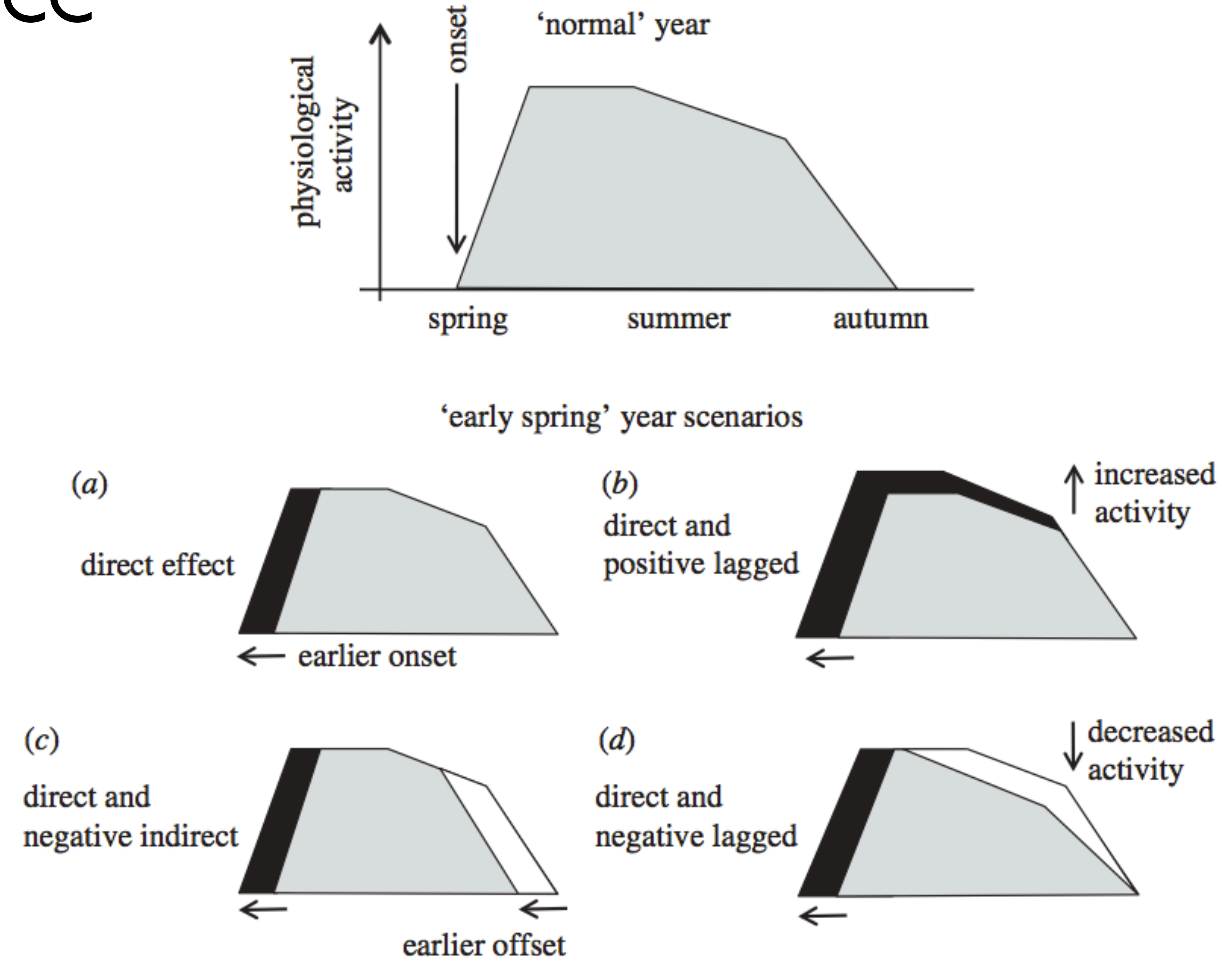
La levée de dormance: Evènement ou processus dynamique intégré aux autres déterminants du débourrement?

Hendrik Davi, Frédéric Jean, François Madon, Julie Gaüzère, Cécile Dantec, Sylvain Delzon, Isabelle Chuine, Marc Bonhomme

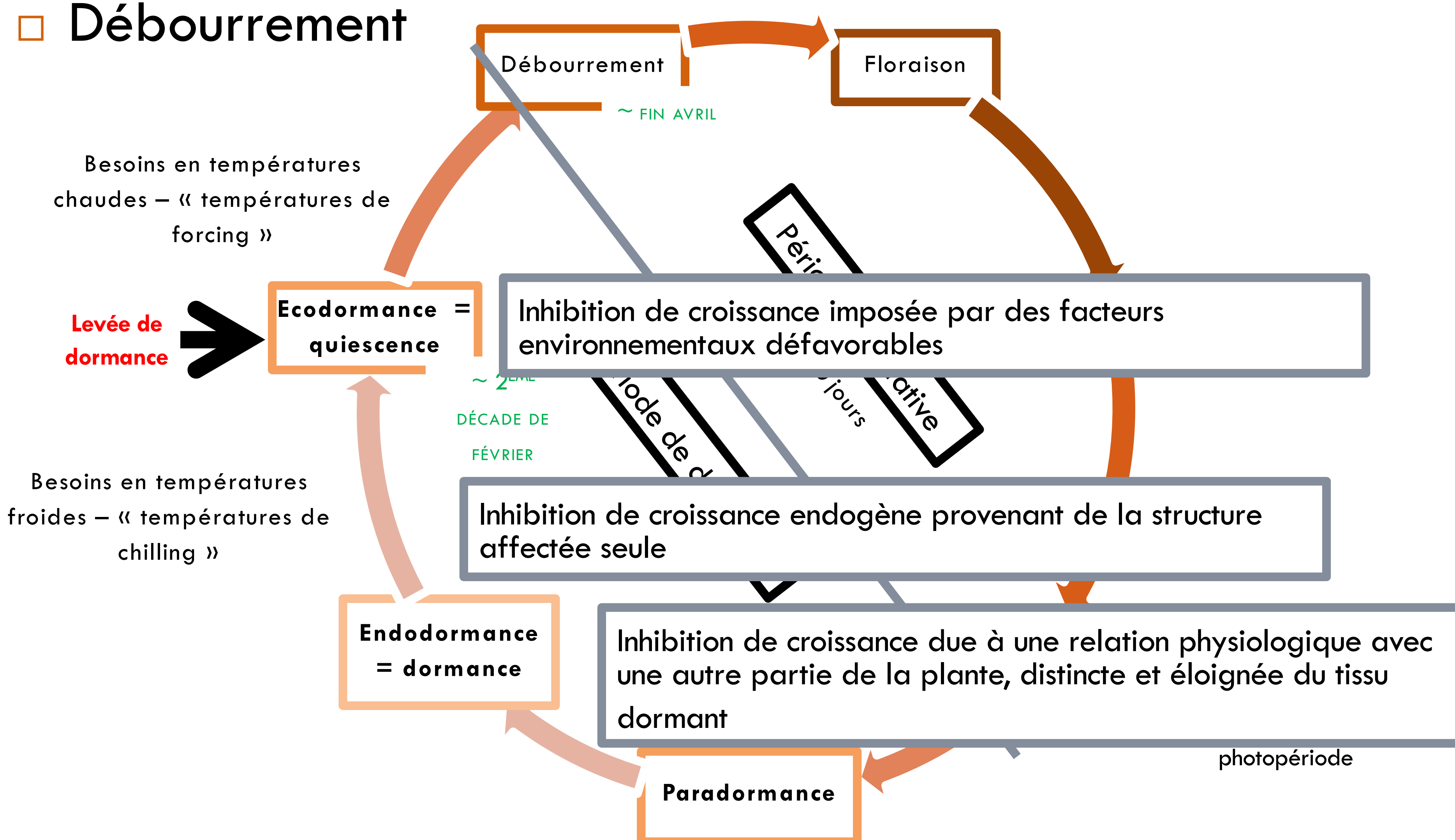
PHENO 2015

- ☐ Phénologie et CC



Richardson et al.,2010 (*Phil. Trans. R. Soc. B*)

