Hmmmmm later I will move this into Latex.

Started November 13, 2021

Updated April 16, 2022

Alina Zeng

**Methodology for LA project**

Hmmmm need to define spring and fall events (check AB 2015)

* Leaf flush, bud set, leaf senescence, leaf abscission (Hamman et al)st

# Provenance location and spring DOY data gathering

* 1. Read SB 2015 and A 2013, took paper with spring doy and provenance coordinates from them
  2. Searched online for more papers, only find a few more
  3. Out of 59 papers related to common garden/spring phenology that I read, only 22 can supply data that we need
     1. Out of the 22, 4 studies have provenance and gardens on different continents
        1. gotten rid of -> influences our analysis
           1. NG PSEUME Sweet 1965 North American provenance plus New Zealand garden
           2. NA ALNURU Cannell et al. 1987
           3. NG PSEUME Lavadinovic etal 2013
           4. NG PSEUME Lavadinovic etal 2018

out of the remaining 17 studies, we have 19 gardens

* sharing the same garden:
  + - NA POPUTR McKown et al. 2013
    - NG PICESI Mimura & Aitken 2007
* two studies have multiple gardens
  + NA BETUPA Hawkins & Dhar 2012
    - R
    - S
    - T
  + EA QUEPET Alberto et al 2011 Garden
    - U
    - V
    1. 4 studies are European provenances and European gardens, 12 are North American provenances plus North American gardens;
    2. Only 2 out of the 4 European studies have fall event data, one leaf flush, one is leaf senescence.
* EA FAGUSY Petkova et al 2017
* EA FRAXEX Rosique-Esplugas 2021

**we have 15 species**

7 angiosperm

8 gymnosperm

[1] "Alnus rubra" "Picea engelmannii" "Picea sitchensis" "Pinus albicaulis"

[5] "Populus trichocarpa" "Tsuga heterophylla" "Fraxinus excelsior" "Fagus sylvatica"

[9] "Populus balsamifera" "Picea abies" "Pseudotsuga menziesii" "Picea mariana"

[13] "Pinus ponderosa" "Betula papyrifera" "Quercus petraea"

**we have 101 European provenances**

4 species, 6 gardens

* 3 angiosperm
* 1 gymnosperm

"Fraxinus excelsior" "Fagus sylvatica" "Picea abies" "Quercus petraea"

**we have 384 North American provenances**

11 Species, 13 gardens

* 4 angiosperm
* 7 gymnosperm

"Alnus rubra" "Picea engelmannii" "Picea sitchensis" "Pinus albicaulis"

"Populus trichocarpa" "Tsuga heterophylla" "Populus balsamifera" "Pseudotsuga menziesii"

"Picea mariana" "Pinus ponderosa" "Betula papyrifera"

* + Label for studies
    - e.g.: EA FRAXEX Rosique-Esplugas 2021
    - Europe Angiosperm *Fraxinus excelsior* Year of publication
* **Data scraping Tool (ImageJ)** was used for some papers including:
  + - * EA FRAXEX Rosique-Esplugas 2021
        + Fall: leaf senescence
      * EG PICEAB Sogaard et al. 2008
      * EA FAGUSY Petkova et al 2017
        + Fall: leaf flush
      * ALT EX XXXXXX Vitasse et al 200
        + Fall: leaf senescence
      * ALT EA QUEPET Alberto et al 201
        + Spring: budburst
      * ALT NG ABIAMA Worrall 1983
        + Spring: budburst

need to calculate how many/which gardens we have fall events for

Need to update R notes in excel

# Climate data gathering

## Simple climate matrix (MAT & MSP/MAP) gathering

Tools used for simple climate matrices:

