

How interactive effects of temperature and photoperiod shape spring plant phenology responses to warming

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1 Overview of OSPREE database

We built the Observed Spring Phenology Responses in Experimental Environments (OSPREE) database, by searching both ISI Web of Science and Google Scholar the following terms:

1. TOPIC = (budburst OR leaf-out) AND (photoperiod or daylength) AND temperature*, which yielded 85 publications
2. TOPIC = (budburst OR leaf-out) AND dorman*, which yielded 193 publications

We extracted data (using ImageJ for figures, transcribing values from tables and extracting date, location and other methods from the text) from papers on woody plants that test for photoperiod and/or temperature effects on budburst, leafout, or flowering. Ettinger *et al.* (2020) used a subset of these data (studies on budburst for which we could estimate forcing, chilling and photoperiod treatments), while here we present the full database, capturing data from 84 papers (see Table S1 for a list), of which 21 are focused on crops (*Actinidia deliciosa*, *Malus domestica*, *Vitis vinifera*, *Ribes nigrum*, *Vaccinium ashei*, *Vaccinium corymbosum*, *Prunus persica*). Papers often reported more than one experiment, which we refer to as a ‘study.’ OSPREE includes 136 studies (with the earliest study was conducted in 1947 (Lamb, 1948)), which spanned a variety of plant materials, though studies on ‘seedlings’ (51 studies) and ‘cuttings’ (55 studies) were most common. The most reported events were related to vegetative phases (days until or percent budburst or leafout, 66% of events across studies), followed by flowering (12% of events across studies).

2 Trends in experimental treatments over space

Treatments (cue levels) varied across latitude, with a general trend toward more extreme values at higher latitudes. Forcing and chilling treatments decline 0.1°C per 1° of latitude (for forcing, min is -0.1, for max it is -0.06, see Fig S3; for chilling it is -0.06 for min and -0.09 for max); and the maximum studied photoperiod increases with latitude (0.09 hr per ° latitude, see Fig S3).

3 Comparing experimental treatments to forecasted trends

To compare the magnitude of experimental treatments to forecasted changes in temperature we calculated treatment differences as the differences within varying forcing and chilling treatments within a single study (e.g., a study with a 1 and 4°C chilling treatment would yield a value of 3°C). We did this across all studies (136 total) and for the 19 studies of *Fagus sylvatica* and 17 studies of *Betula pendula*. We calculated forecasted changes in minimum and maximum average daily temperatures over a 60 day window using RCP8.5 from the NCAR Large Ensemble (LENS, a multi-member ensemble of a single general circulation model, GCM, the Community Earth System Model Kay *et al.*, 2015).

4 References

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Supplemental Tables

Table S1: **Dataset names and references for papers in the OS-PREE database.**

Dataset	Reference
ashby62	(Ashby, 1962)
basler12	(Basler & Körner, 2012)
basler14	(Basler & Körner, 2014)
biasi12	(Biasi <i>et al.</i> , 2012)
boyer	(Boyer & South, 1986)
caffarra11a	(Caffarra & Donnelly, 2011)
caffarra11b	(Caffarra <i>et al.</i> , 2011)
calme94	(Calmé <i>et al.</i> , 1994)
campbell75	(Campbell & Sugano, 1975)
cannell83	(Cannell & Smith, 1983)
charrier11	(Charrier <i>et al.</i> , 2011)
chavarria09	(Chavarria <i>et al.</i> , 2009)
cook00b	(Cook & Jacobs, 2000)
cook05	(Cook <i>et al.</i> , 2005)
cronje03	(Cronjé <i>et al.</i> , 2003)
dantec14	(Dantec <i>et al.</i> , 2014)
devries82	(De Vries <i>et al.</i> , 1982)
falusi03	(Falusi & Calamassi, 2003)
falusi90	(Falusi & Calamassi, 1990)
falusi96	(Falusi & Calamassi, 1996)
falusi97	(Falusi & Calamassi, 1997)
fu13	(Fu <i>et al.</i> , 2013)
gansert02	(Gansert, 2002)
ghelardini10	(Ghelardini <i>et al.</i> , 2010)
gianfagna85	(Gianfagna & Mehlenbacher, 1985)
gomory15	(Gömöry <i>et al.</i> , 2015)
granhus09	(Granhus <i>et al.</i> , 2009)
guak98	(Guak <i>et al.</i> , 1998)
guerriero90	(Guerriero <i>et al.</i> , 1990)
gunderson12	(Gunderson <i>et al.</i> , 2012)
hawerroth13	(Hawerroth <i>et al.</i> , 2013)
hawkins12	(Hawkins & Dhar, 2012)
heide03	(Heide, 2003)
heide05	(Heide & Prestrud, 2005)
heide08	(Heide, 2008)
heide11	(Heide, 2011)
heide12	(Heide & Sønsteby, 2012)
heide15	(Heide & Sonsteby, 2015)
heide93	(Heide, 1993a)
heide93a	(Heide, 1993b)
howe95	(Howe <i>et al.</i> , 1995)
jones12	(Jones <i>et al.</i> , 2012)
junttila12	(Junttila & Hänninen, 2012)
karlsson03	(Karlsson <i>et al.</i> , 2003)
lamb37	(Lamb, 1948)
laube14a	(Laube <i>et al.</i> , 2014a)
laube14b	(Laube <i>et al.</i> , 2014b)