□ Débourrement

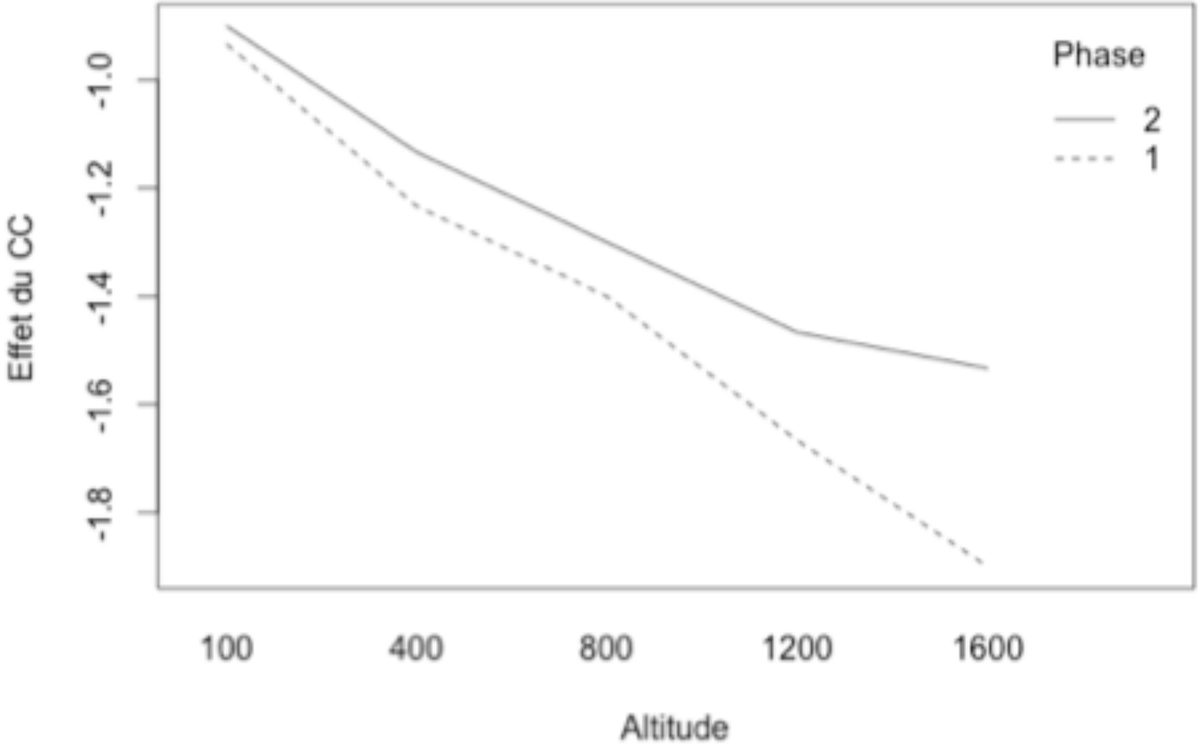


Inhibition de croissance imposée par des facteurs environnementaux défavorables

Inhibition de croissance endogène provenant de la structure affectée seule

Inhibition de croissance due à une relation physiologique avec une autre partie de la plante, distincte et éloignée du tissu dormant

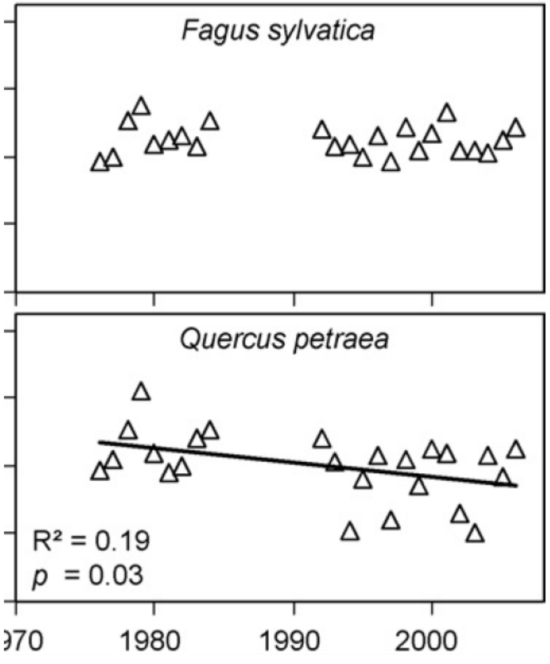
Comparaison des modèles 1 Phase et 2 phases sur la précocité du débourrement entre 2000 et 2100 (jour/décade).



Vitasse et al., 2011
Fagus, Quercus, Abies

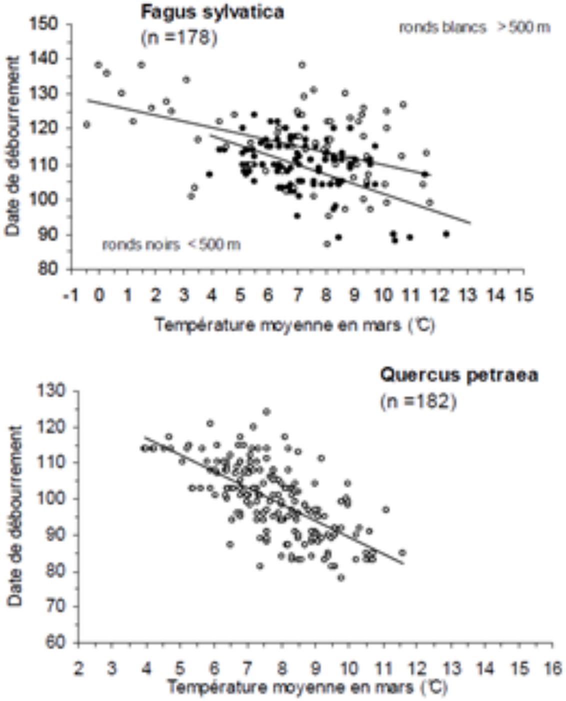
Le débourrement du Hêtre

Faible variation temporelle



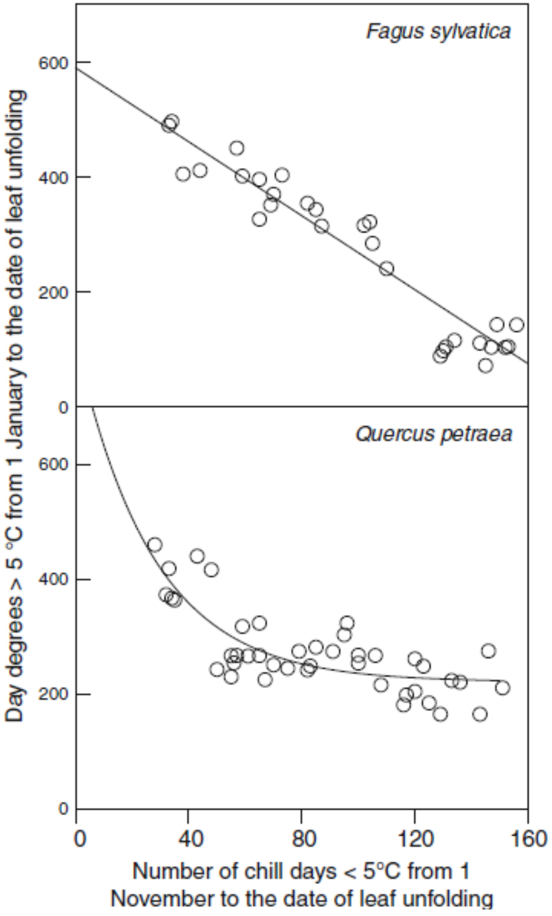
Vitasse et al., 2009

Moindre plasticité



Lebourgeois et al., 2008

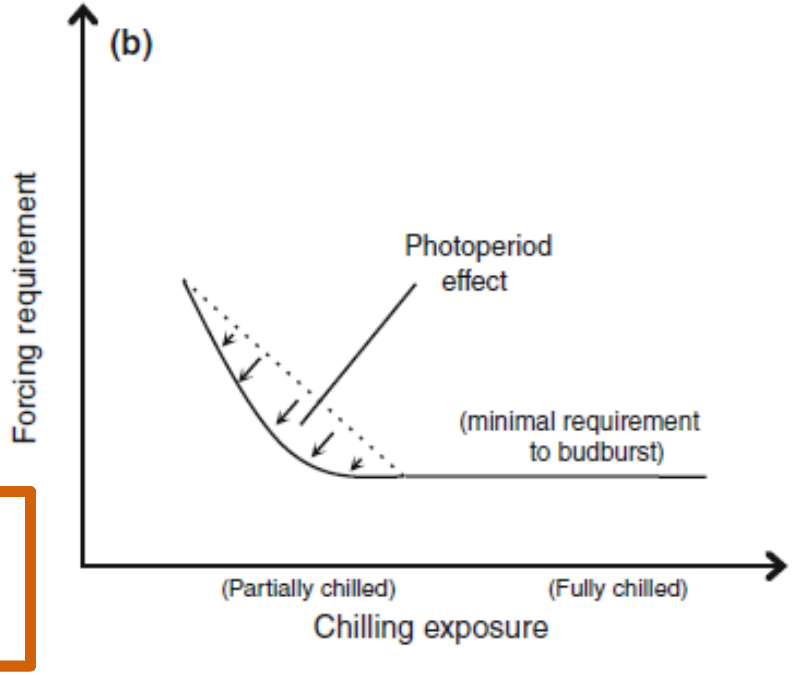
Rôle de la dormance



Le débourrement du Hêtre: le rôle de la photopériode

- (a) Effet d'un seuil photopériodique dans le cas de T° printanières anormalement élevées

- (b) Effet de l'allongement de la photopériode lorsque la levée de dormance est tardive

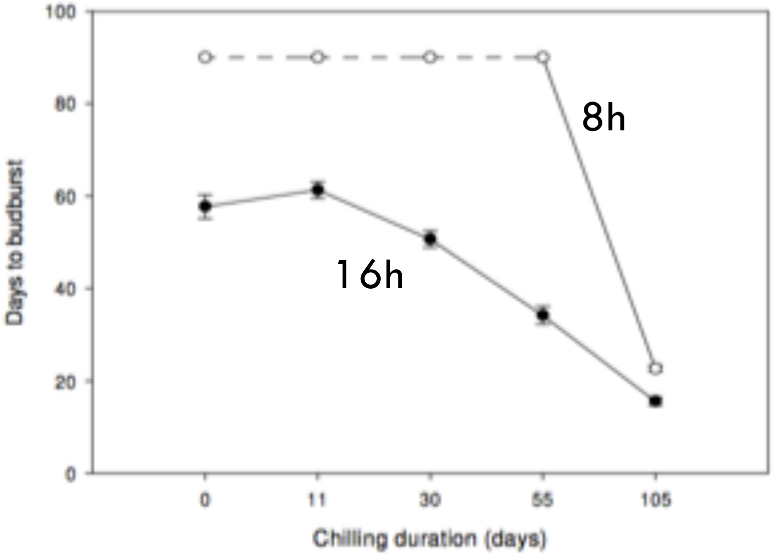


SCHEMA CONCEPTUEL SUR LE ROLE HYPOTHETIQUE DE LA PHOTOPERIODE SUR LES BESOINS EN FORCING DANS LA PHENOLOGIE DU DEBOURREMENT CHEZ LE HETRE COMMUN.