### ClimateNA by Dr. Tongli Wang

* + ClimateNA is a standalone MS Windows application that downscales PRISM (Daly et al. 2008) 1971-2000 gridded monthly climate normal data (800 x 800 m) to scale-free point locations. It calculates and derives many (>200) monthly, seasonal and annual climate variables. ClimateNA also uses the scale-free data as a baseline to downscale historical and future climate variables for individual years and periods between 1901 and 2100.
    - Wang T, Hamann A, Spittlehouse D, Carroll C (2016) [Locally Downscaled and Spatially Customizable Climate Data for Historical and Future Periods for North Americ](https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0156720)a. PLoS ONE 11(6): e0156720. doi:10.1371/journal.pone.0156720

### [**Climate Information Tool by FAO**](https://www.fao.org/aquastat/en/geospatial-information/climate-information)

* + The Climate Information Tool is an interactive tool to query a spatial dataset containing long-term mean monthly climate data.
    - MAT calculated by taking the average of monthly temperature
  + The dataset covers the global land surface at a 10 minute spatial resolution for the period 1961-1990. The tool displays the latitude, longitude and elevation of the chosen location, and several climate variables per month (average over the period 1961-1990) related to: precipitation, temperature, relative humidity, sunshine, wind speed, reference evapotranspiration. In more details the tool displays: XXXXX
  + All data, apart from the reference evapotranspiration, originate from the [**CRU CL 2.0**](http://www.cru.uea.ac.uk/~timm/grid/CRU_CL_2_0.html) data-set which is described in: [**New, M., Lister, D., Hulme, M. and Makin, I., 2002: A high-resolution data set of surface climate over global land areas. Climate Research 21:1-25**](https://crudata.uea.ac.uk/cru/data/hrg/tmc/new_et_al_10minute_climate_CR.pdf). The data are available through the [**School of Geography Oxford**](http://www.geog.ox.ac.uk/), the [**International Water Management Institute World Water and Climate Atlas**](http://www.iwmi.cgiar.org/resources/world-water-and-climate-atlas/) and the Climatic Research Unit of the University of East Anglia
* The difference in temperature between these two sources is (+ - 0.13333)

## Daily climate data gathering

* Gridded daily climate data downloaded for all provenances and gardens
  + A few provenances were outside of the range of Daymet (i.e. XXXXXXXX)
  + Sweet 1985 garden is in New Zealand, have not gotten daily climate yet

### Europe daily climate data (gridded: NetCDF-4) retrieved from **E-OBS**

* https://cds.climate.copernicus.eu/cdsapp#!/dataset/insitu-gridded-observations-europe?tab=overview
  + For 2011-2020
  + Note that E-OBS considers leap days (3653 days from 2011-2020)
    - DOI: [10.24381/cds.151d3ec6](https://doi.org/10.24381/cds.151d3ec6)

### North American daily climate data from **Daymet R package**

* https://daac.ornl.gov/cgi-bin/dsviewer.pl?ds\_id=1840
* Daymet: Daily Surface Weather Data on a 1-km Grid for North America, Version 4
  + Bounding rectangle
    - N: 82.91
    - S: 14.07
    - E: -53.06
    - W: -178.1
  + Temporal Coverage: 1950-01-01 to 2020-12-30
  + For 2011-2020
  + Note that Daymet does not consider leap days (3650 days from 2011-2020)
    - Thornton, M.M., R. Shrestha, Y. Wei, P.E. Thornton, S. Kao, and B.E. Wilson. 2020. Daymet: Daily Surface Weather Data on a 1-km Grid for North America, Version 4. ORNL DAAC, Oak Ridge, Tennessee, USA. <https://doi.org/10.3334/ORNLDAAC/1840>

**15/778 provenances were missing climate data**

## Daily clim percentage overlap

Using the overlap package in R and calculated percentage and sd of temperature overlap of March April May temp of each provenance from 2011-2020 in relation to daily temperature of garden

* Will make plots
* Will also run model

Hmmm thoughts: need a table documenting all the studies this project collected data from

