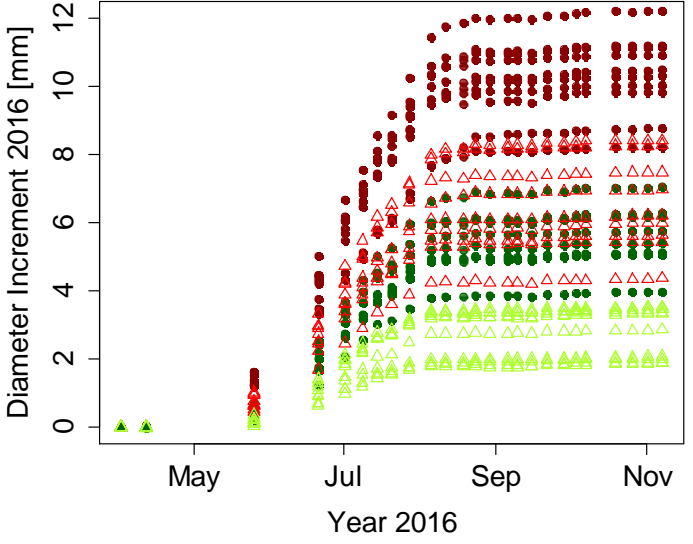
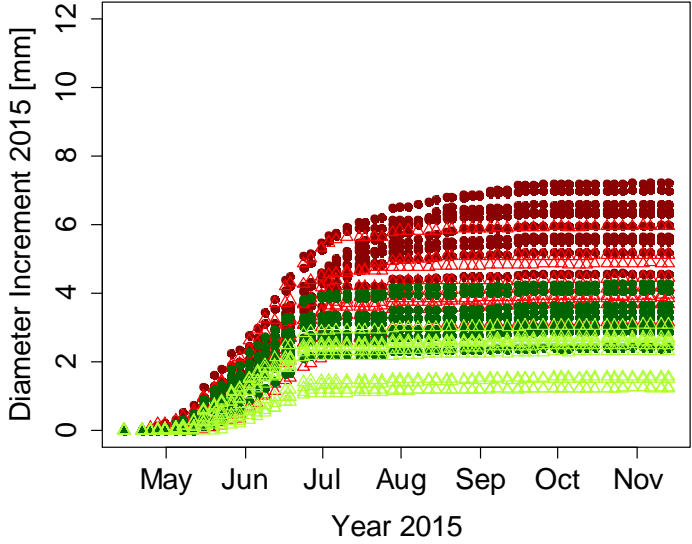


Annual Height Increment



- Measured retrospectively after felling
- No significant differences between
 - Treatments
 - Years
- Results contradictory to previous findings...?
 - Apical control less pronounced for beech than for conifers or poplar in young stages?
 - Height of guying is $\sim 1/2 H_T$ and hence the differences of branches motion due to wind for a tree guyyed or not is not perceptible by the tree

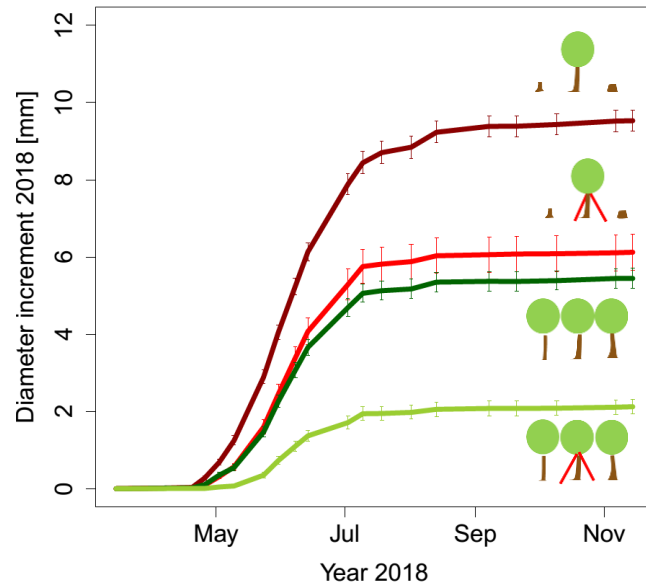
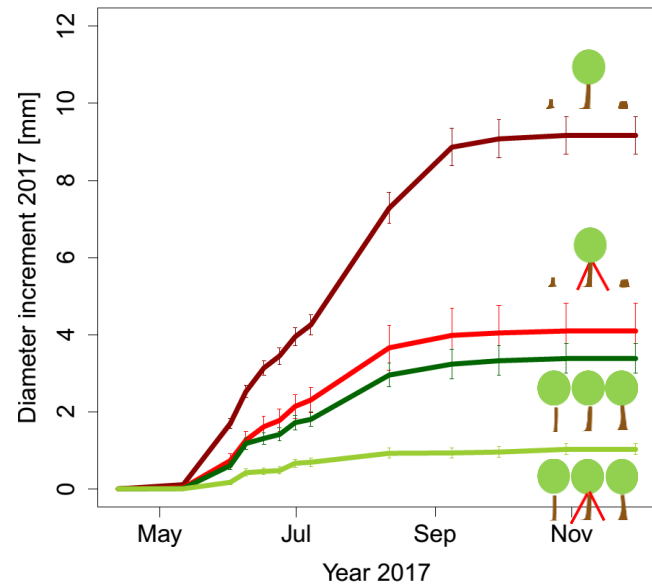
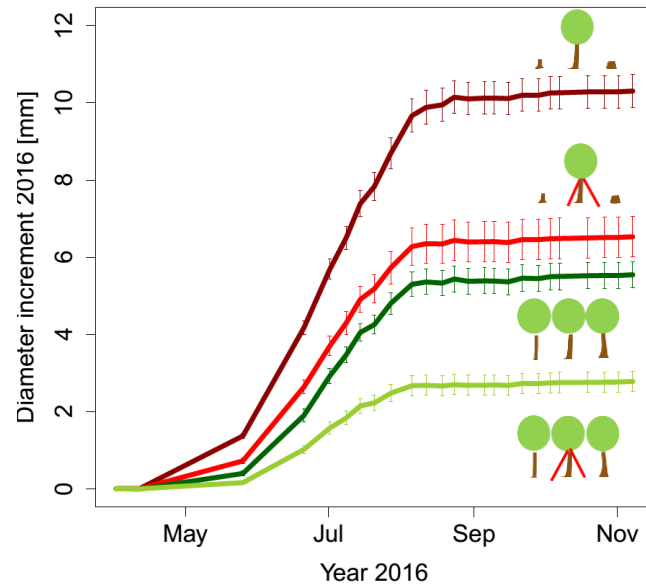
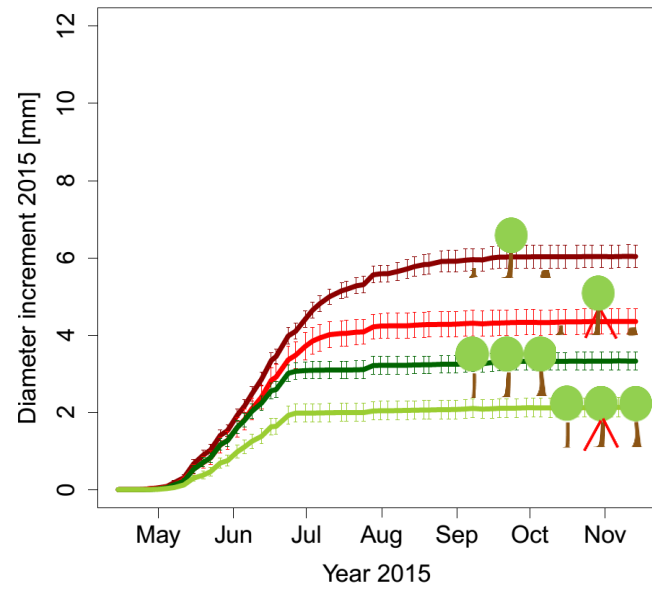
Measured Diameter Increments