SOURCE : VITASSE ET BASLER, 2013

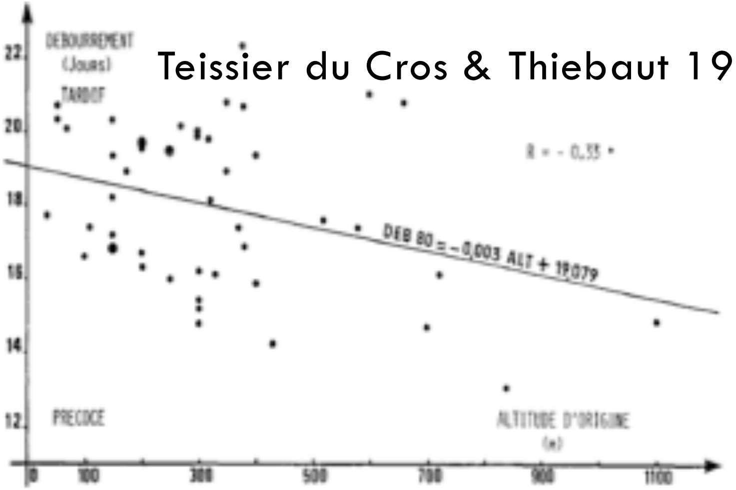
Le débourrement du Hêtre: photopériode et dormance

Laube et al., 2014

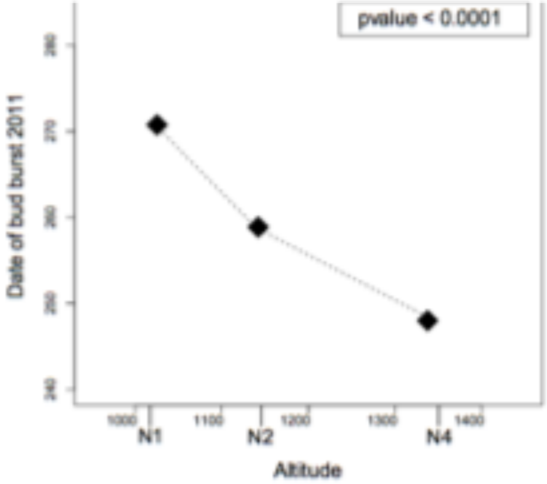


Caffarra 2007

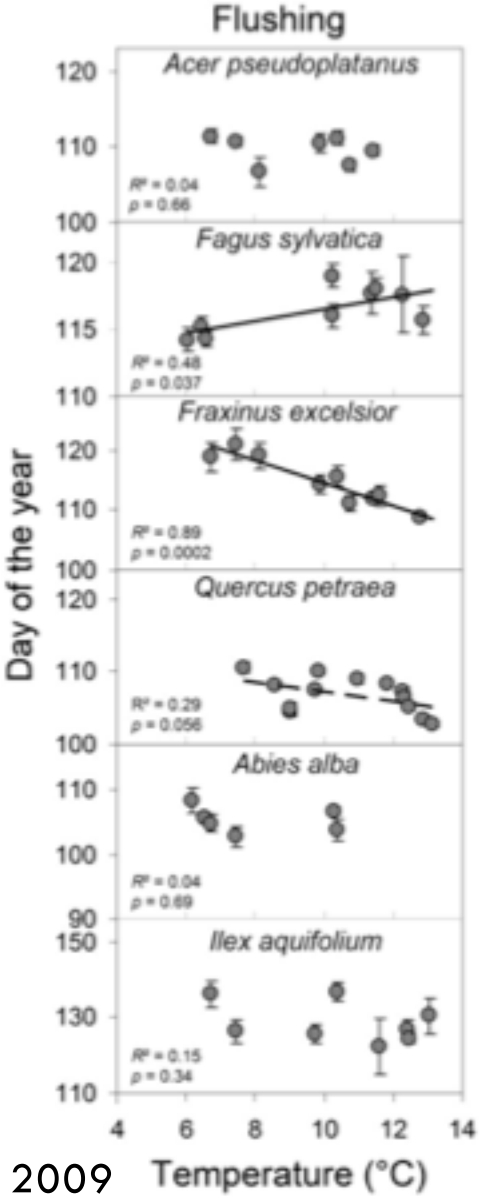
Le débourrement du Hêtre: Un contre-gradient génétique



Teissier du Cros & Thiebaut 1988



Gaüzere 2013



Vitasse et al., 2009

1. Comment la photopériode intéragit avec la levée de dormance?
2. Quels sont les seuils de photopériode et de quantité de froid? Quelle est à la nature du processus de levée de dormance?
3. Est ce que les effets conjugués de la dormance et photopériode expliquent la faible plasticité du Hêtre dans le temps et l'espace?
4. Quels processus expliquent le contre-gradient génétique?

Site d'étude	**Niveaux altitudinaux (nom, lieu-dit)**	**Altitude (m)**	**Données disponibles**	
			Levée de dormance	**Débourrement**
Mont Ventoux	N1	900	2012-2015	2012-2014
	N2	1100	2011-2015	2008-2015
	N4	1400		2008 et 2010-2015
Vallée des Gaves	Laveyron	150	2011	2005-2007 et 2009-2012
	Barèges	1650		
Clermont-Ferrand	Fontfreyde	925	2008-2011	2008-2014
	La Prairie	875	2012-2014	

NIVEAUX ALTITUDINAUX ET DONNEES DISPONIBLES DES DIFFERENTS SITES D'ETUDE

Comment détermine-t-on la date de levée de dormance ?

Prélèvement de novembre à mars de rameaux de hêtre

Recoupe des rameaux dans l’eau pour éviter l’embolie des vaisseaux conducteurs

Rassemblement dans un contenant unique des rameaux d’un même arbre

Identification précise de chaque échantillon prélevé

Suivi du débourrement de chaque rameau en chambre climatique (23°C 16 h de lumière)

Résultats observés en 2012 sur le site atelier du Mont Ventoux (84)

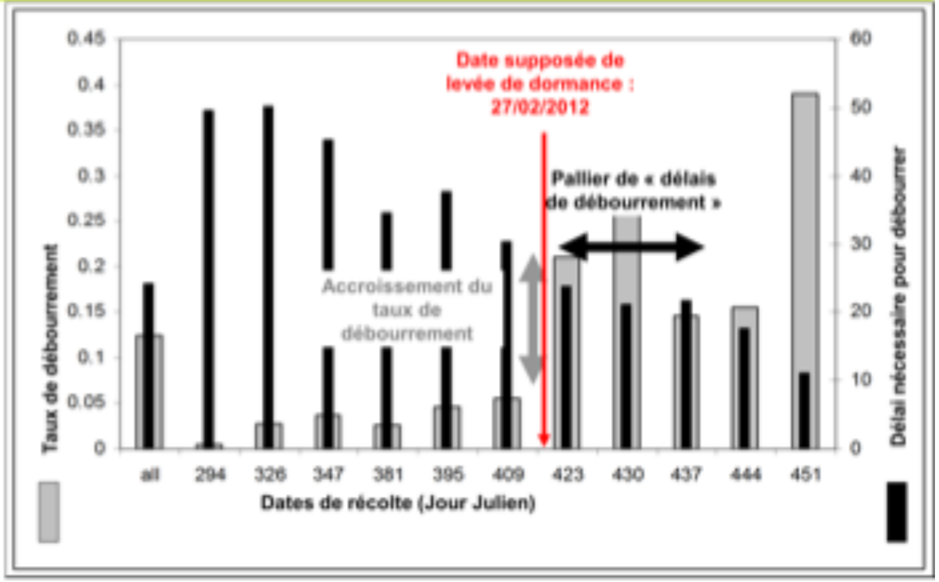
Détermination de la date supposée de levée de dormance par :