# Plots made to date

## 1. scatter plots

### plotted the difference of lat\_prov and lat\_garden against DOY

### plotted the difference of mat\_prov and mat\_garden against DOY

## 2. line plots

### daily temperature (doy 50-150) of each provenance for 2011-2020 against daily temp of garden

## 3. distribution overlap

Distribution of March April May temp of each provenance from 2011-2020 against garden

* Overlap percentage for each provenance over 10 years
* Standard deviation

## distance between garden and provenance to find the closest provenance to garden and use that doy as base line to calculate doy difference

1. **taking the difference of lat garden and lat provenance**
2. **distance on the globe** ->using the distm() in geosphere package (<https://www.rdocumentation.org/packages/geosphere/versions/1.5-14/topics/distm>)

for (i in c(1:nrow(d))){

d$earth\_distance\_from\_garden[i] <- geosphere::distm(c(d$long\_prov[i],d$lat\_prov[i]), c(d$long\_garden[i],d$lat\_garden[i]), fun= geosphere::distGeo)

}

when multiple provenances are the same distance away, we took the average of the doy

\*\* repeated the steps for all events to get fall difference

# Modelling

st\_glmer

## LAT/MAT ~ spring/fall doy

**Spring**

#1 ----

fit1\_lat <- stan\_glmer(spring\_event~lat\_prov + (1|species)+ (1|garden\_identifier), data = d)

fit1\_mat <- stan\_glmer(spring\_event~MAT\_prov + (1|species)+ (1|garden\_identifier), data = d)

#2 ----

fit2\_lat <- stan\_glmer(spring\_event~lat\_prov\*prov\_continent + (1|species)+ (1|garden\_identifier), data = d)

fit2\_mat <- stan\_glmer(spring\_event~MAT\_prov\*prov\_continent + (1|species)+ (1|garden\_identifier), data = d)

#3 ----

fit3\_lat <- stan\_glmer(spring\_event~(lat\_prov|species)+(1|garden\_identifier), data = d)

fit3\_mat <- stan\_glmer(spring\_event~(MAT\_prov|species)+(1|garden\_identifier), data = d)

#4 ----

fit4\_lat <- stan\_glmer(spring\_event~lat\_prov + lat\_garden + (1|species), data = d)

fit4\_mat <- stan\_glmer(spring\_event~MAT\_prov + MAT\_garden + (1|species), data = d)

**Fall**

#1 ----

fit\_fall\_1\_lat <- stan\_glmer(fall\_event~lat\_prov + (1|species)+ (1|garden\_identifier), data = d\_fall)

fit\_fall\_1\_mat <- stan\_glmer(fall\_event~MAT\_prov + (1|species)+ (1|garden\_identifier), data = d\_fall)

#2 ---- can't plot this yet becuz no fall events for european provenances..... need to scrap, but ImageJ is broken :((

fit\_fall\_2\_lat <- stan\_glmer(fall\_event~lat\_prov\*prov\_continent + (1|species)+ (1|garden\_identifier), data = d\_fall)

fit\_fall\_2\_mat <- stan\_glmer(fall\_event~MAT\_prov\*prov\_continent + (1|species)+ (1|garden\_identifier), data = d\_fall)

#3 ----

fit\_fall\_3\_lat <- stan\_glmer(fall\_event~(lat\_prov|species)+(1|garden\_identifier), data = d\_fall)

fit\_fall\_3\_mat <- stan\_glmer(fall\_event~(MAT\_prov|species)+(1|garden\_identifier), data = d\_fall)

#4 ----

fit\_fall\_4\_lat <- stan\_glmer(fall\_event~lat\_prov + lat\_garden + (1|species), data = d\_fall)

fit\_fall\_4\_mat <- stan\_glmer(fall\_event~MAT\_prov + MAT\_garden + (1|species), data = d\_fall)

<https://github.com/lizzieinvancouver/localadaptclim/issues/10#issuecomment-1050073148>

including studies with different continents:

* no relationship with MAT
* with LAT, north American exhibits stronger clines (refer to abstract)
* we plotted two lines (intercept of Europe vs. North America for now
  + later can plot line for each species, and color code by garden

**not including studies with different continents:**

* **little relationship with LAT and MAT**
* **European studies exhibit stronger clines (slightly)**

### histogram plots for spring event LAT and MAT

<https://github.com/lizzieinvancouver/localadaptclim/issues/10#issuecomment-1050526747>

## 

## LAT/MAT ~ spring/fall doy difference

**spring (not including studies with different continents):**

* **little relationship with LAT and MAT**
* **European studies exhibit stronger clines (slightly)**

**fall (not including studies with different continents):**

* **strong relationship**
* **NA has stronger clines than Europe**

## Daily clim overlap Percentage ~ distance

1. lat difference

* the bigger the difference in LAT, the less clim overlap
* NA has higher slope than Europe

1. earth distance

* the bigger the earth distance, the less clim overlap
* NA has higher slope than Europe

## testing the relationship of Spring doy and Daily clim overlap Percentage vs. SD

# model series A: doy~percentage and doy~sd

#1 ----

fit1\_percentage <- stan\_glmer(spring\_event~percentage + (1|species)+ (1|garden\_identifier), data = d)

fit1\_sd <- stan\_glmer(spring\_event~sd + (1|species)+ (1|garden\_identifier), data = d)

#2 ----

fit2\_percentage <- stan\_glmer(spring\_event~percentage\*prov\_continent + (1|species)+ (1|garden\_identifier), data = d)

fit2\_sd <- stan\_glmer(spring\_event~sd\*prov\_continent + (1|species)+ (1|garden\_identifier), data = d)

#3 ----

fit3\_percentage <- stan\_glmer(spring\_event~(percentage|species)+(1|garden\_identifier), data = d)

fit3\_sd <- stan\_glmer(spring\_event~(sd|species)+(1|garden\_identifier), data = d)

#4 ---- # no need to run fit 4... or need to change it

fit4\_percentage <- stan\_glmer(spring\_event~percentage + percentage\_garden + (1|species), data = d)

fit4\_sd <- stan\_glmer(spring\_event~sd + sd\_garden + (1|species), data = d)

including studies with different continents:

* stronger relationship with SD than percentage

## Spring doy difference (difference of doy to the doy of the closest provenance) ~ Daily clim overlap Percentage vs. SD

# model series B: doy\_difference~percentage and doy\_difference~sd ----

#1 ----

fit1\_percentage\_doy\_diffo <- stan\_glmer(spring\_event\_difference~percentage + (1|species)+ (1|garden\_identifier), data = d)

fit1\_sd\_doy\_diffo <- stan\_glmer(spring\_event\_difference~sd + (1|species)+ (1|garden\_identifier), data = d)

#2 ----

fit2\_percentage\_doy\_diffo <- stan\_glmer(spring\_event\_difference~percentage\*prov\_continent + (1|species)+ (1|garden\_identifier), data = d)

fit2\_sd\_doy\_diffo <- stan\_glmer(spring\_event\_difference~sd\*prov\_continent + (1|species)+ (1|garden\_identifier), data = d)

#3 ----

fit3\_percentage\_doy\_diffo <- stan\_glmer(spring\_event\_difference~(percentage|species)+(1|garden\_identifier), data = d)

fit3\_sd\_doy\_diffo <- stan\_glmer(spring\_event\_difference~(sd|species)+(1|garden\_identifier), data = d)

#4 ---- # no need to run fit 4... or need to change it

fit4\_percentage\_doy\_diffo <- stan\_glmer(spring\_event\_difference~percentage + percentage\_garden + (1|species), data = d)

fit4\_sd\_doy\_diffo <- stan\_glmer(spring\_event\_difference~sd + sd\_garden + (1|species), data = d)

including studies with different continents:

* stronger relationship with SD than percentage
* The higher the percentage overlap, the less difference in spring doy -> slightly stronger relationship observed in Europe
* The higher the sd, the less difference in spring doy -> slightly stronger relationship observed in Europe

## testing the relationship of Daily clim overlap Percentage vs. SD and LAT vs. MAT

# model series C: percentage~lat/mat and sd~lat/mat ----

**#percentage**

#1 ----

fit1\_lat\_percentage <- stan\_glmer(percentage~lat\_prov + (1|species)+ (1|garden\_identifier), data = d)

fit1\_mat\_percentage <- stan\_glmer(percentage~MAT\_prov + (1|species)+ (1|garden\_identifier), data = d)

#2 ----

fit2\_lat\_percentage <- stan\_glmer(percentage~lat\_prov\*prov\_continent + (1|species)+ (1|garden\_identifier), data = d)

fit2\_mat\_percentage <- stan\_glmer(percentage~MAT\_prov\*prov\_continent + (1|species)+ (1|garden\_identifier), data = d)

#3 ----

fit3\_lat\_percentage <- stan\_glmer(percentage~(lat\_prov|species)+(1|garden\_identifier), data = d)

fit3\_mat\_percentage <- stan\_glmer(percentage~(MAT\_prov|species)+(1|garden\_identifier), data = d)

#4 ----

fit4\_lat\_percentage <- stan\_glmer(percentage~lat\_prov + lat\_garden + (1|species), data = d)

fit4\_mat\_percentage <- stan\_glmer(percentage~MAT\_prov + MAT\_garden + (1|species), data = d)

**#sd**

#1 ----

fit1\_lat\_sd <- stan\_glmer(sd~lat\_prov + (1|species)+ (1|garden\_identifier), data = d)

fit1\_mat\_sd <- stan\_glmer(sd~MAT\_prov + (1|species)+ (1|garden\_identifier), data = d)

#2 ----

fit2\_lat\_sd <- stan\_glmer(sd~lat\_prov\*prov\_continent + (1|species)+ (1|garden\_identifier), data = d)

fit2\_mat\_sd <- stan\_glmer(sd~MAT\_prov\*prov\_continent + (1|species)+ (1|garden\_identifier), data = d)

#3 ----

fit3\_lat\_sd <- stan\_glmer(sd~(lat\_prov|species)+(1|garden\_identifier), data = d)

fit3\_mat\_sd <- stan\_glmer(sd~(MAT\_prov|species)+(1|garden\_identifier), data = d)

#4 ----

fit4\_lat\_sd <- stan\_glmer(sd~lat\_prov + lat\_garden + (1|species), data = d)

fit4\_mat\_sd <- stan\_glmer(sd~MAT\_prov + MAT\_garden + (1|species), data = d)

# \*Standardization

- NG PICEEN Rehfeldt 1994

experiment green house -> standardized by + 90 days to spring DOYS; + 270 days to fall DOYS  
- NA ALNURU Hamann et al. 1998

Leaf abscission -> standardized by – 90 days fall DOYS

\*\*\*\*\* NEW: lizzie suggested that I do Z-score….

**Excluded because**

EA Chmura & Rozkowski 2002: does not have Doy, only has BB scores using a 7 point scale

EA Kramer et al 2017: don’t know which DOY corresponds to which provenance; no coordinates of provenance

EA Schueler & Liesebach 2015 only has bud burst rating, no DOY

EA Mijnsbrugge et al 2016 no DOY, modelled probability of reaching BB 3.

EA Santini et al 2004 field observation of 6 sites in 5 countries: no common garden

EA Mijnsbrugge et al 2015 no DOY, only has bud burst rating on specific days

NA Wang et al 2014 only concerns about bud set

EA Schieber 2006 no different provenance -> a study of observation of a 90 year-old stand

**EA Robinson et al 2013 no DOY, only has bud burst rating on specific days**

**efecto de la procedencia geográfica y de la fertilización en la fenología del brote terminal en plántulas de *pseudotsuga* sp.**

Vitasse, Y., S. Delzon, E. Dufrene, J.-Y. Pontailler, J.-M. Louvet, A. Kremer

Sweet 1965 New Zealand paper -> standardized doy by -180

NG PICEEN Rehfeldt 1994 -> standardized doy by +90 (spring) and +180 (fall)

Need to back this up….