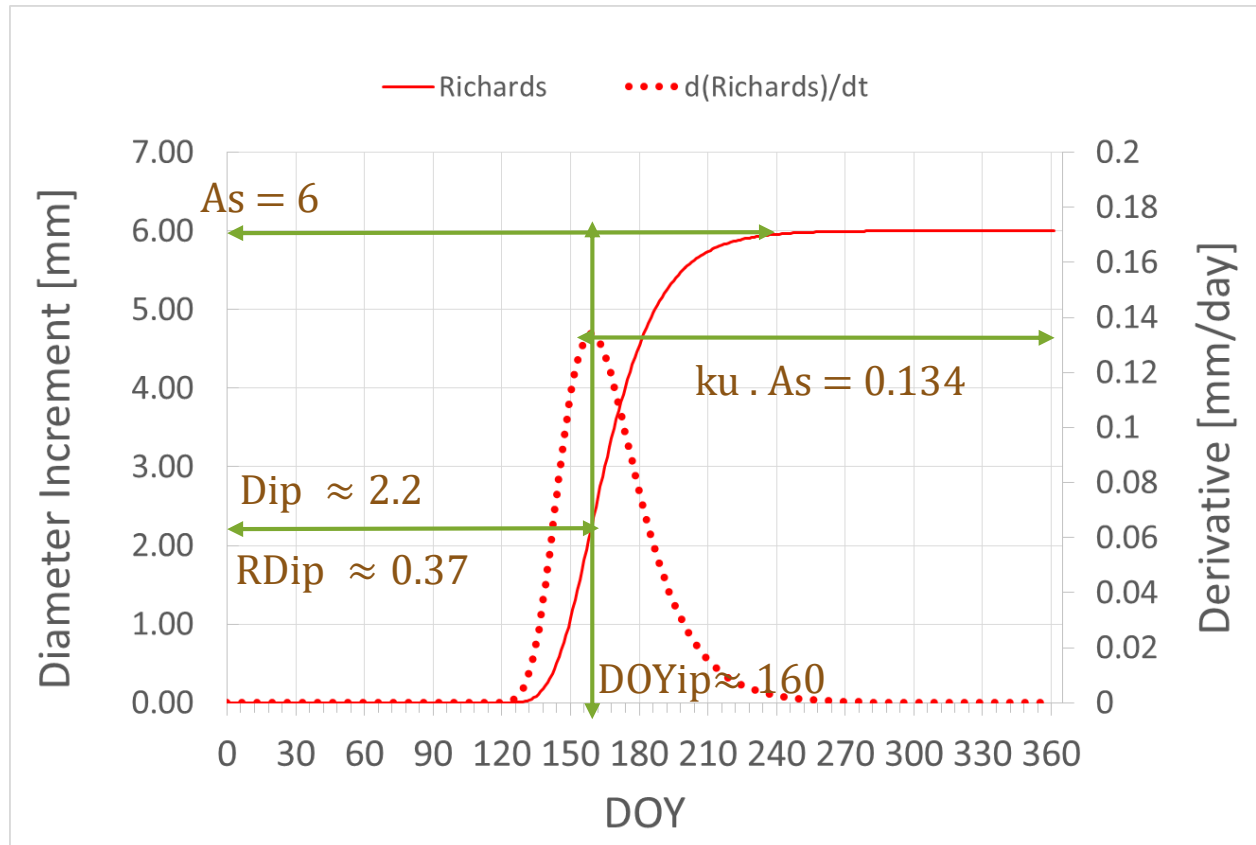


- From band dendrometers
- By year
- By treatment
- By tree

Averaged Values with CI95

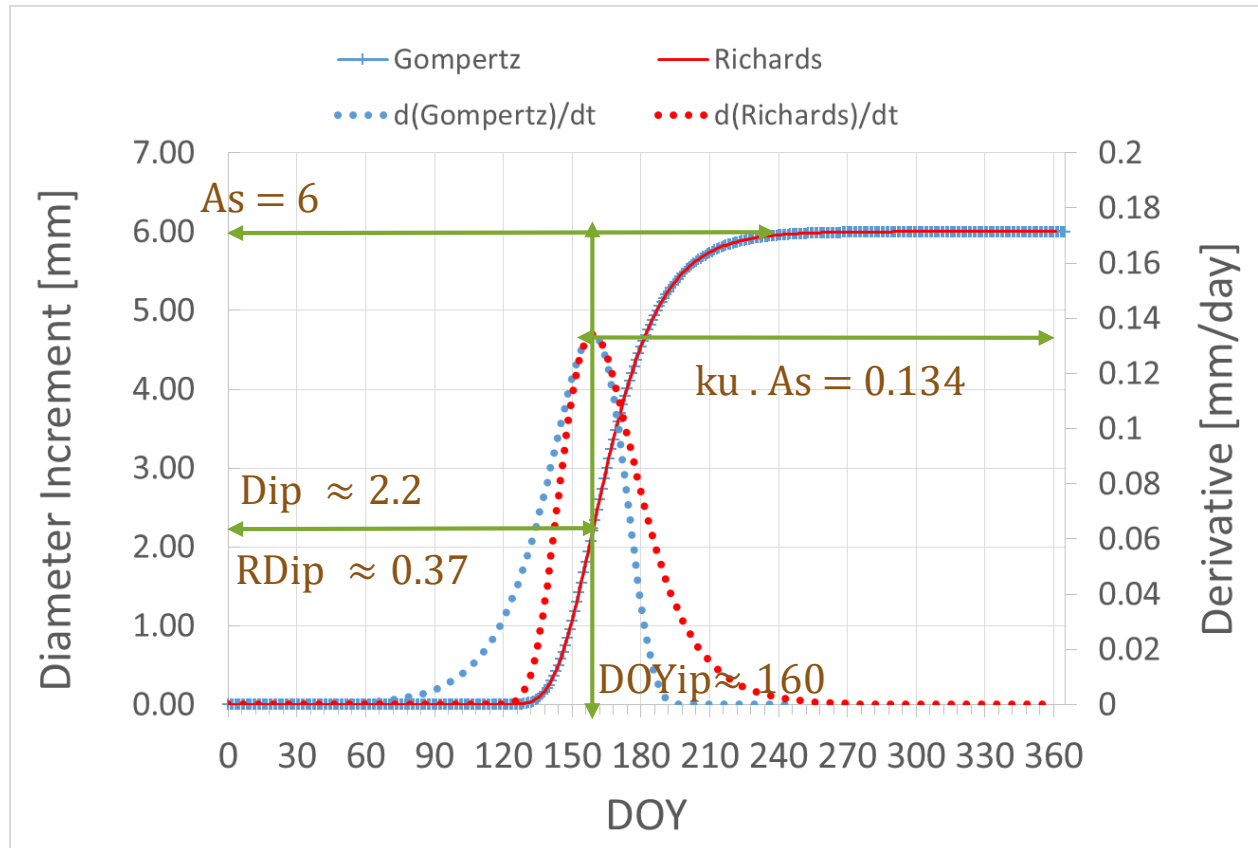
By date and Treatment





- Sigmoidal model with 4 Parameters
- Uniform parameterization [Tjørve & Tjørve 2010]
- A_s : Upper Asymptote [mm]
- ku : Maximum Relative Growth Rate [%/day]
- DOY_{ip} : Day of Inflection Point (IP)
- $d \rightarrow RDip =$ Proportion of A_s at IP

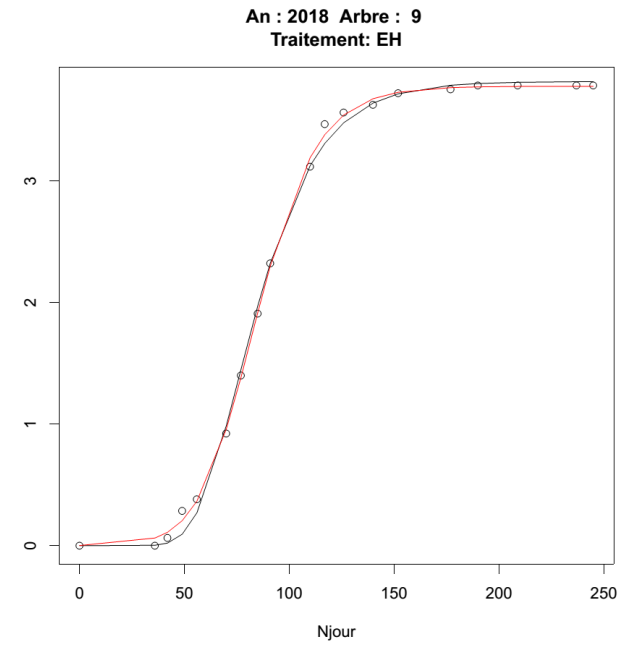
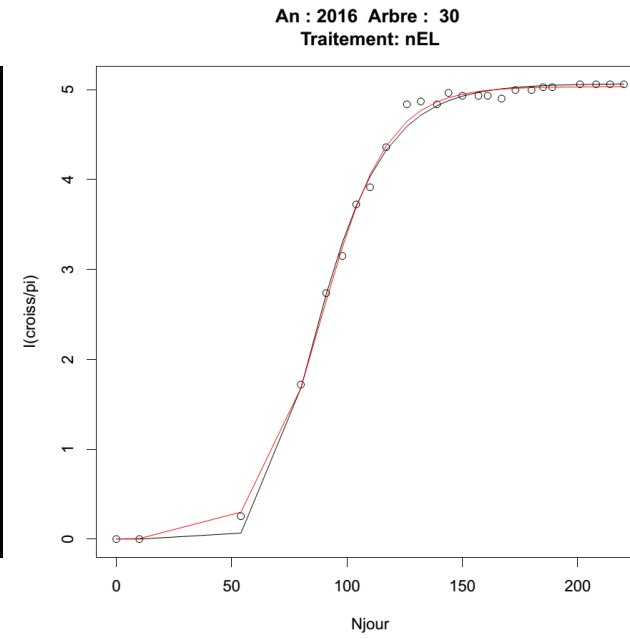
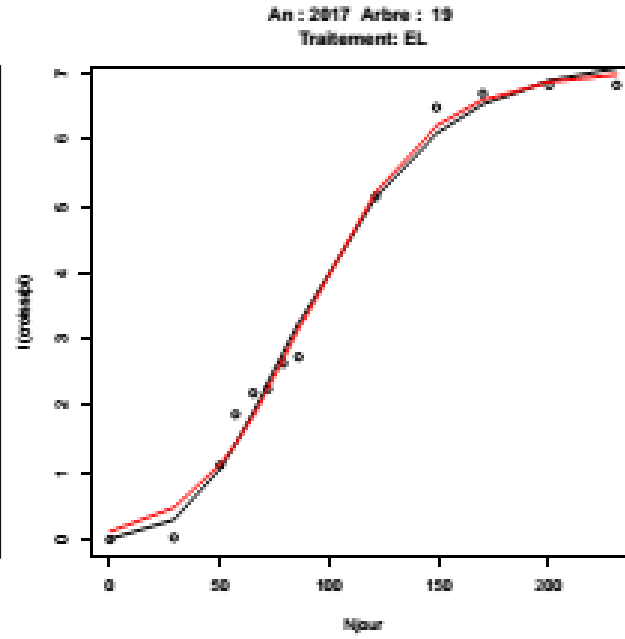
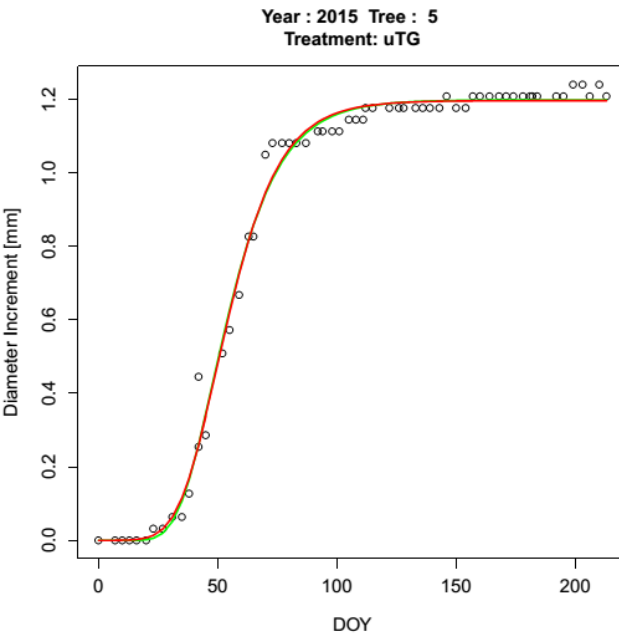
$$RDip = d^{1-d}$$
- Pros : joins the upper asymptote gradually
- Cons.: Risk of no convergence with 4 parameters
-> Gompertz's Model (3 parameters)