- l’accroissement du taux de débourrement

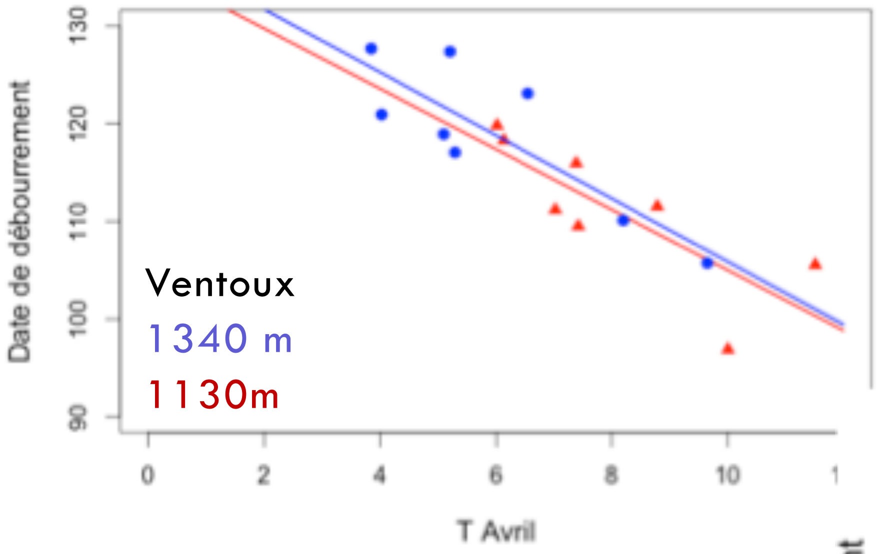
et

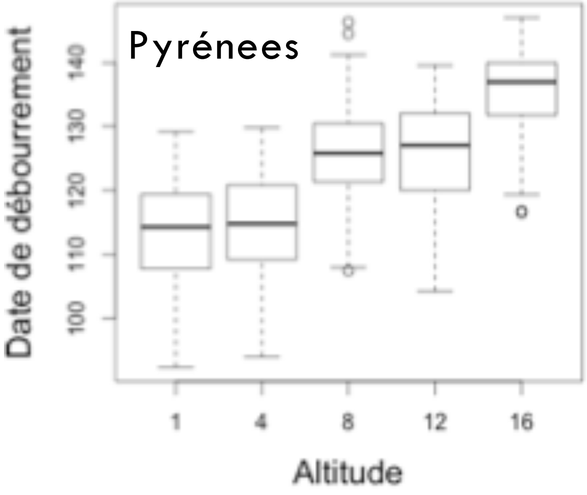
- la diminution du délais moyen de débourrement se stabilisant autour d’un premier pallier