Table S1: **Dataset names and references for papers in the OS-PREE database.**

Dataset	Reference
li05	(Li <i>et al.</i> , 2005)
linkosalo06	(Linkosalo & Lechowicz, 2006)
man10	(Man & Lu, 2010)
manson91	(Manson & Snelgar, 1991)
morin10	(Morin <i>et al.</i> , 2010)
myking95	(Myking & Heide, 1995)
myking97	(Myking, 1997)
myking98	(Myking, 1998)
nienstaedt66	(Nienstaedt, 1966)
nishimoto95	(Nishimoto & Fujisaki, 1994)
okie11	(Okie & Blackburn, 2011)
pagter15	(Pagter <i>et al.</i> , 2015)
partanen01	(Partanen <i>et al.</i> , 2001)
partanen05	(Partanen <i>et al.</i> , 2005)
partanen98	(Partanen <i>et al.</i> , 1998)
pettersen71	(Pettersen, 1972)
pop2000	(Pop <i>et al.</i> , 2000)
ramos99	(Ramos & Rallo, 1999)
rinne94	(Rinne <i>et al.</i> , 1994)
rinne97	(Rinne <i>et al.</i> , 1997)
ruesink98	(Ruesink, 1998)
sanx-perez09	(Sanz-Perez <i>et al.</i> , 2009)
sanx-perez10	(Sanz-Pérez & Castro-Díez, 2010)
schnabel87	(Schnabel & Wample, 1987)
skre08	(Skre <i>et al.</i> , 2008)
skuterud94	(Skuterud & Dietrichson, 1994)
sogaard08	(Søgaard <i>et al.</i> , 2008)
sonsteby13	(Sønsteby & Heide, 2013)
sonsteby14	(Sønsteby & Heide, 2014)
spiers74	(Spiers & Draper, 1974)
swartz81	(Swartz & Powell Jr, 1981)
thielges75	(Thielges & Beck, 1976)
viheraaarnio06	(Viherä-Aarnio <i>et al.</i> , 2006)
webb78	(Webb, 1977)
worrall67	(Worrall & Mergen, 1967)
yazdaniha64	(Yazdaniha, 1967)
zohner16	(Zohner <i>et al.</i> , 2016)