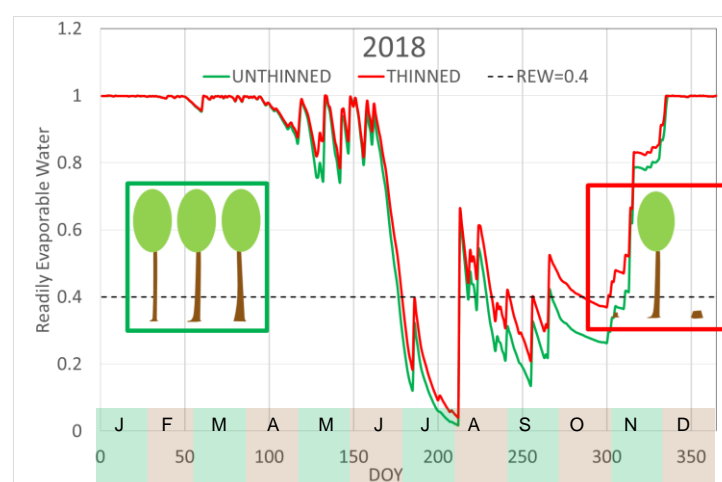
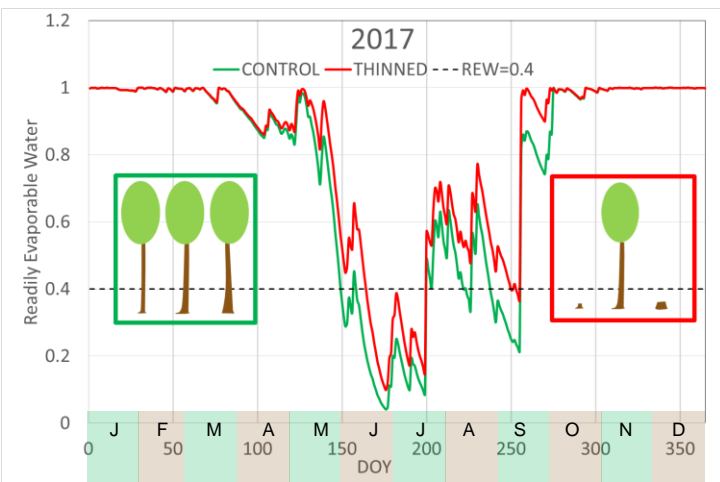
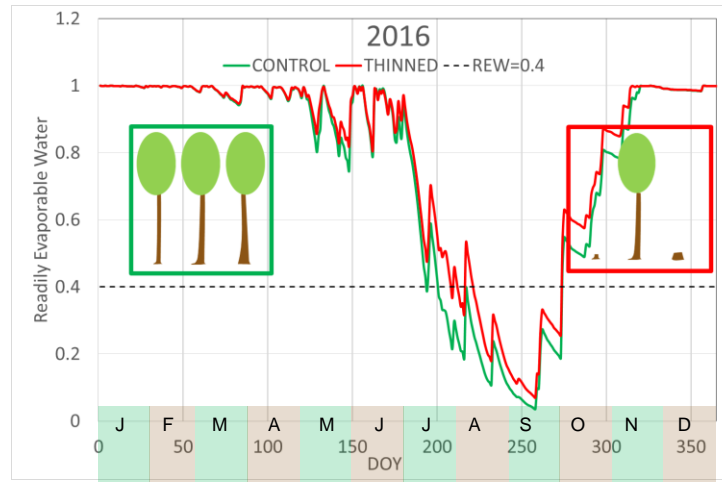
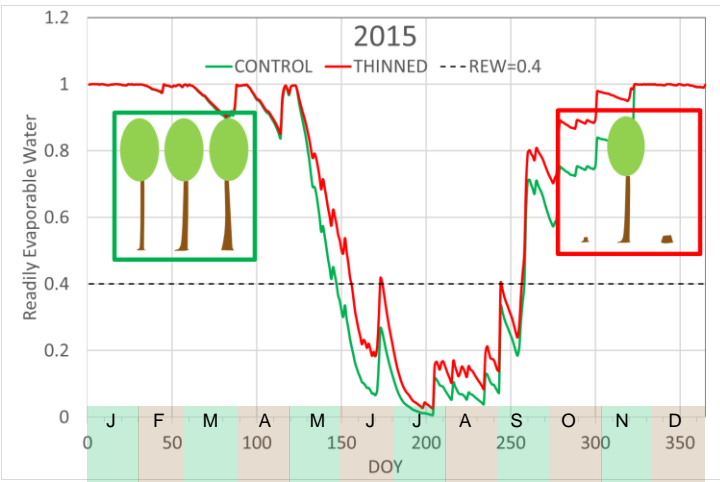
- Sigmoidal model with 4 Parameters
- Uniform parameterization [Tjørve & Tjørve 2010]
- As : Upper Asymptote [mm]
- ku : Maximal Relative Growth Rate [%/day]
- $DOYip$: Day of Inflection Point (IP)
- $d \rightarrow RDip =$ Proportion of As at IP

$$RDip = d \frac{As}{1-d}$$
- Pros : joins the upper asymptote gradually
- Cons.: Risk of no convergence with 4 parameters
-> Gompertz's Model (3 parameters)

Some examples of the fitting between Gompertz and Richards (Red)



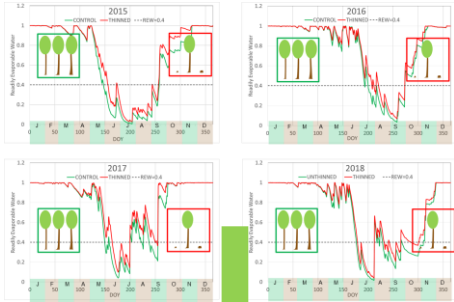
Which ranking between years for the tree growth potential (~ no water stress) ?



- Daily Water Balance computation by BILJOU © <https://appgeodb.nancy.inra.fr/biljou/en>
- Result = Daily Readily Evaporable Water
- $REW < 0.4 \Rightarrow$ Water Stress
- Start of water stress is year dependent
- Unthinned trees (LAI~7) more stressed than thinned trees (LAI ~5) and earlier but we don't want to be so detailed in our ranking

Which ranking between years for the tree growth potential (~ no water stress) ?

Criterion : Number of days / per month without stress

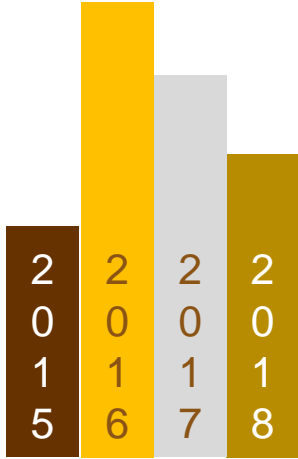


REW > 0.4

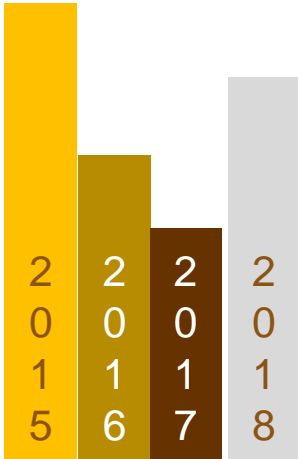
Number of days per month without water stress

	May	June	July	August	September
2015	27	0	0	0	16
2016	31	30	17	0	1
2017	29	2	13	21	18
2018	31	25	0	14	2