en conditions optimales de croissance



Date de débourrement en fonction des températures d'Avril

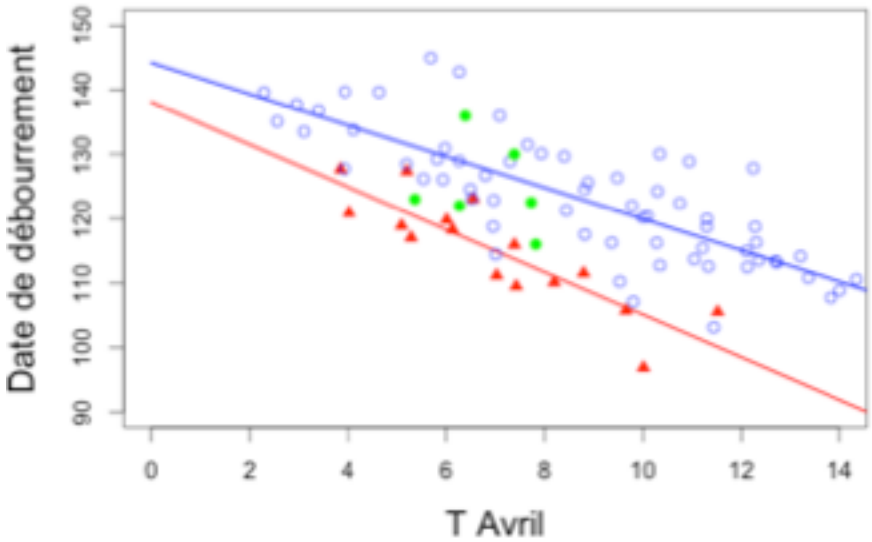




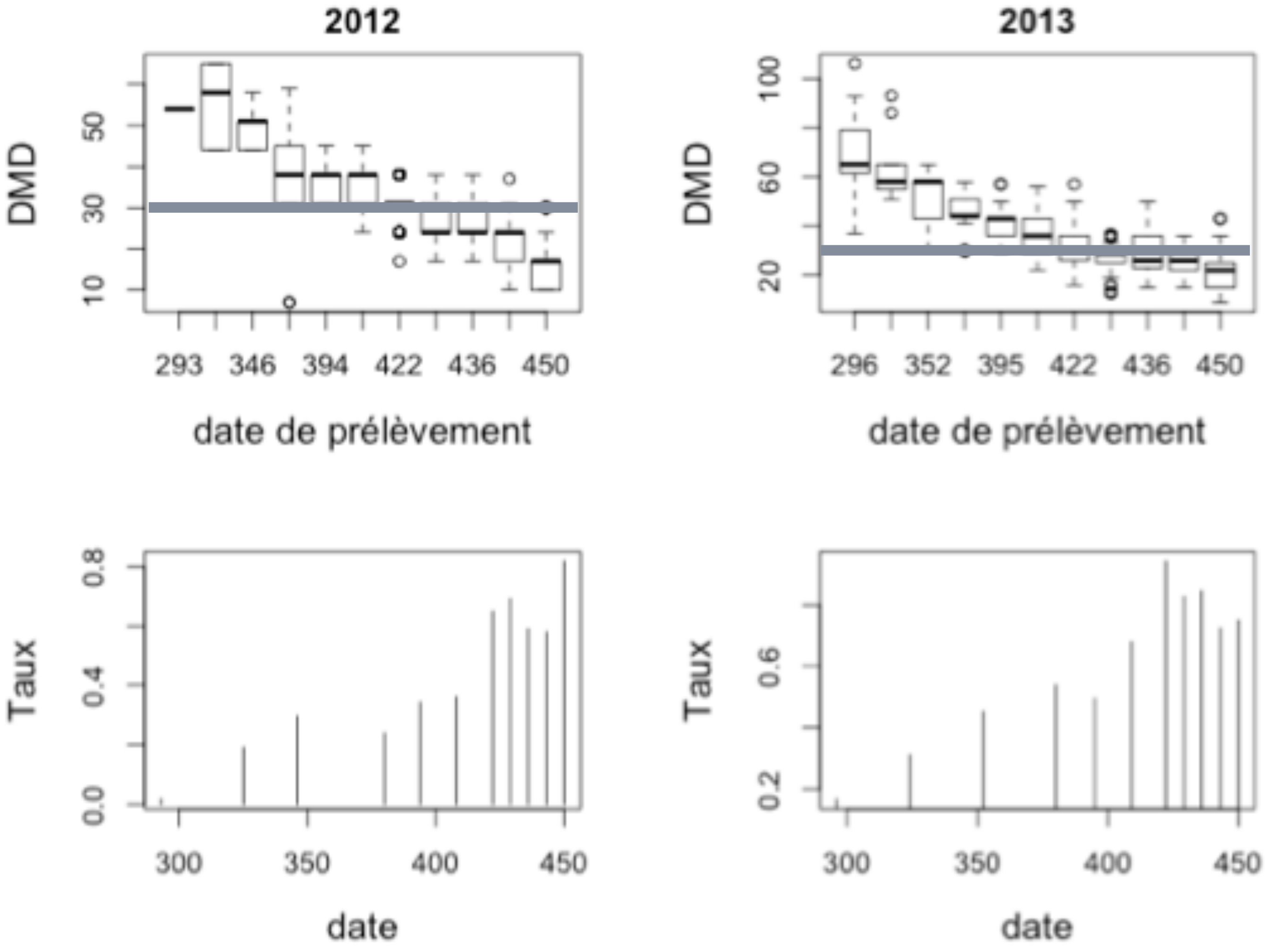
Ventoux

Massif Central

Pyrénees

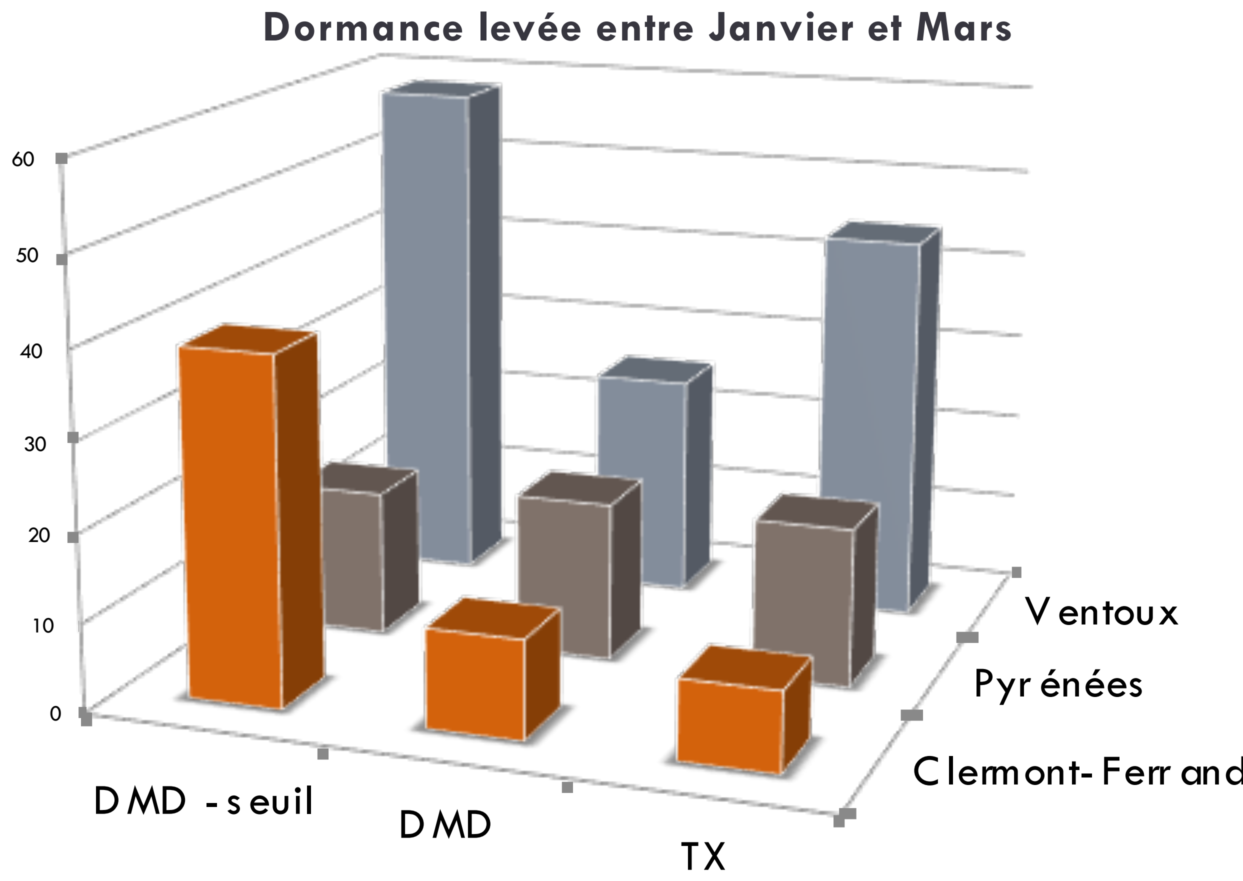


Dynamique de levée de dormance



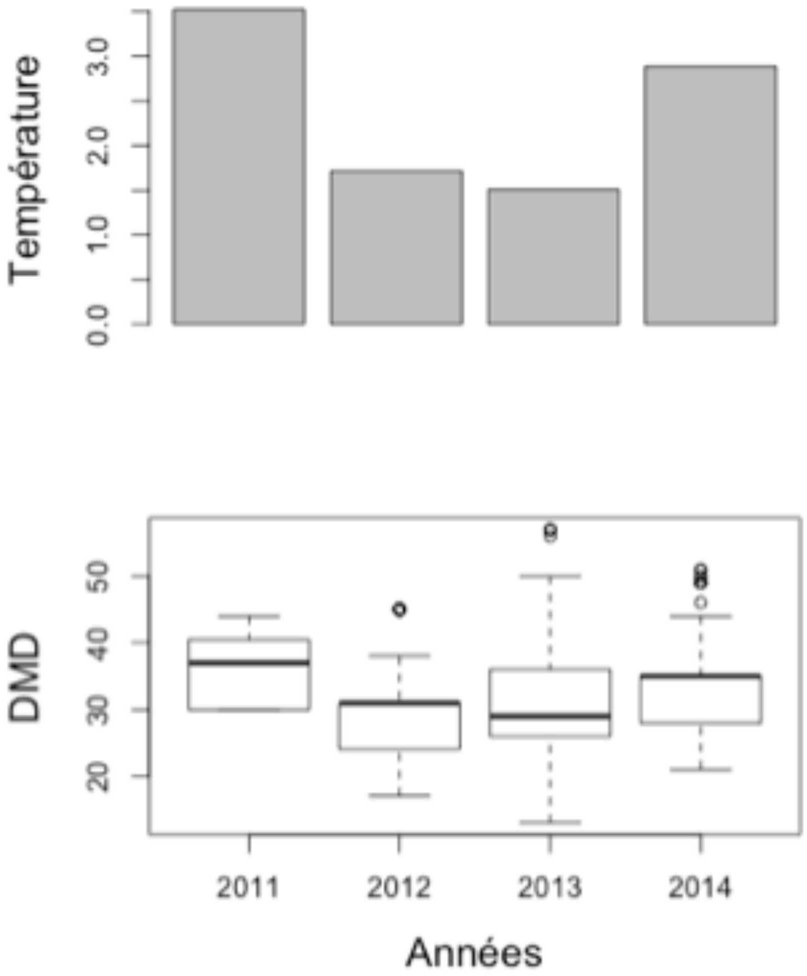
Différentes méthodes => différents résultats

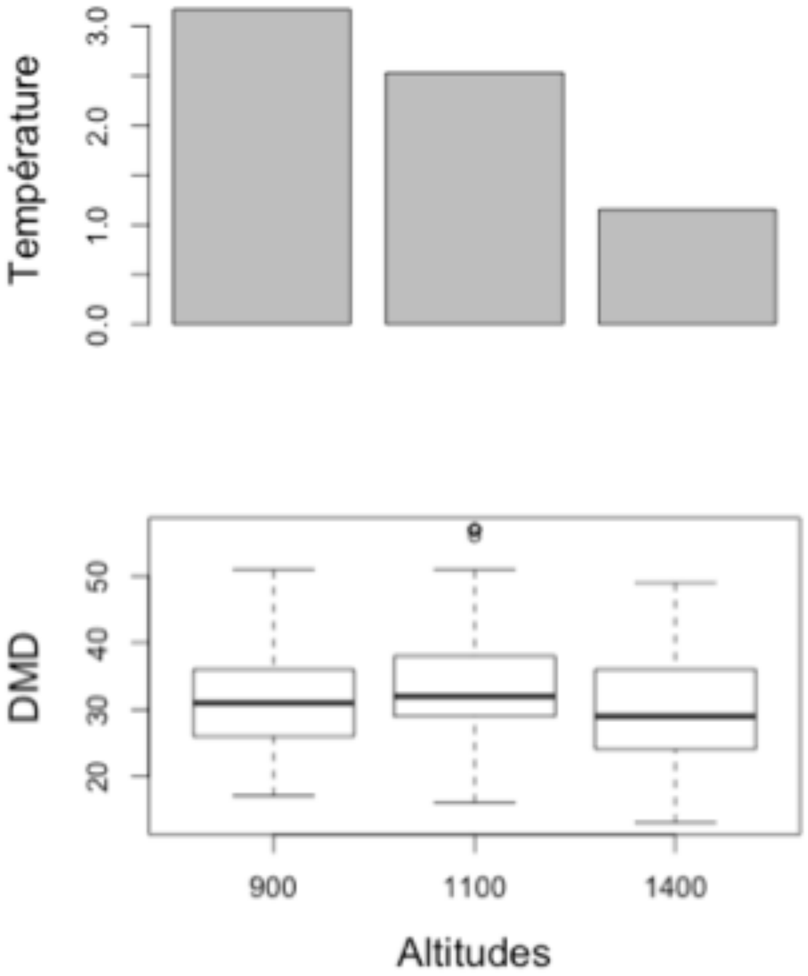
Site	Températures Hiver
Ventoux	1.84°C
Pyrénées	2.55°C
Massif Central	2.02°C



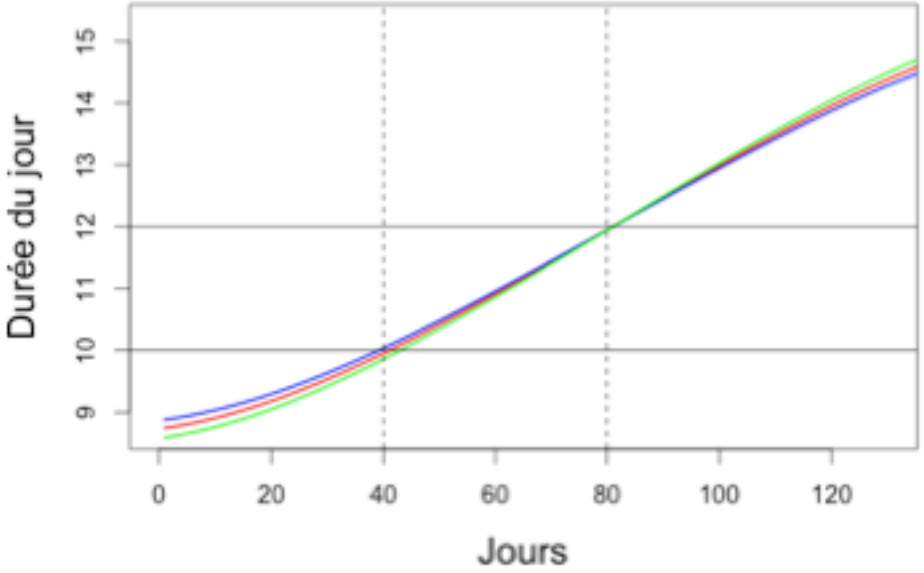
DATES DE LEVEE DE DORMANCE SELON LA METHODE DE DETERMINATION ET LES DIFFERENTS SITES

Effet année et altitude sur la DMD

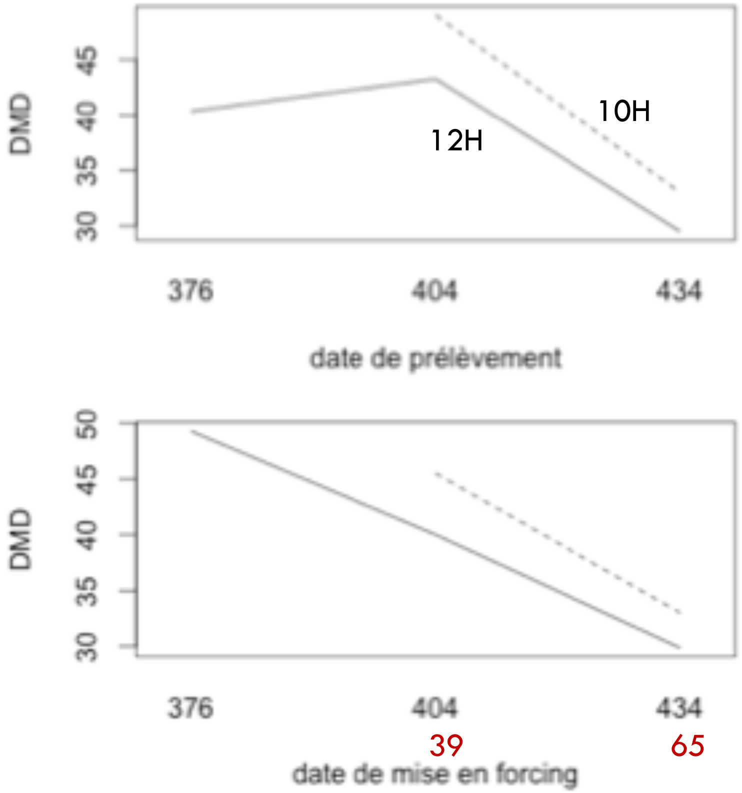




Rôle de la photopériode



Même contrainte de photopériode sur les 3 sites



Accumulation de froid plus d'effet à 12h de photopériode

Principales conclusions

- Débourrement majoritairement expliqué par les températures printanières
- Différences de forcing et de levée de dormance entre sites non expliquées par le froid ou la photopériode
- Validation du schéma de Vitasse et Bassler 2012
- Remise en cause de la notion de « sortie de dormance »
- Modèle dynamique prenant en compte l'effet photopériodique