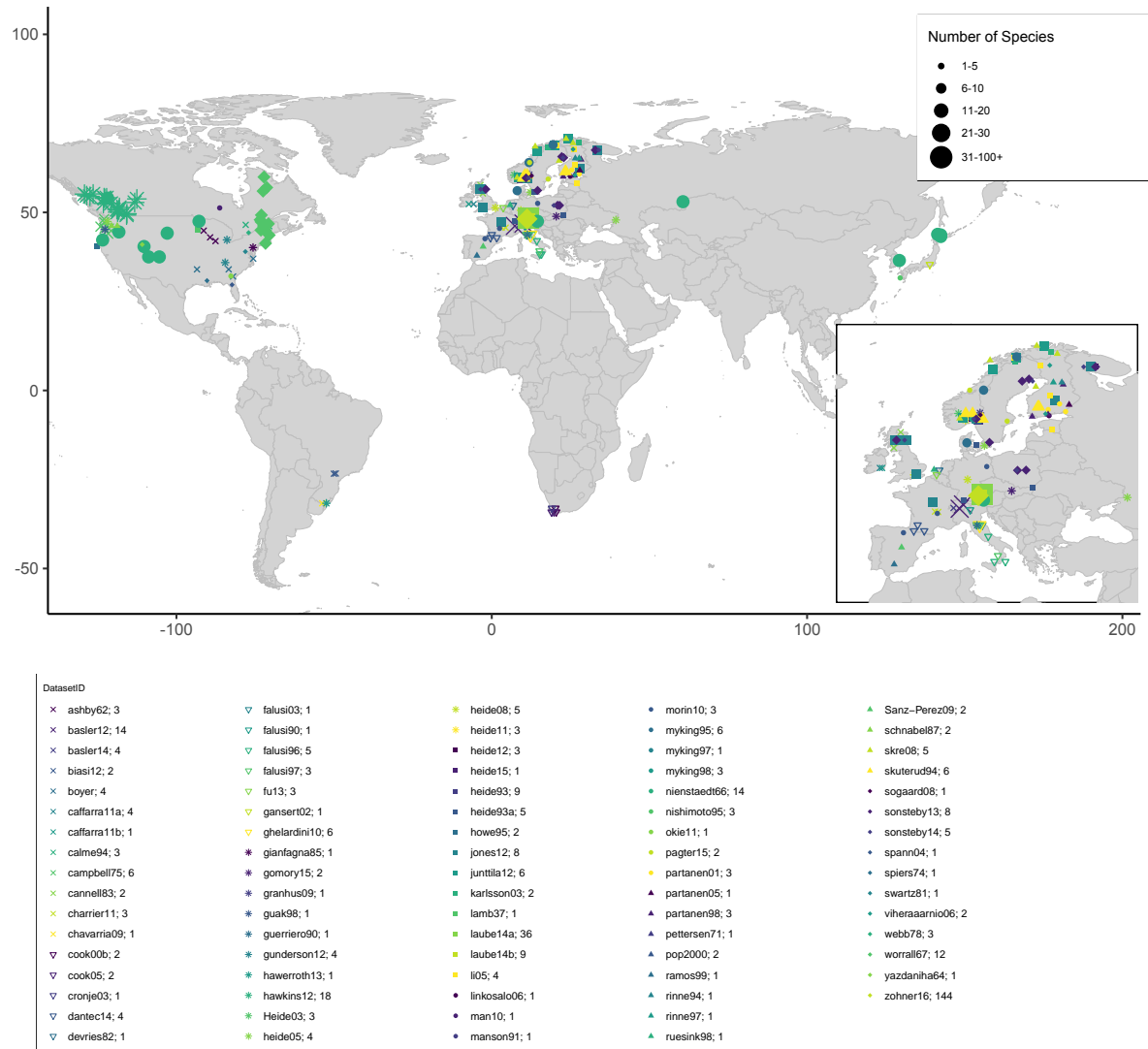


Figure S1: We reviewed seven decades of controlled environment studies, from Lamb (1948) to Zohner *et al.* (2016), conducted across the globe generally on 1-3 species in each experiment (size of circles and exact number of species given after each each study). See Table S1 for references for each ‘Dataset.’