Podium Water Availability

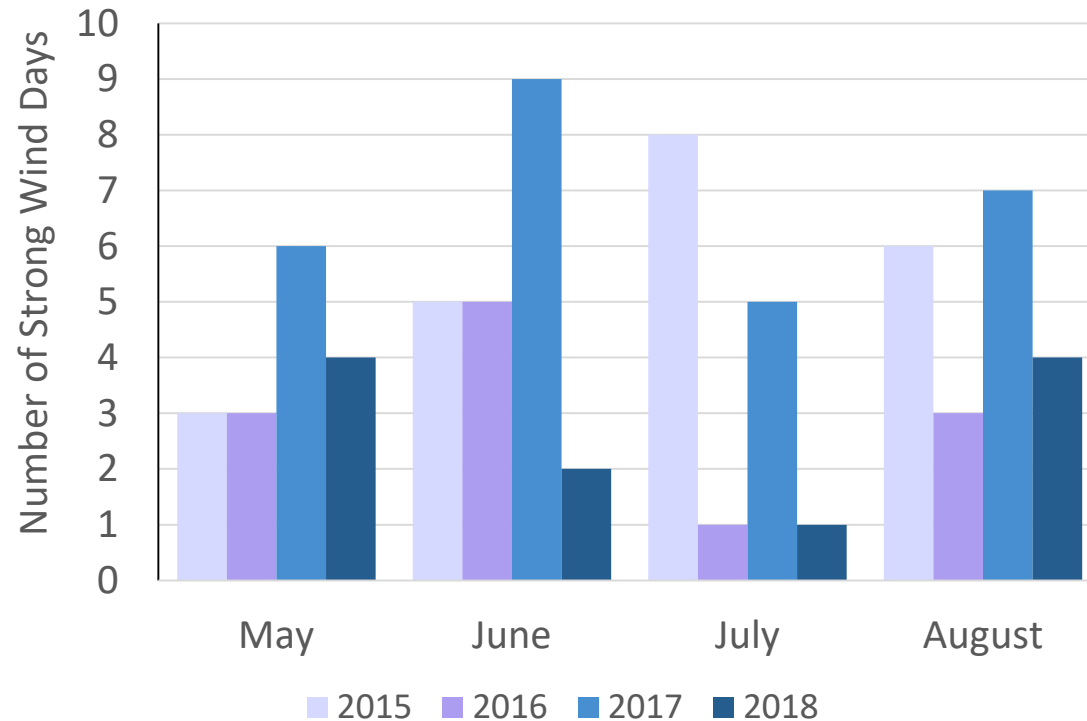


Shortest Growth Period

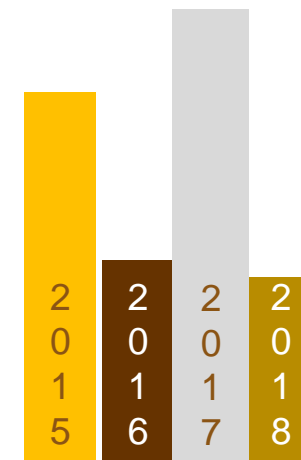


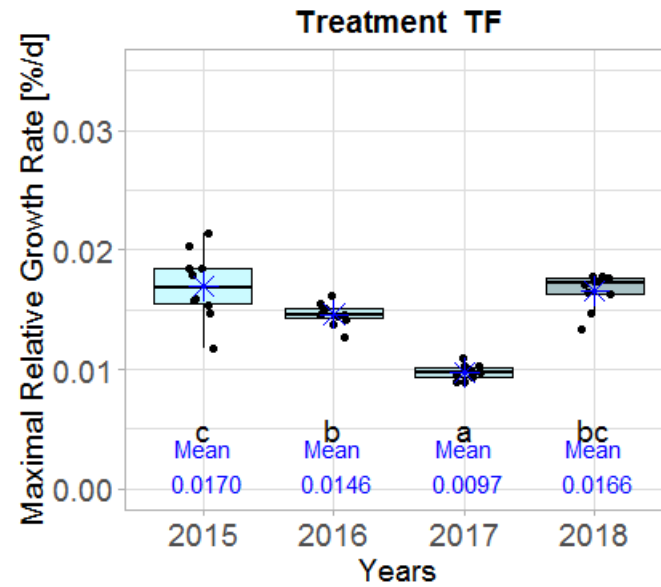
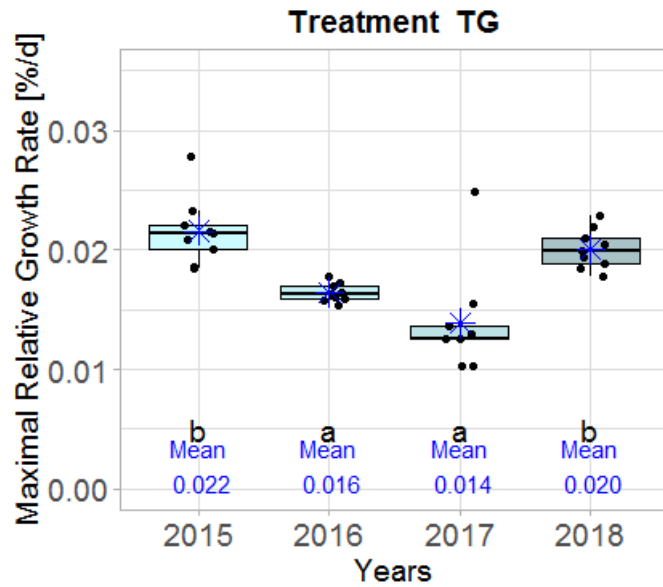
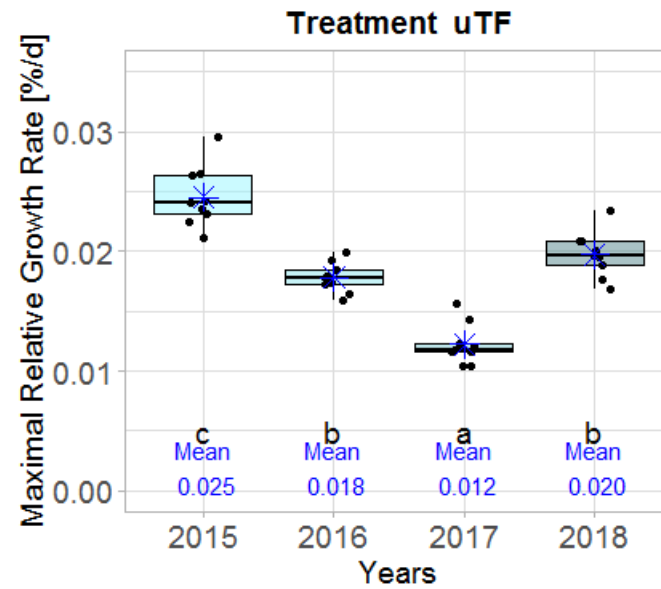
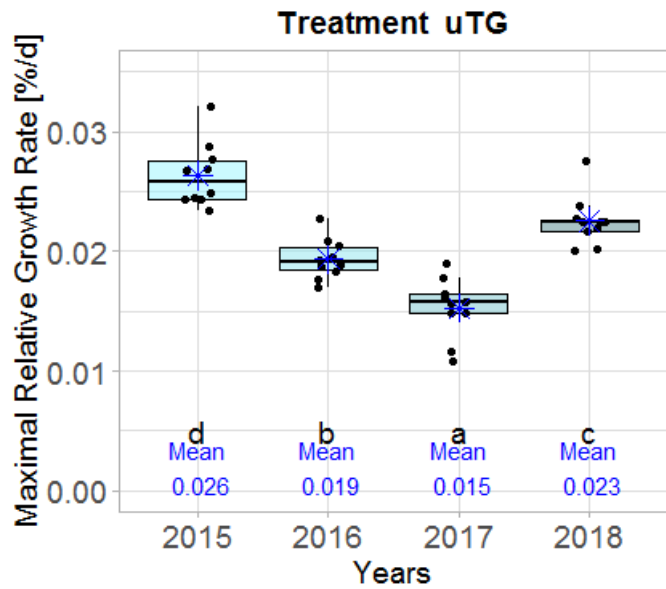
Which ranking between years for a potential thigmomorphogenetic effect ?

- Criterion : Number of days with strong wind (> 50 km/h) between May and August



Windy years



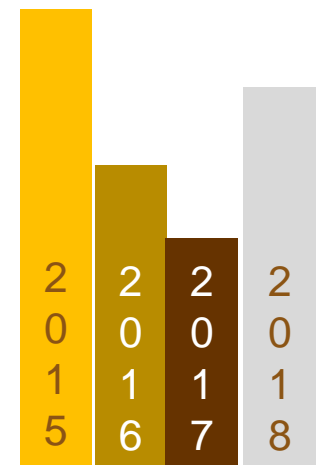


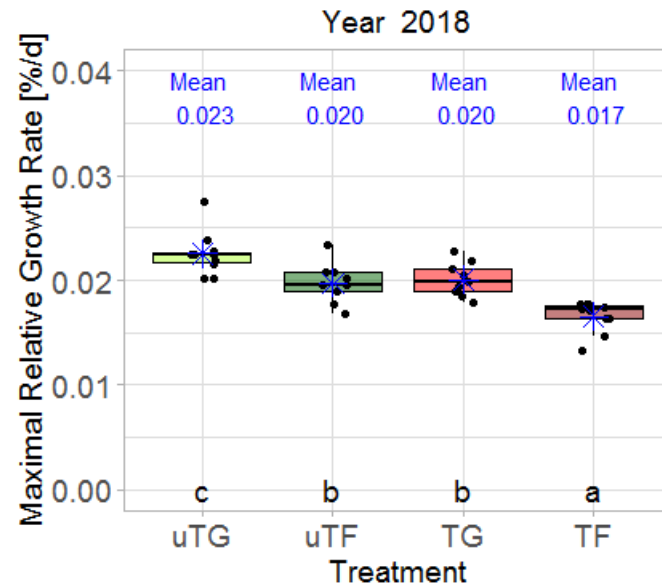
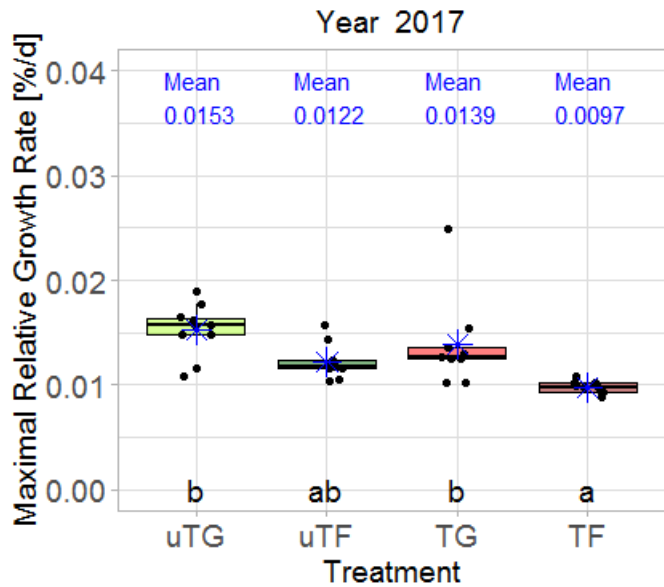
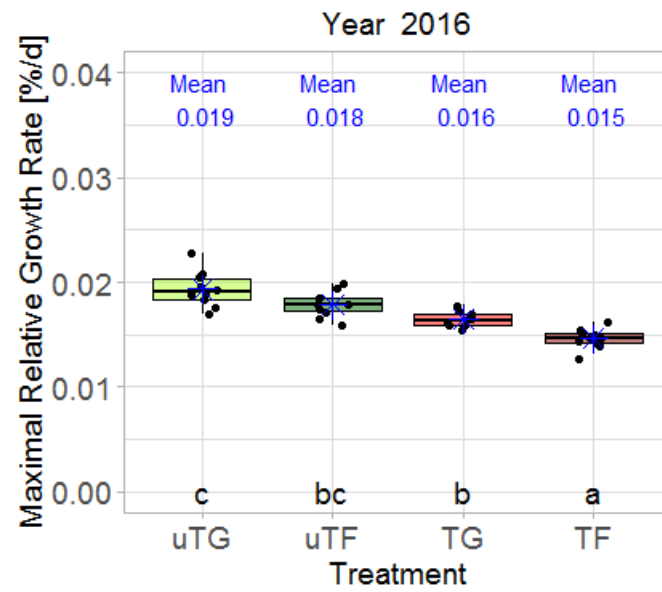
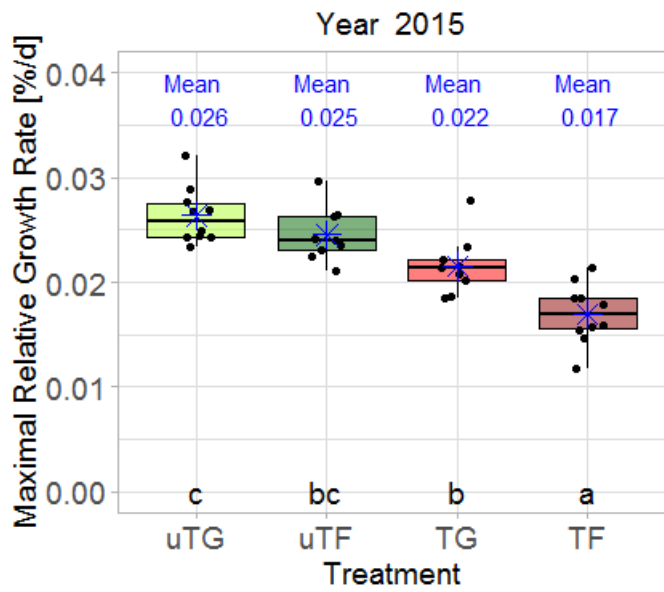
Maximum Relative Growth Rate