Différentes méthodes => différents résultats

- Perspectives
  - Prolonger l'étape de modélisation par la simulation du débourrement
  - Effectuer des simulations sur le long terme
  - Vérifier les hypothèses photopériodiques en chambres expérimentales
  - Modéliser les jeux de données RENECOFOR afin d'observer l'effet photopériodique
  - La régulation thermo-photopériodique permet d'éviter le « scénario catastrophe » du réchauffement climatique

Vitasse & Körner 2012

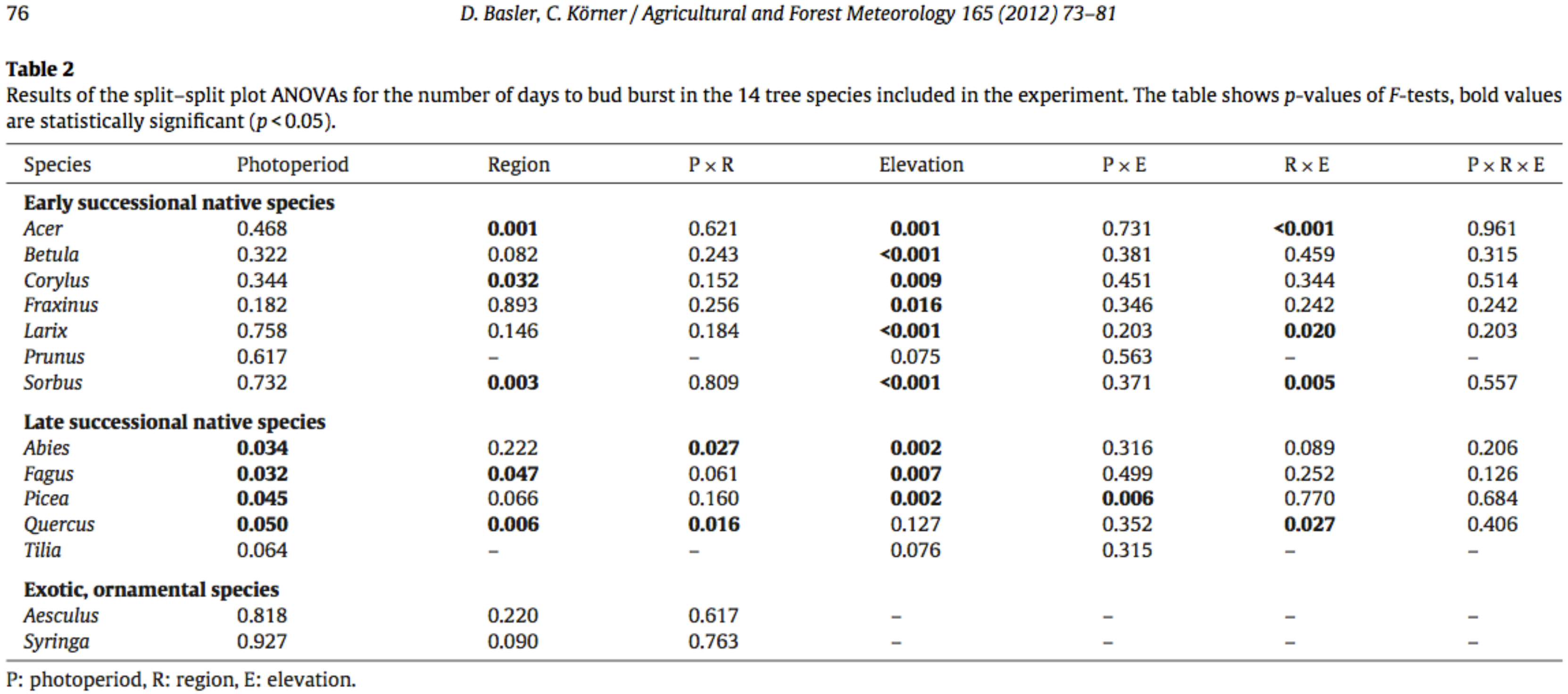


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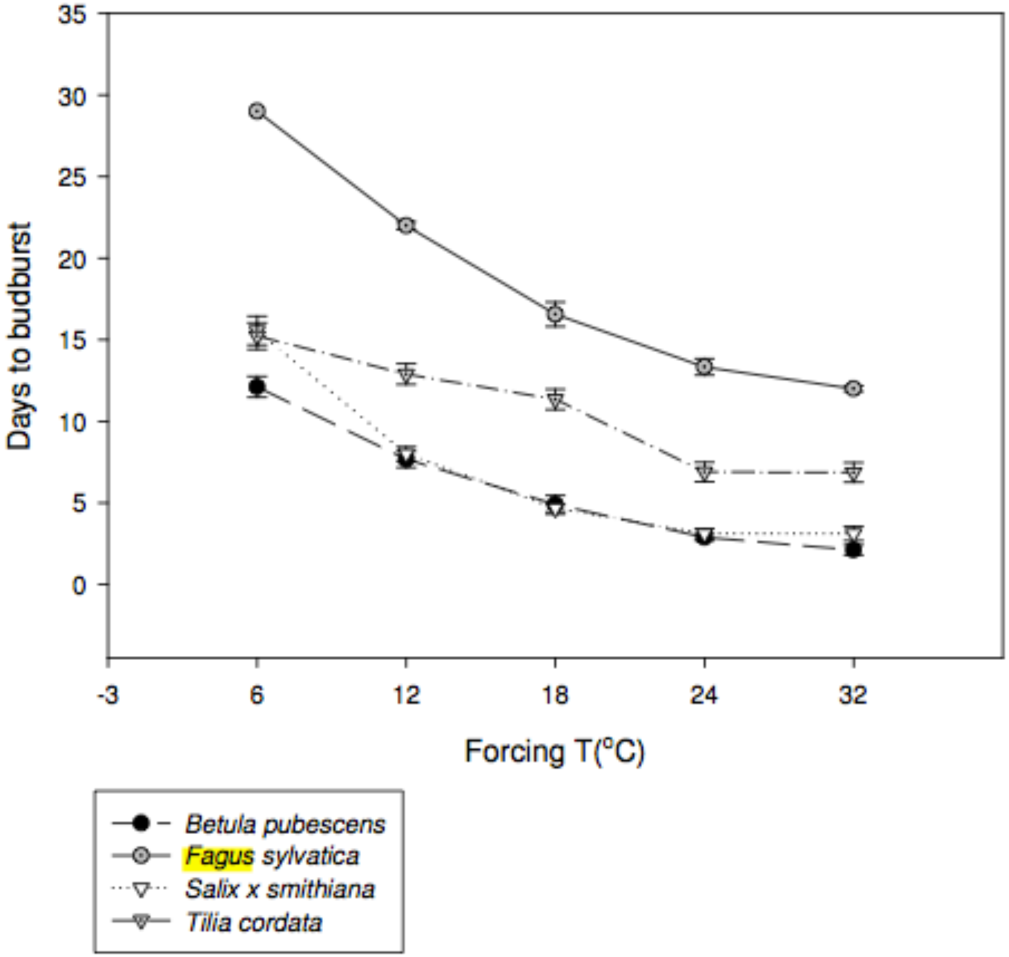
Table 2
Results of the split–split plot ANOVAs for the number of days to bud burst in the 14 tree species included in the experiment. The table shows *p*-values of *F*-tests, bold values are statistically significant ($p < 0.05$).

Species	Photoperiod	Region	P × R	Elevation	P × E	R × E	P × R × E
Early successional native species							
Acer	0.468	**0.001**	0.621	**0.001**	0.731	**<0.001**	0.961
Betula	0.322	0.082	0.243	**<0.001**	0.381	0.459	0.315
Corylus	0.344	**0.032**	0.152	**0.009**	0.451	0.344	0.514
Fraxinus	0.182	0.893	0.256	**0.016**	0.346	0.242	0.242
Larix	0.758	0.146	0.184	**<0.001**	0.203	**0.020**	0.203
Prunus	0.617	–	–	0.075	0.563	–	–
Sorbus	0.732	**0.003**	0.809	**<0.001**	0.371	**0.005**	0.557
Late successional native species							
Abies	**0.034**	0.222	**0.027**	**0.002**	0.316	0.089	0.206
Fagus	**0.032**	**0.047**	0.061	**0.007**	0.499	0.252	0.126
Picea	**0.045**	0.066	0.160	**0.002**	**0.006**	0.770	0.684
Quercus	**0.050**	**0.006**	**0.016**	0.127	0.352	**0.027**	0.406
Tilia	0.064	–	–	0.076	0.315	–	–
Exotic, ornamental species							
Aesculus	0.818	0.220	0.617	–	–	–	–
Syringa	0.927	0.090	0.763	–	–	–	–

P: photoperiod, R: region, E: elevation.