**NA POPUBA Soolanayakanahally et al. 2013**

All statistical analyses used SAS version 9.1.3 (SAS 2002/

2003) or SigmaPlot 11.0 (Systat Software, San Jose, CA,

USA). One- and two-way analysis of variance (anova) was

performed to test for effects of provenance and/or differences

between common garden sites.Where possible, data

were transformed to conform to assumptions of normality

and homogeneity of variance; otherwise, anovas on rank

were performed. Regression lines in figures are based on

population means within each common garden. Common

garden averages for each phenological event were calculated

from pooled data across years.

Hmmm could use this for introduction

Search terms

Graphical user interface, text, application

Description automatically generated<https://www.webofscience.com/wos/woscc/summary/8fa8c2f9-849b-476b-9b88-f03c05346763-19938b15/relevance/1>

NG PINUPO Dixit et al 2020 -> having the latest BB (around 160ish) cuz its closer to the equator (35 lat)

* ponderosa pine -> need to read more

NA POPUTR McKown et al. 2013 -> outlying -> doy as early as 40ish -> need to see how far the provenances are from the garden

# Notes

ALT NG ABIAMA Worrall 1983

* for now I have it as one garden… but if later on we want to include elevation as a factor.. I will then make it 4 gardens

Chart, scatter chart

Description automatically generated

The date

of bud burst was defined as ‘‘when the first green

ragged edges visually appear between the bud scales,

almost like the opening of a clam shell’’ (Berger,

2001).

Publication | Provenance Continent | Garden Continent | Garden Country | Garden ID | Species | Species Type | # of Provenances | How spring event is defined | Fall event yes or no | how fall event is defined