Differences between year by treatment

- Range [0.012; 0.026] %/day
- the differences of means are often significant
- uTG Nb = 4
- uTF Nb = 3
- TG Nb = 3
- TF Nb = 3
- 2015 ≥ 2018 ≥ 2016 ≥ 2017
- Same ordering than

Shortest Growth Period



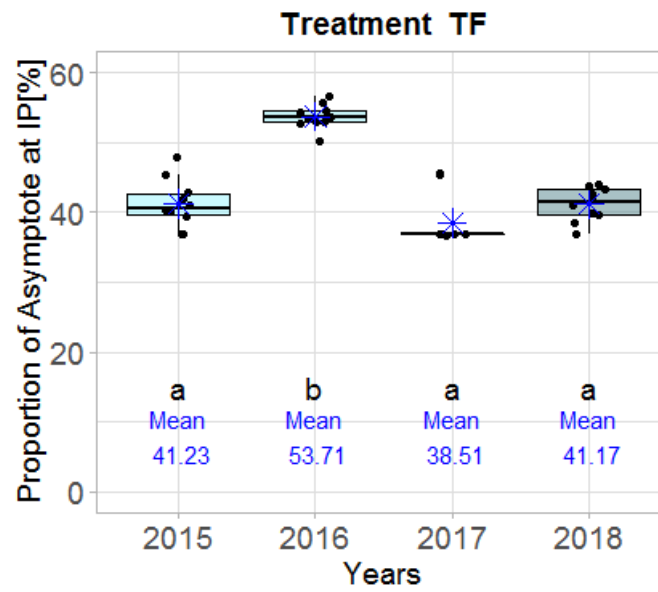
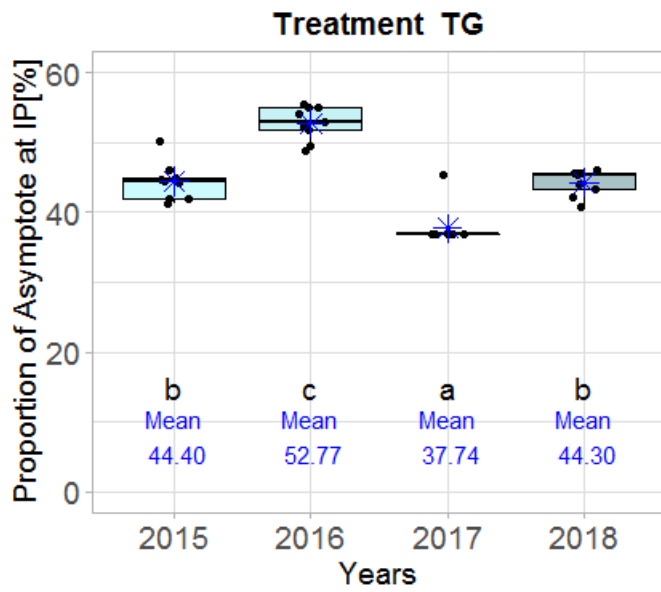
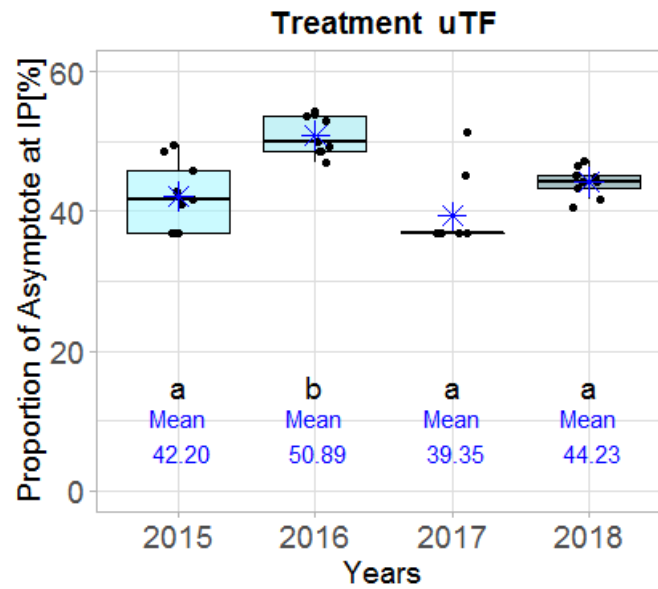
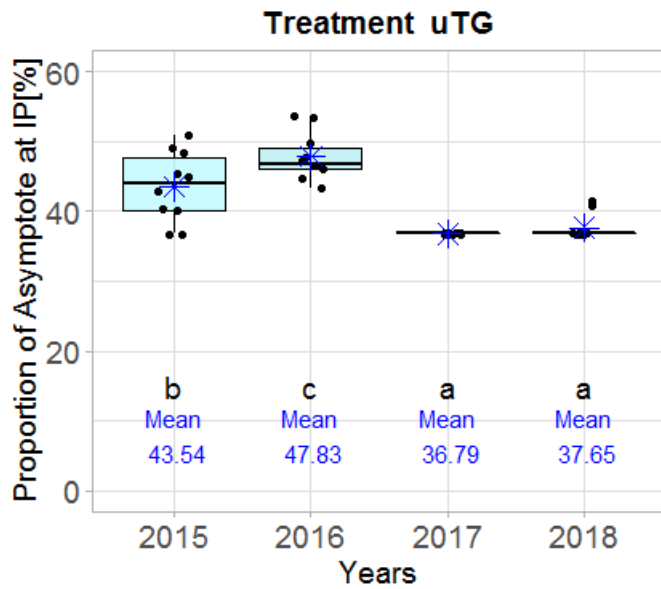