Thesis Amelia



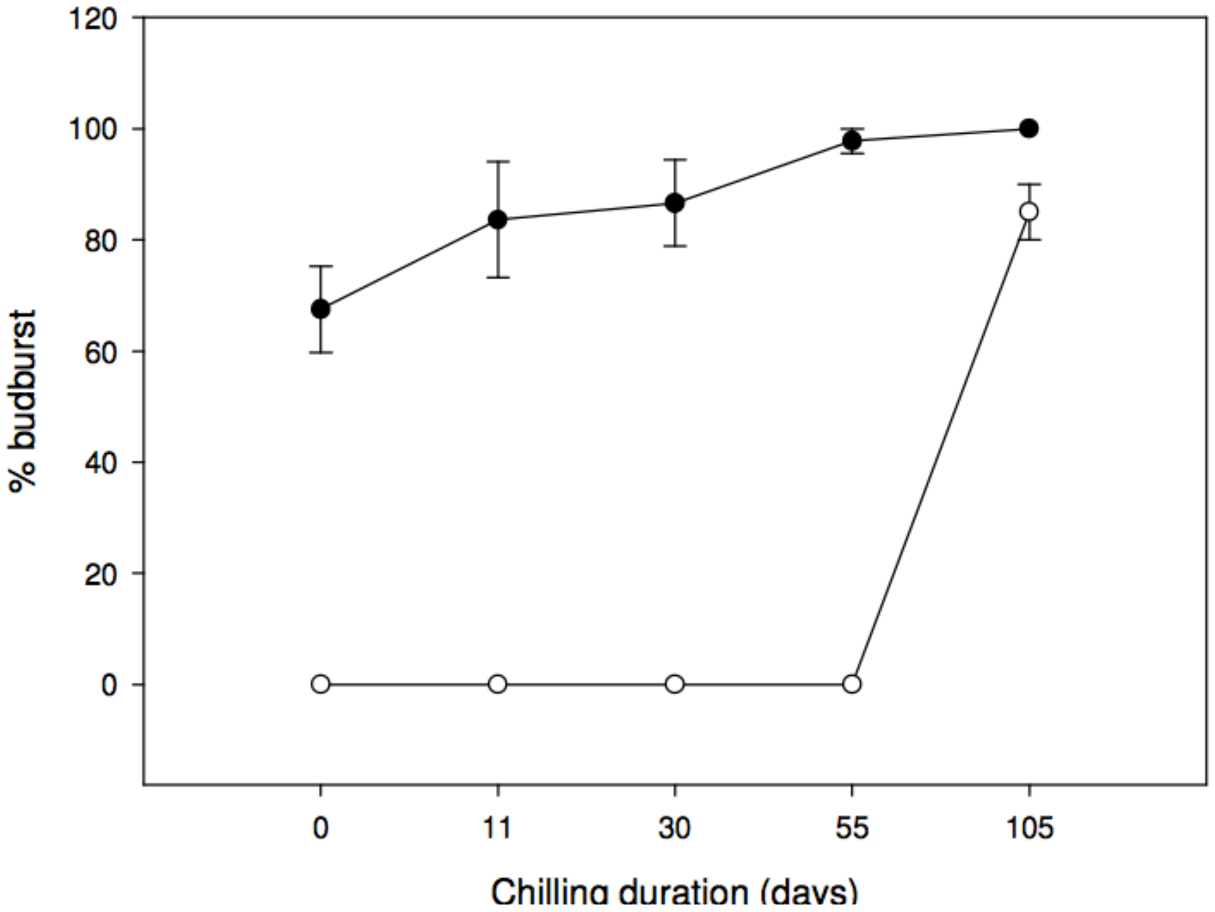
Thesis Amelia

- *Fagus sylvatica* is influenced by a light dominant mechanism for the prevention of dormancy (the day must be long rather than the night short), and by a night dominant mechanism for the breaking of dormancy (the night must be short rather than the day long) (Thomas and Vince Prue, 1997).
- Photoperiod has been found to interact with temperature in the resumption of growth. Some species like *Fagus sylvatica* require LD for budburst after chilling has been fulfilled (Heide, 1993b).

Thesis Amelia

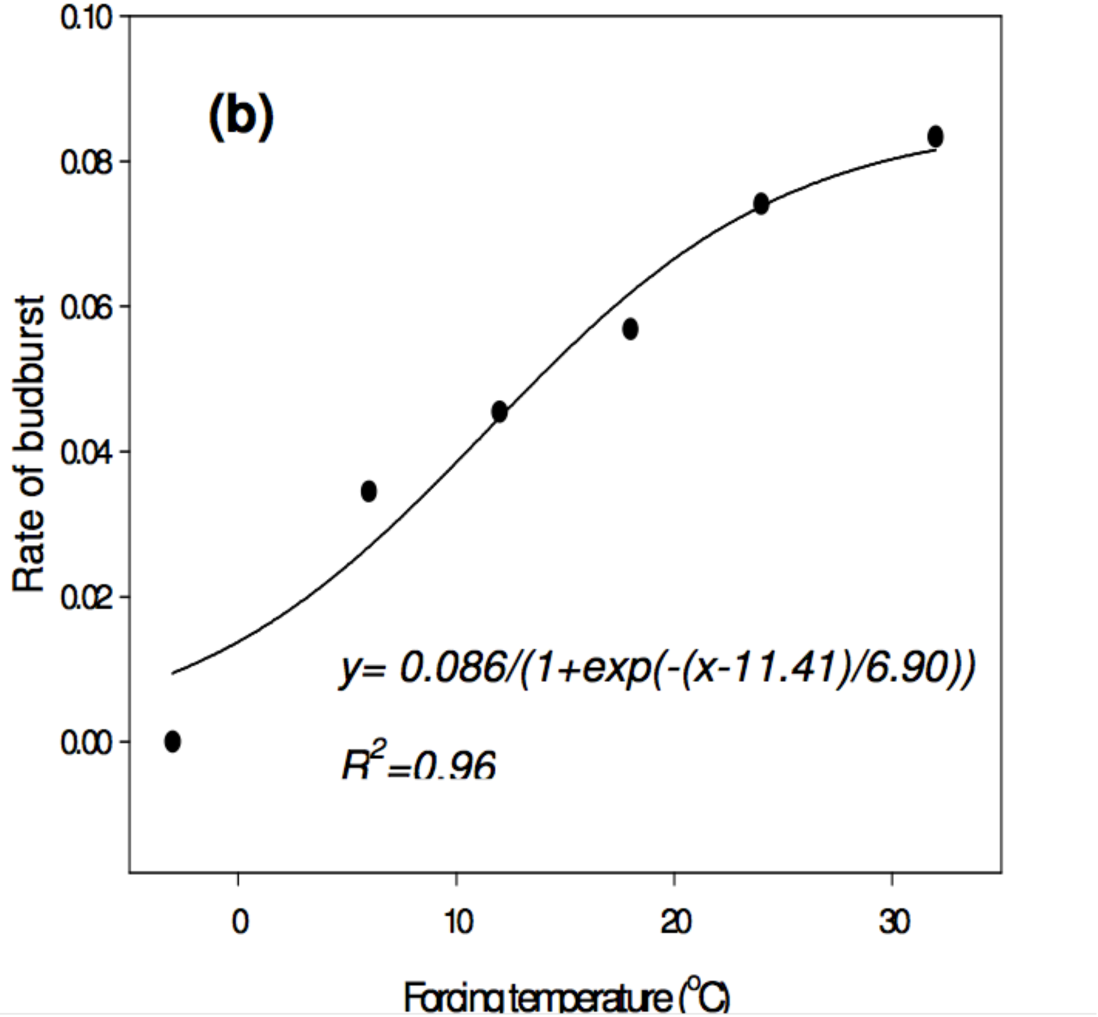
- Forcing photoperiod had a significant effect on both percentage budburst and timing of budburst (*P-values* <0.01) (Table 9). In experiment 3.a, LD forcing conditions triggered budburst in unchilled plants and plants that had received 11, 30, 55 and 105 days of chilling, while SD forcing triggered budburst only in plants receiving the longest chilling duration (105 days). These effects were confirmed by the significance of the main effect of forcing photoperiod on percentage budburst ($P<0.001$) (Table 9) and by the significance of the interaction between chilling duration and forcing photoperiod on percentage budburst (the LD-triggered increase in percentage budburst was smaller after 105 days of chilling than after shorter chilling durations) ($P<0.001$) (Table 9). These effects can be seen in Figure 23.b, showing percentage budburst in relation to chilling duration for both SD an LD forced plants. As for timing of budburst, it was not possible to test any interactions between forcing photoperiod and chilling duration, as in only one out of five chilling durations budburst occurred in both SD and LD forcing treatments. However, the ANOVA for main effects indicated that photoperiod had a significant effect on the timing of budburst ($P=0.001$) (Table 9). In fact, even after 105 days of chilling, LD forcing advanced the mean time to budburst from 22.7 to 15.6 days compared with SD forcing (Figure 23.b).