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| No. | Publication | Provenance  Continent | Garden Continent | Garden ID | Species | Species Type | # of Provenances | Observation Year | Spring Event Definition | Fall Event | Fall Event Definition |
| 1 | Hamann et al., 1998 | North America | North America | A | Alnus rubra | Angiosperm | 55 | 1996 | Bud burst | Yes | Leaf abscission |
| 2 | Rehfeldt, 1994 | North America | North America | B | Picea engelmannii | Gymnosperm | 103 | n.d. | Bud burst | Yes | Leaf cessation |
| 3 | Bower & Aitken, 2008 | North America | North America | C | Pinus albicaulis | Gymnosperm | 25 | 2003 | Leaf flush | No | n.a. |
| 4 | McKown et al., 2013 | North America | North America | D | Populus trichocarpa | Angiosperm | 97 | 2010 | Bud burst  Leaf flush | Yes | Bud set |
| 5 | Mimura & Aitken 2007 | North America | North America | D | Picea sitchensis | Gymnosperm | 17 | 2003 | Bud burst | Yes | Bud set |
| 6 | Kuser, 1980 | North America | North America | E | Tsuga heterophylla | Gymnosperm | 19 | 1978 | Bud burst | Yes | Bud set |
| 7 | Farmer, 1993 | North America | North America | F | Populus balsamifera | Angiosperm | 4 | 1985  1986  1987 | Bud burst | No | n.a. |
| 8 | Hannerz et al., 1999 | North America | North America | G | Tsuga heterophylla | Gymnosperm | 4 | 1998 | Bud burst | No | n.a. |
| 9 | White et al., 1979 | North America | North America | H | Pseudotsuga menziesii | Gymnosperm | 16 | 1962  1963  1965 | Bud burst | No | n.a. |
| 10 | Guo et al., 2021 | North America | North America | I | Picea mariana | Gymnosperm | 5 | 2015  2017  2018  2019 | Bud burst | No | n.a. |
| 11 | Dixit et al., 2020 | North America | North America | J | Pinus ponderosa | Gymnosperm | 21 | 2019 | Bud burst | No | n.a. |
| 12 | Hawkins & Dhar 2012 | North America | North America | K  L  M | Betula papyrifera | Angiosperm | 18 | 1998 | Bud burst | No | n.a. |
| 13 | Cannell et al. 1987 | North America | Europe | N | Alnus rubra | Angiosperm | 12 | 1895 | Bud burst | Yes | Bud set |
| 14 | Lavadinovic et al., 2013 | North America | Europe | O | Pseudotsuga menziesii | Gymnosperm | 14 | 2002  2003  2004 | Bud burst | No | n.a. |
| 15 | Sweet, 1965 | North America | Oceania | P | Pseudotsuga menziesii | Gymnosperm | 23 | 1961 | Bud burst | No | n.a. |
| 16 | Rosique-Esplugas, 2021 | Europe | Europe | Q\* | Fraxinus excelsior | Angiosperm | 42 | 2013 | Leaf flush | Yes | Leaf senescence |
| 17 | Petkova et al., 2017 | Europe | Europe | R\* | Fagus sylvatica | Angiosperm | 8 | 2013  2016 | Bud burst | Yes | Leaf senescence |
| 18 | Sogaard et al., 2008 | Europe | Europe | S\* | Picea abies | Gymnosperm | 9 | 2004 | Bud burst | No | n.a. |
| 19 | Gömöry & Paule 2011 | Europe | Europe | T\* | Fagus sylvatica | Angiosperm | 32 | 2007  2008 | Bud burst | No | n.a. |
| 20 | Alberto et al., 2011 | Europe | Europe | U\*  V\* | Quercus petraea | Angiosperm | 10 | 2009 | Bud burst | No | n.a. |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | # of Angiosperms | # of Gymnosperms | # of Provenances | # of Common Gardens | Species |
| North American Studies | 3 | 1 | 101 | 6 | *Fagus sylvatica,*  *Fraxinus excelsior,*  *Picea abies,     Quercus petraea* |
| European Studies | 4 | 7 | 384 | 13 | *Alnus rubra,*  *Betula papyrifera,*  *Picea engelmannii,*  *Picea mariana,     Pinus ponderosa,*  *Picea sitchensis,     Pinus albicaulis,*  *Populus balsamifera,   Pseudotsuga menziesii,*  *Populus trichocarpa,*  *Tsuga heterophylla* |
| Total | 7 | 8 | 485 | 19 |  |

Hmmmm defo need to color this by Angiosperm VS gymnosperm….

<https://link.springer.com/article/10.1007/s00484-021-02190-1>

Contradictory results have been reported about leaf senescence significant cline, where some plant species at low elevations have started to senesce earlier than those from high elevations, but others species have presented an opposite tendency showing small amount of evidence of leaf senescence among natural tree populations, particularly along altitudinal gradients (Deans and Harvey [1995](https://link.springer.com/article/10.1007/s00484-021-02190-1#ref-CR15); Chmura [2006](https://link.springer.com/article/10.1007/s00484-021-02190-1#ref-CR10)). One of the main environmental effects at high elevation is the lowering of temperatures at the end of the growing season, which may cause early leaf drop, while many authors report that the growing season responds to latitude due to variations in day length. High latitude populations generally begin to senesce or to finish their growth earlier than low latitude populations (Hänninen et al. [1990](https://link.springer.com/article/10.1007/s00484-021-02190-1#ref-CR36); Deans and Harvey [1995](https://link.springer.com/article/10.1007/s00484-021-02190-1#ref-CR15); Mimura and Aitken [2007](https://link.springer.com/article/10.1007/s00484-021-02190-1#ref-CR57); Jensen and Hansen [2008](https://link.springer.com/article/10.1007/s00484-021-02190-1#ref-CR44)).