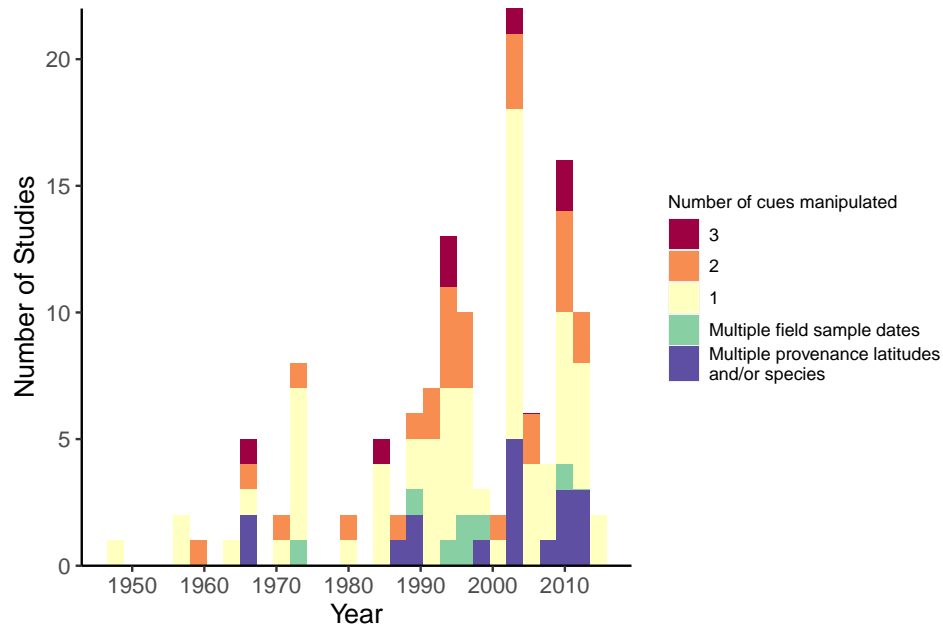


Figure S2: Prevalence of number of cues (1-3 possible: chilling, forcing, photoperiod) manipulated in studies over time. Studies that had multiple field sample dates but did not otherwise manipulate experimental chilling were counted as manipulating the chill cue. We separately counted the number of studies that had multiple field sample dates and manipulated experimental chilling (shown in green). Some studies had only multiple provenance latitudes and/or species (shown in blue).

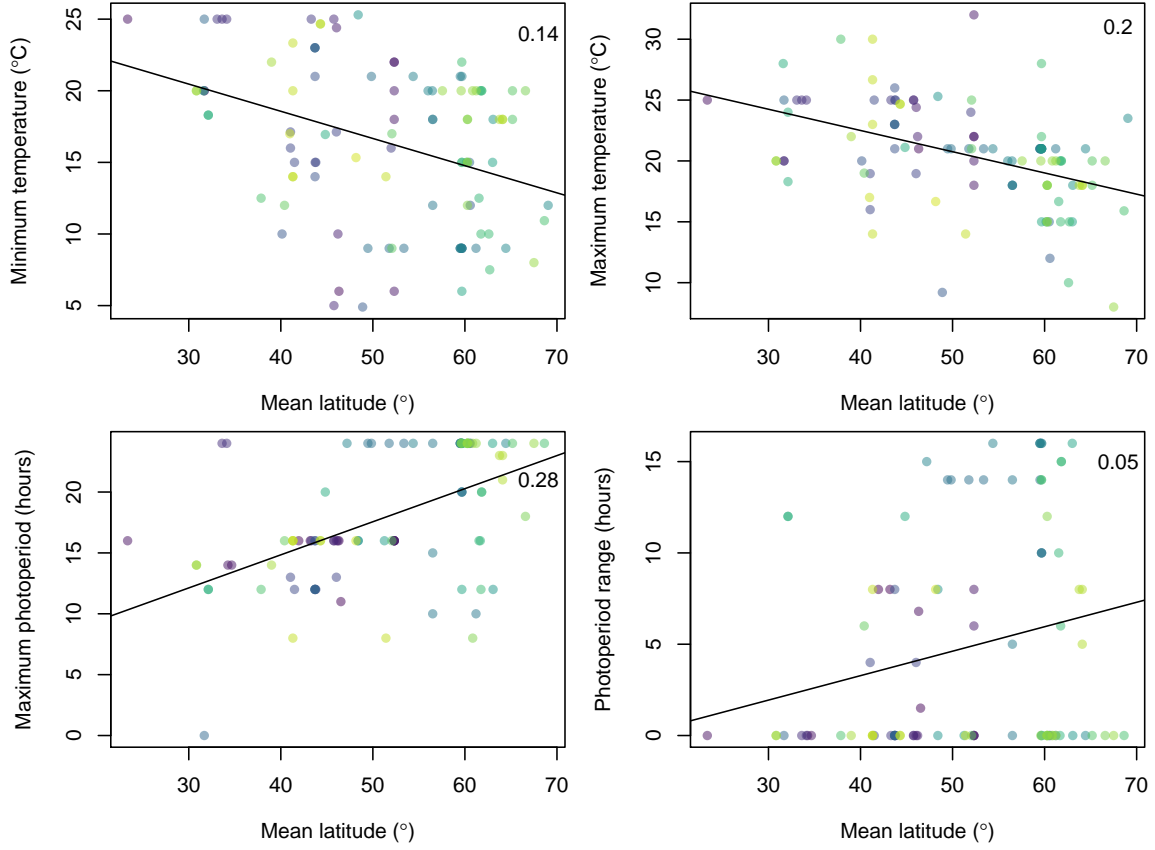


Figure S3: Experimental treatments correlate with latitude. Here we show the average latitude of a study (averaged over all latitudes from which tissue was taken) versus the minimum (upper left) and maximum (upper right) forcing treatments and the maximum (lower left) photoperiod treatment and range of photoperiod treatments (lower right, range calculated as maximum versus minimum treatments in a study). Colors represent unique datasets (see Table S1) and R^2 values are given in the upper-right corner of each plot.