Thesis Amelia



Close 16h open 8h

Thesis Amelia



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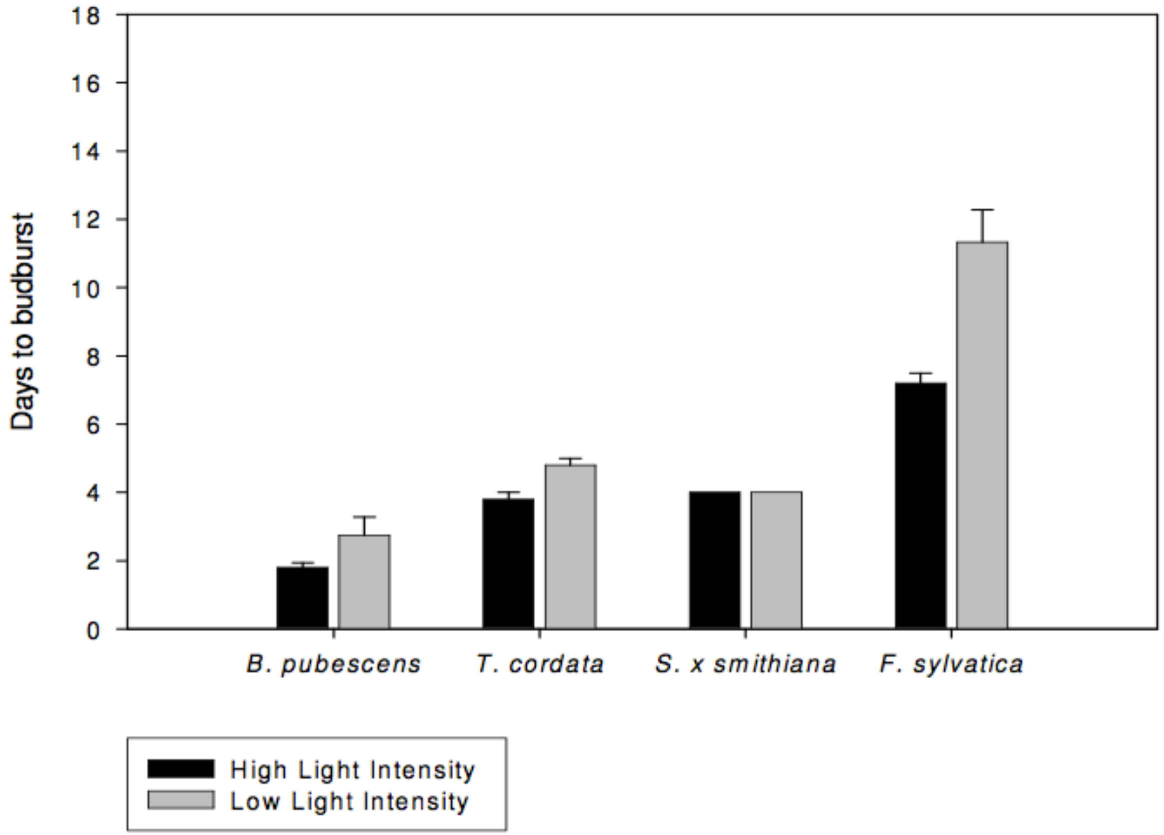


Thesis Amelia

- Beech has been demonstrated to be very sensitive to photoperiod by studies testing its response to LD exposure at various stages of chilling (Wareing, 1953; Heide, 1993). Wareing (1953) showed that unchilled beech seedlings were able to burst in October when exposed to continuous light. He found the same response in beech that had been chilled outdoor until March, and concluded that the only requirement for beech budburst was a long photoperiod (Wareing, 1953). Falusi and Calamassi conducted a similar experiment, exposing chilled and unchilled beeches to two different photoperiods, 9 h and 13 h (1990). The absence of significant differences between the two photoperiod treatments lead them to conclude that the dormancy releasing effect of photoperiod is negligible when compared to the effect of winter chilling (Falusi and Calamassi, 1990).

Thesis Amelia

- Heide (1993), against the background of these conflicting results, systematically tested the daylength requirements of beech buds exposed to various degrees of chilling throughout the fall and the winter. He found that beech twigs sampled from outdoor trees at various stages of winter chilling responded to LD only in October, prior to chilling, and in January, after receiving outdoor chilling for a couple of months (Heide, 1993). On the other hand, twigs exposed to SD never showed percentages of budburst >40%, even after extensive chilling lasting until mid March. He concluded that twigs sampled in October respond to photoperiod because they are in a state of “predormancy”, and that both chilling and long photoperiod are required for dormancy release (Heide, 1993).

Thesis Amelia

- The results reported here are in contrast with the conclusions of Heide (1993). It was found that beech exposed to LD after various durations of artificial chilling (in the dark at 3oC) were always able to flush provided that they received LD for a long enough period. LD forced plants in experiment 3.a (effect of chilling duration and photoperiod) that had received 0 and 11 days of chilling flushed after an average of 58 and 61 days respectively.

Thesis Amelia

- This suggests a strong photoperiodic response of beech to photoperiod that, at least in this study, was able to override the metabolic constraints imposed by dormancy without requiring extensive chilling. In fact, even accepting that the minimum temperature received by the plants during dormancy induction (12oC) is included in the range of active chilling temperature for beech, the number of days with average daily temperatures equal or close to 12oC received during this period was minimal and not comparable to the extensive chilling requirements described for beech by Murray *et al*. (1989).

Thesis Amelia

- In addition, we found that beech exposed to SD was able to flush after receiving 105 days of artificial chilling, in contrast to the conclusion of Heide (1993) that beech has an LD requirement for budburst. Even though budburst was delayed when compared to LD forced plants, budburst percentage in SD forced plants was quite high (85%), implying that dormancy release was complete. The finding that beech does not necessarily require LD for budburst was further supported by the casual observation that potted cloned beeches left in the cold room at 6-8oC in the darkess, flushed in July after 6 months of chilling in the dark.

Thesis Amelia

- The contrast between our findings and those of Heide (1993) could be due to the fact that while he tested cut twigs we used whole plants. The problem with cut twigs is that, as Heide (1993) pointed out, they quickly use up their carbohydrate reserves and thus cannot be monitored reliably for long periods. For this reason, Heide (1993) terminated his experiments after 50 days from the transfer into forcing conditions. However, our unchilled and slightly chilled (11 days) plants flushed after about 60 days, while the plants that had received 30 days of chilling flushed after about 51 days, which is longer than the duration of the forcing treatment in the experiments of Heide (1993) which suggests that he might have missed the late flushing of the beech buds due to the rapid decay of the twigs.

Thesis Amelia

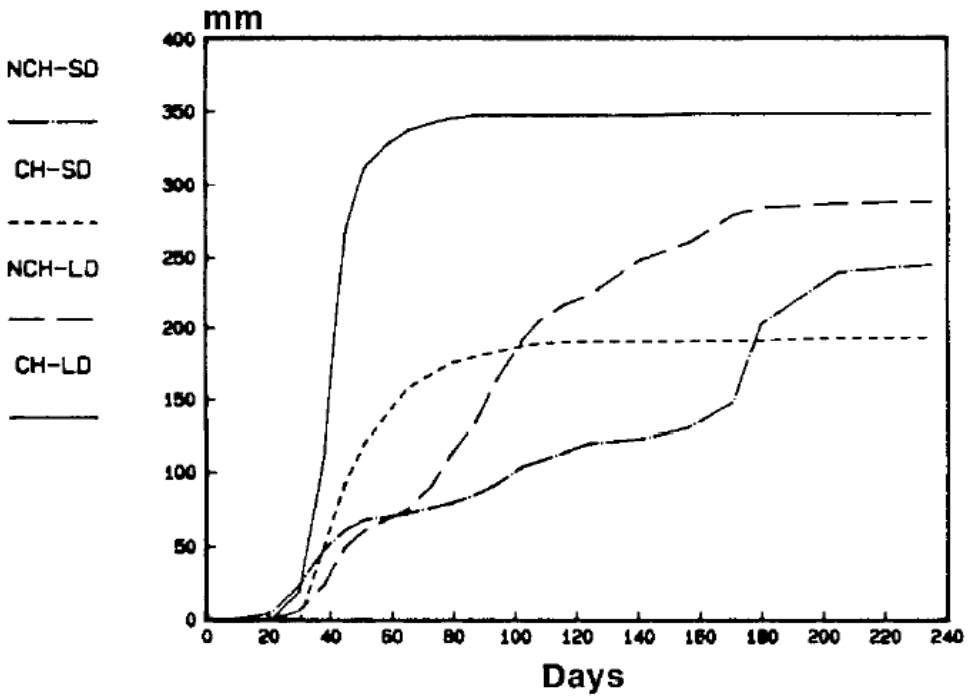
- We should also note that the longest exposure to chilling received by the twigs during the study of Heide (1993) corresponded to natural chilling lasting throughout the winter until the 15th March, after which SD forced plants showed only partial budburst. The end of our longest chilling treatment corresponded to the 4th March, but the constant artificial chilling in the dark that we applied might result in a faster dormancy release.

Thesis Amelia

- Another possible explanation involves the direction of the change of the photoperiod occurring at the time of the transfer from chilling to forcing condition: while in Heide (1993) the SD forced plants experienced a decrease in photoperiod (from about 12 h of the vernal equinox to 8 h of the forcing treatment) our SD forced plants always experienced an increase in photoperiod (from 0 h to 8 h). Shortening the photoperiod delayed budburst in chilled *Picea abies* suggesting that growth initiation was affected by the direction of change rather than its absolute length (Partanen *et al.*, 1998). This effect could be present also in beech.

Thesis Amelia

- **Thus, our results suggest that dormancy release in *F. sylvatica* is regulated by an interaction between chilling and photoperiod and that a substitutive effect occurs between the two factors, such that a long enough period under the effect of LD can substitute for chilling and a long enough period under the effect of chilling can substitute for LD (dormancy release in beech requires either chilling or long days).**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