Maximum Relative Growth Rate

Differences between treatments by year

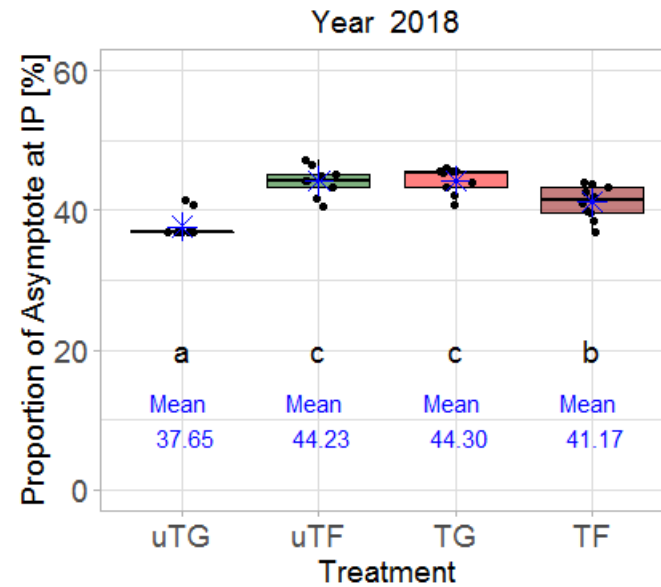
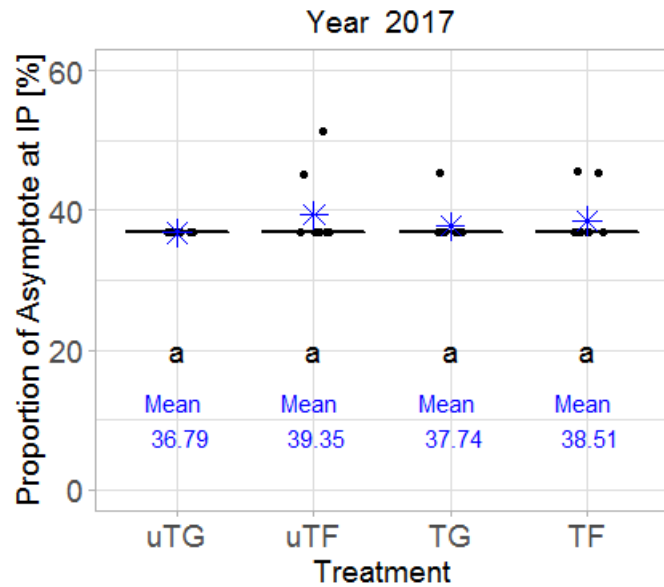
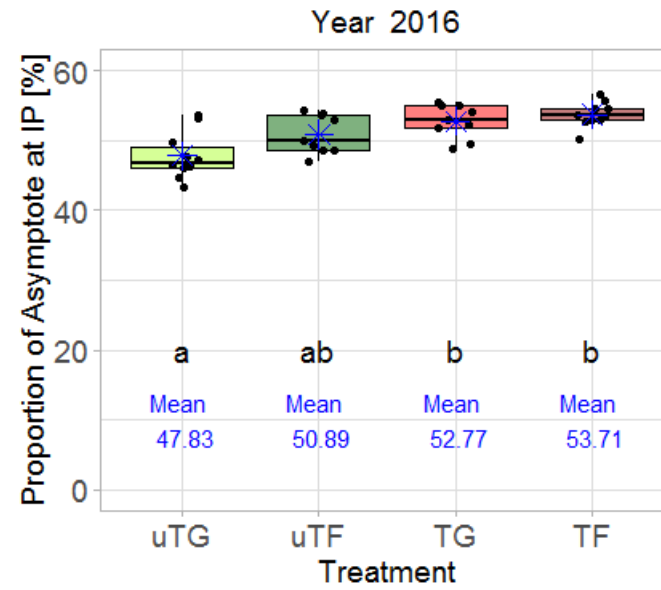
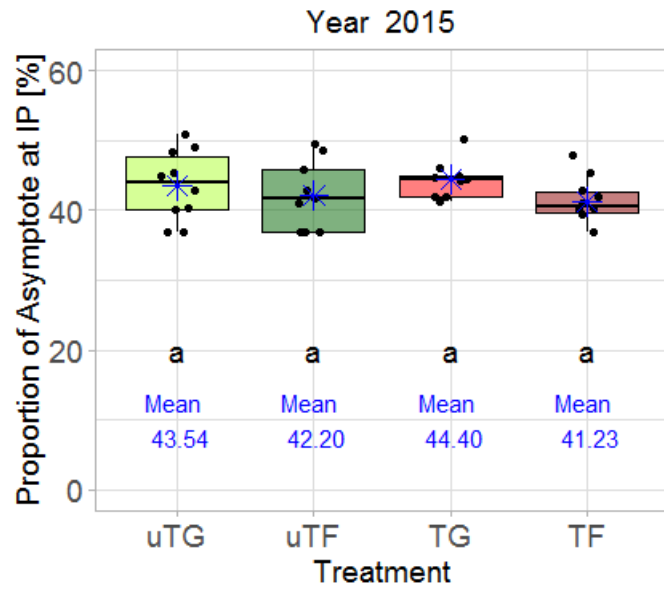
uTG ≥ uTF ≥ TG > TF

No differences between uTF and TG for all years



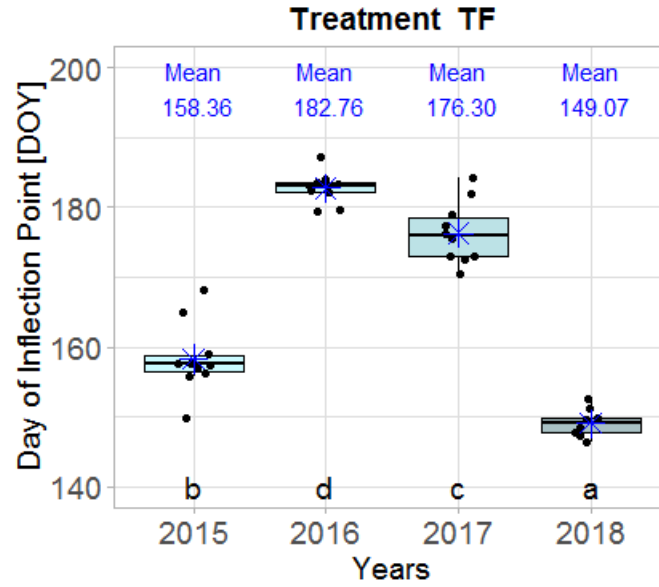
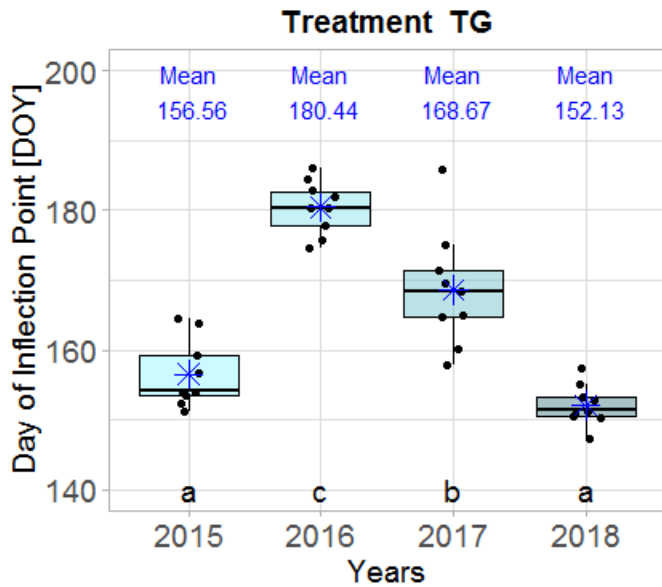
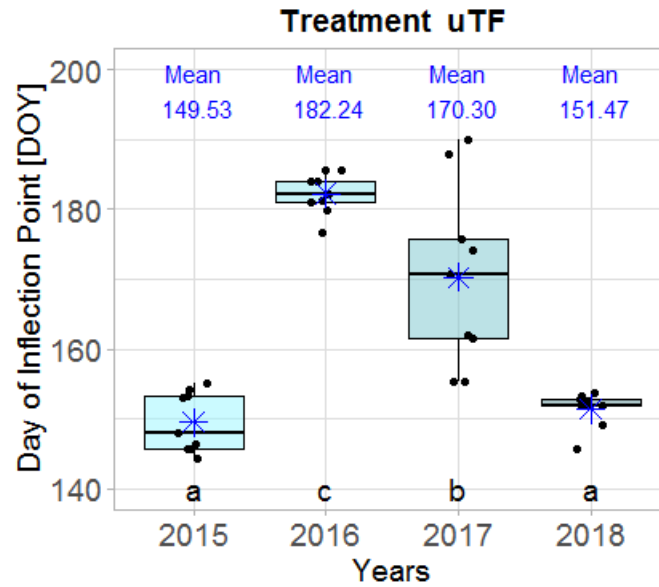
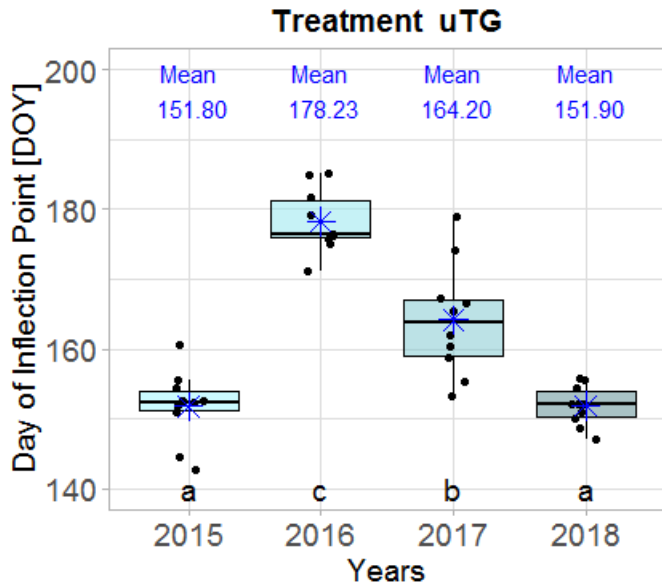
Relative position of inflection points Differences between years by treatment

- Range [37; 54] %/day
- 2016 is the highest value and the difference is significant in all treatments with the other years
- the difference between the other years is poor especially for Free trees, and it is less clear for Guyed trees



Relative position of inflection point Differences between treatments by year

- Some differences between the treatments but it is very narrow
- No clear trend
- No significant difference in 2015 and 2017
- No difference between uTF and TG



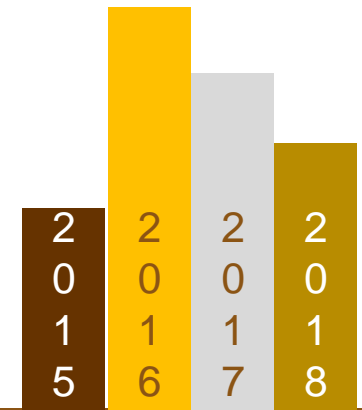
Day of inflection point

Differences between years by treatment

- range [149; 183] DOY
- The variation of the mean day between years has the same pattern between each treatment with some changes in 2015 and 2018.

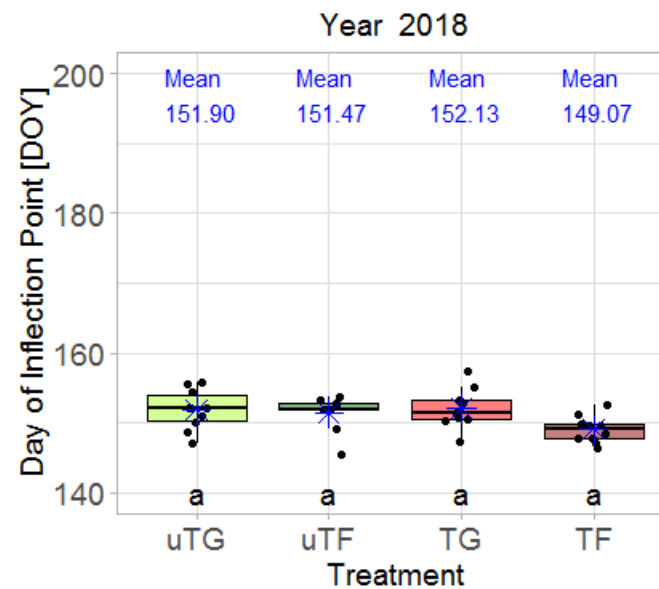
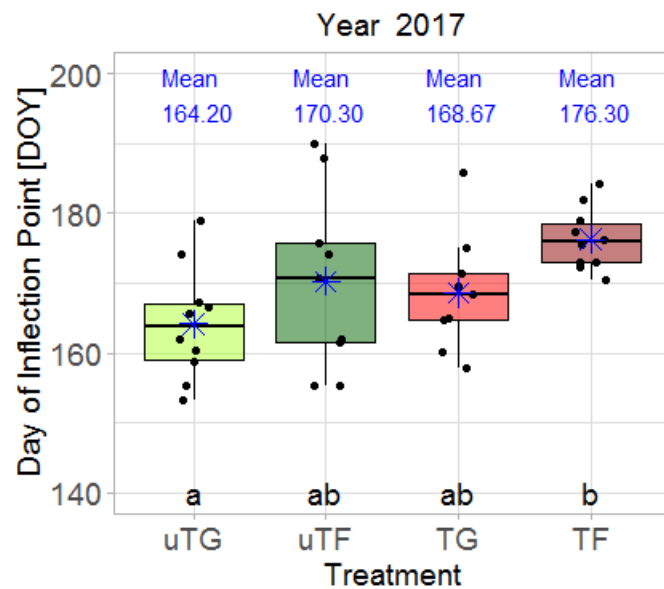
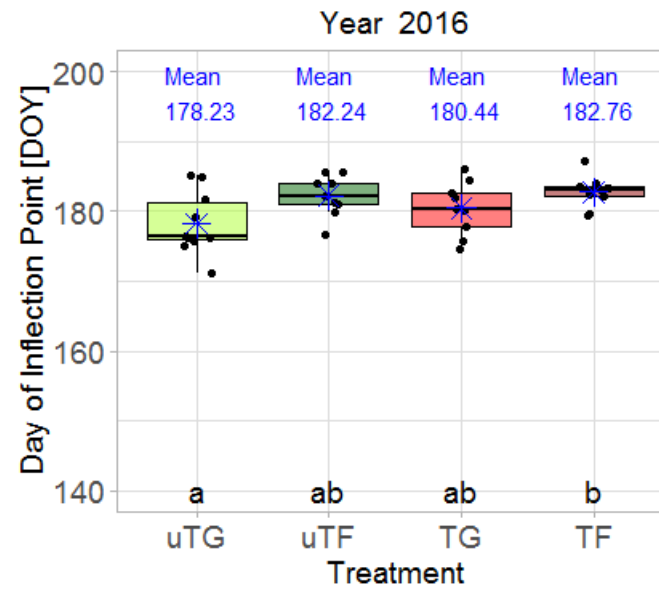
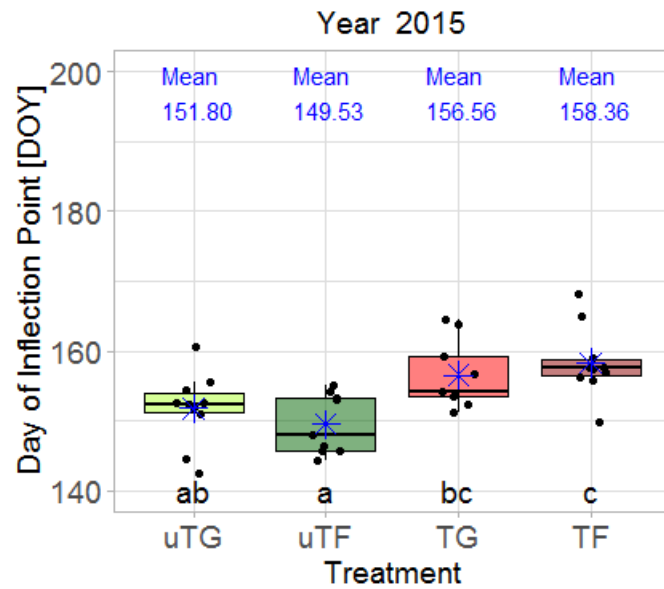
Water Availability

- 2016 > 2017 > 2017 ≥ 2018
- Probably driven by :



Day of inflection point

Differences between treatments by year

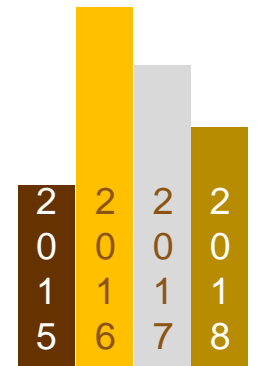


- within a same year the differences for the day of inflection are less than 10 days
- No significant difference between unthinned trees, and between thinned trees
- No difference between uTF and TG except in 2015.

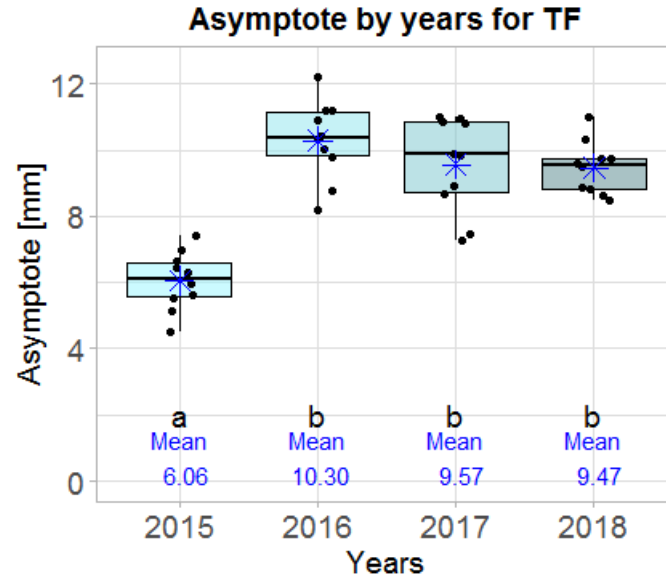
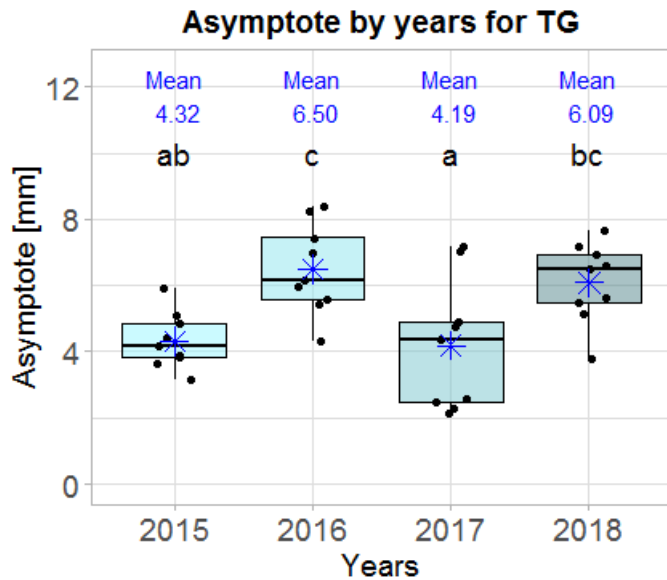
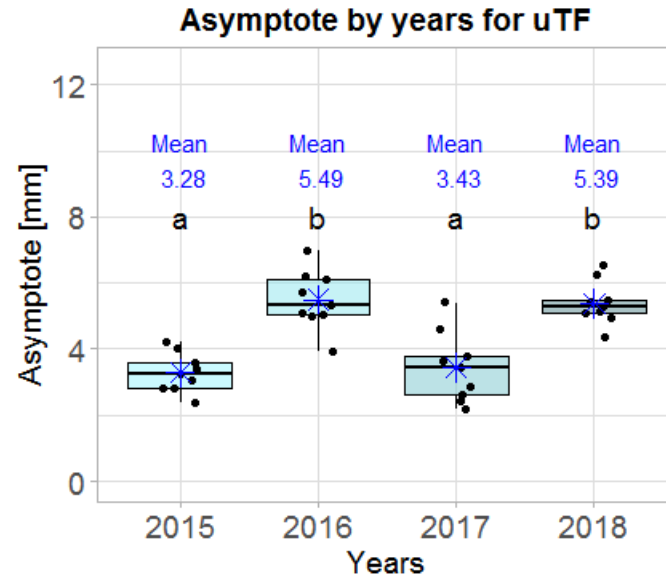
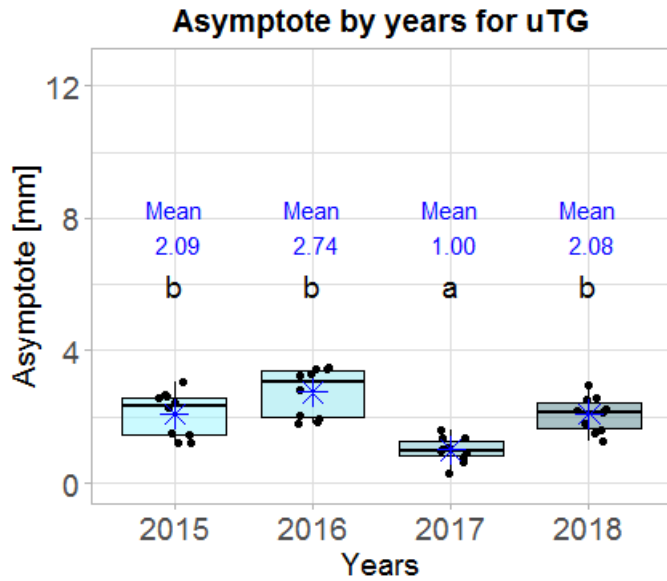
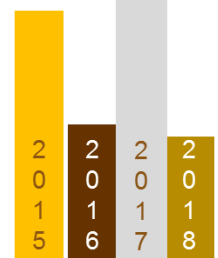
Asymptotic Value

Differences between years by treatment

Water Availability



Windy years



- Range [1;10] mm

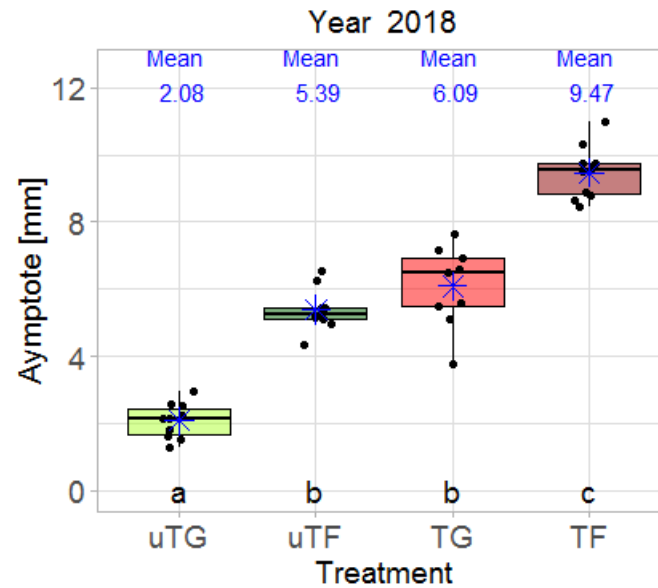
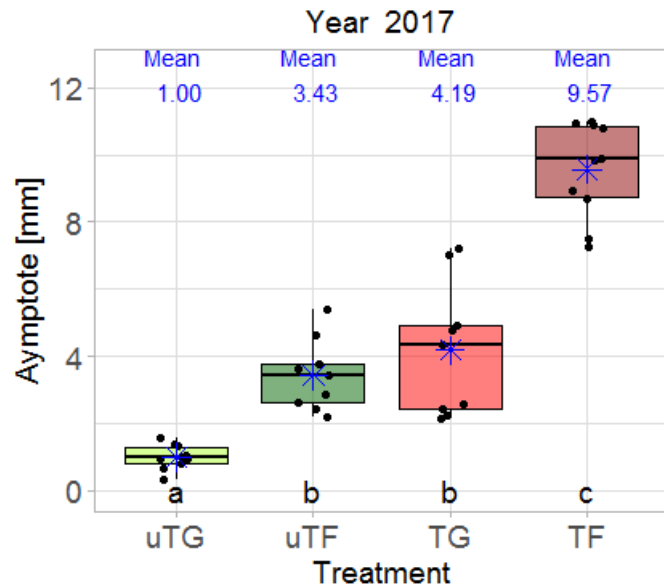
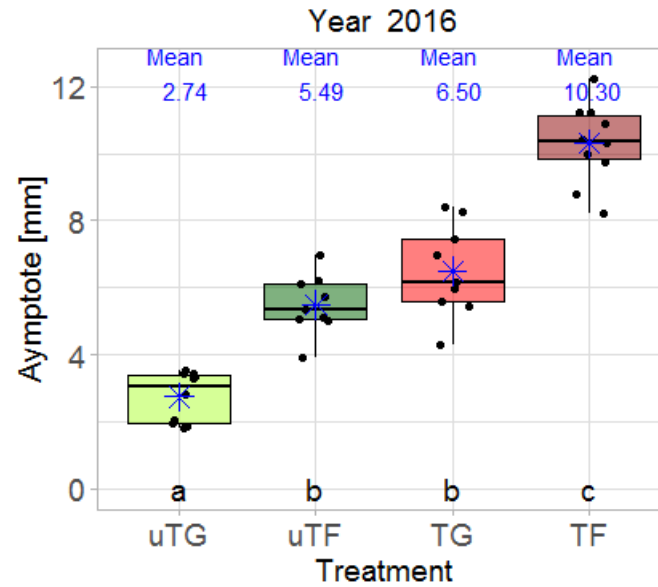
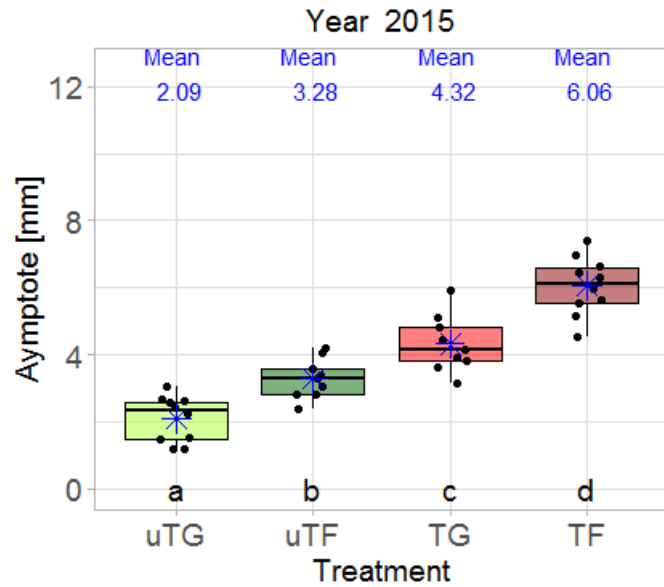
- No similar ranking with

- For TF variation between years is different from others mainly due to a shift to the top for 2017 which doesn't exist for uTF : Thigmomorphogenesis?

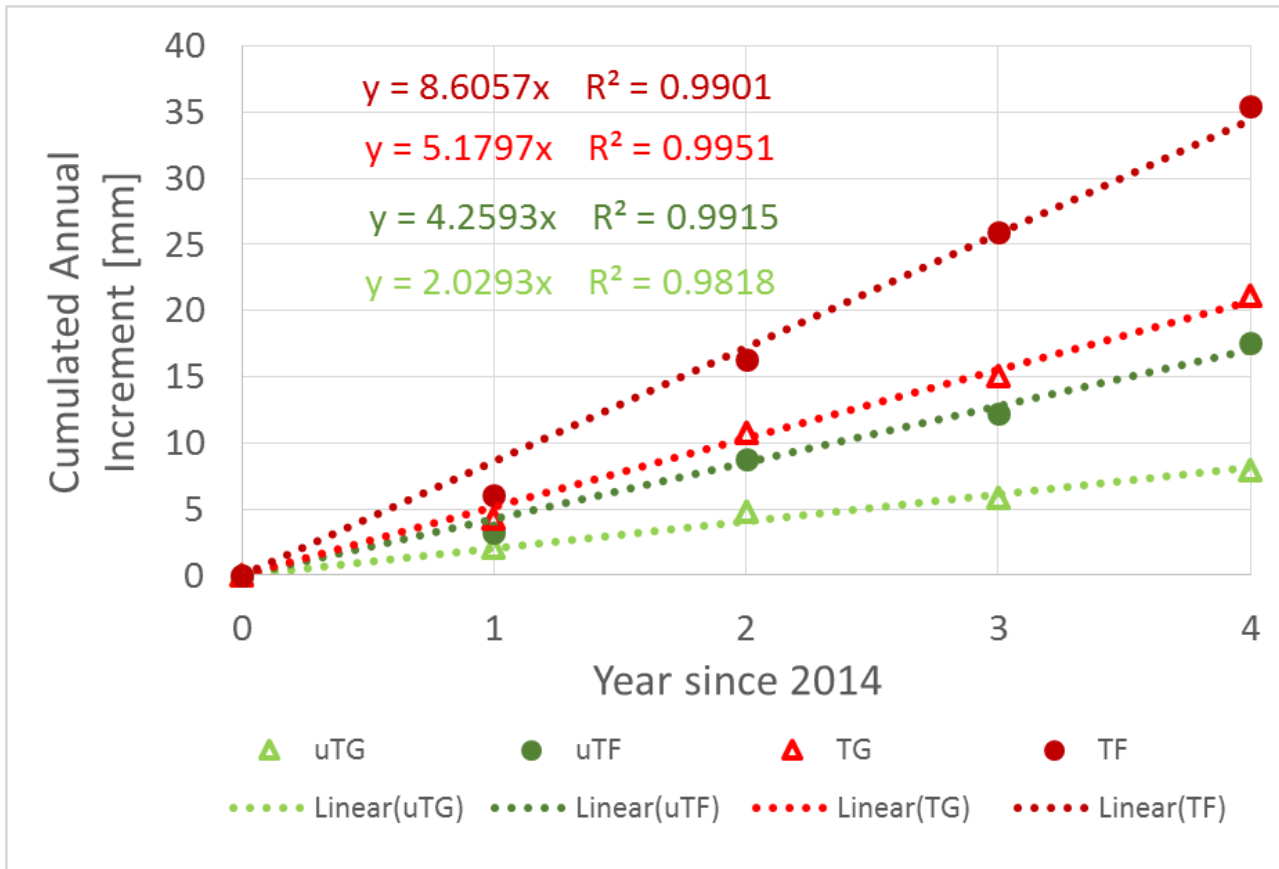
Asymptotic Value

Differences between treatments by year

- TF > TG >= uTF > uTG
- in 2015 significant differences between all treatments
- No differences between uTF and TG for 2016-2017-2018



Comparison of diametral growth rates between treatments



	dD/dt [mm/year]	x Ref _{uTF}
TF	8.6	2.0
TG	5.2	1.2
uTF	4.3	1.0
uTG	2.0	0.5

- Wind plays a major role in the growth response of beech poles to thinning
- Without the mechanical stimuli due to wind, the effect of thinning quasi vanishes
- The growth response in 2015, first year of the experiment, seems different, but this year was drier than the others so it will be difficult to disentangle the effects
- No effect on the height growth was detected
- The strong winds (>50 km/h) regime during the growing period plays a significant role in the regulation of radial growth. To confirm this an analysis of the growth rate at a refined time scale could be possible

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