Whole plant processes

Growth, allocation, life cycles, phenology

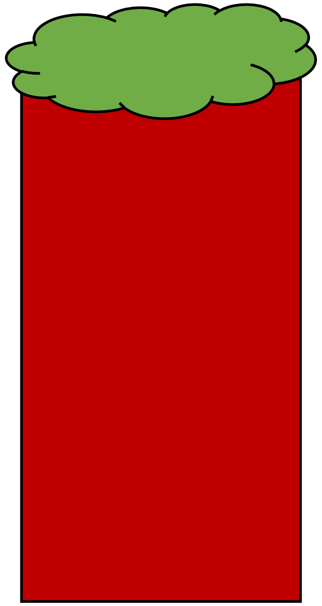
Spicoli question of the day: Why do plants grow?

Allocation

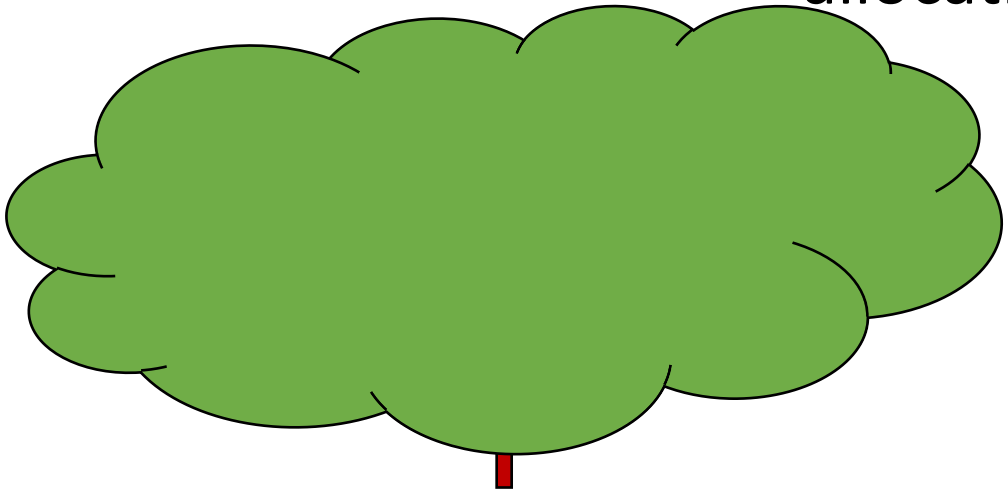
Allocation

- The distribution of growth to different organs
- Allometry: the relative size of different organs

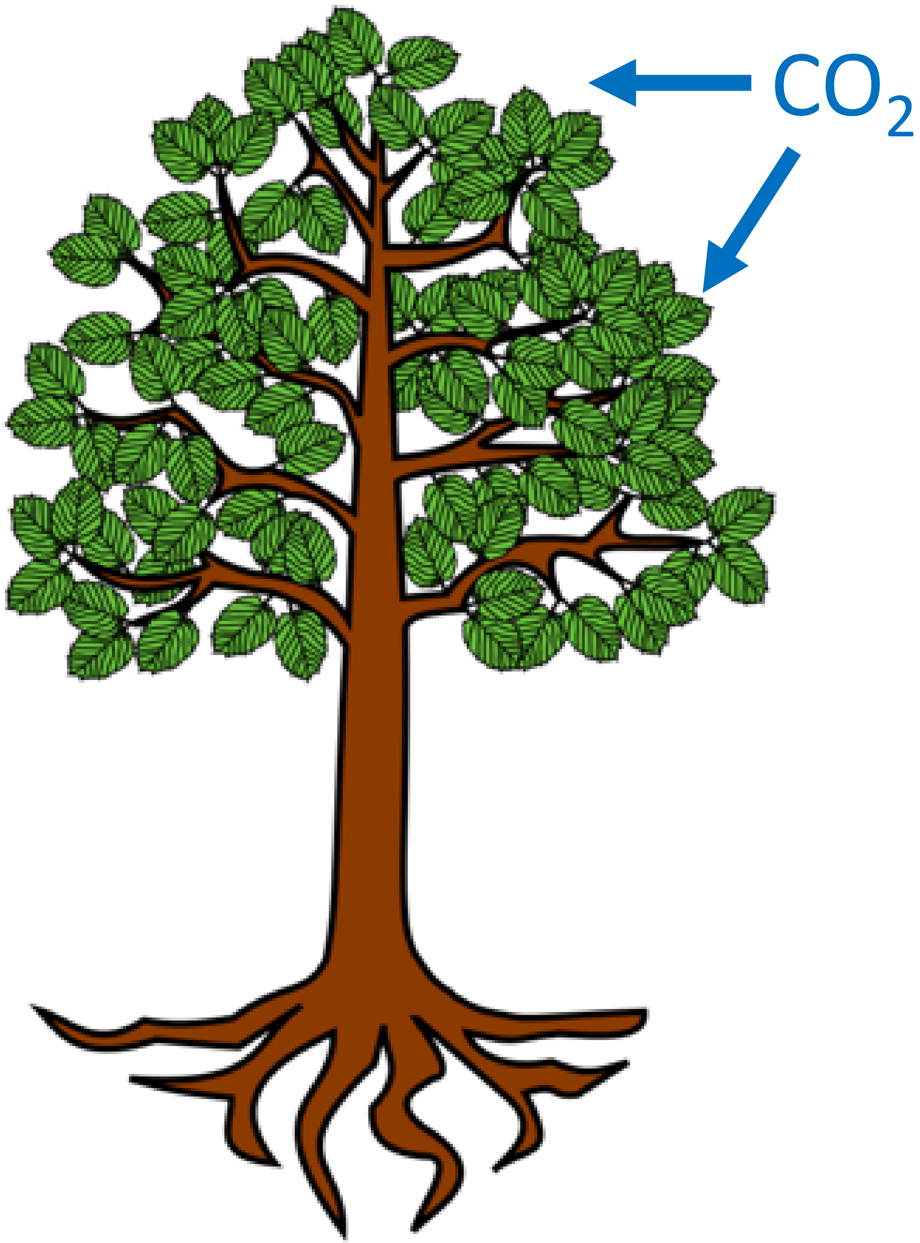
High stem allocation



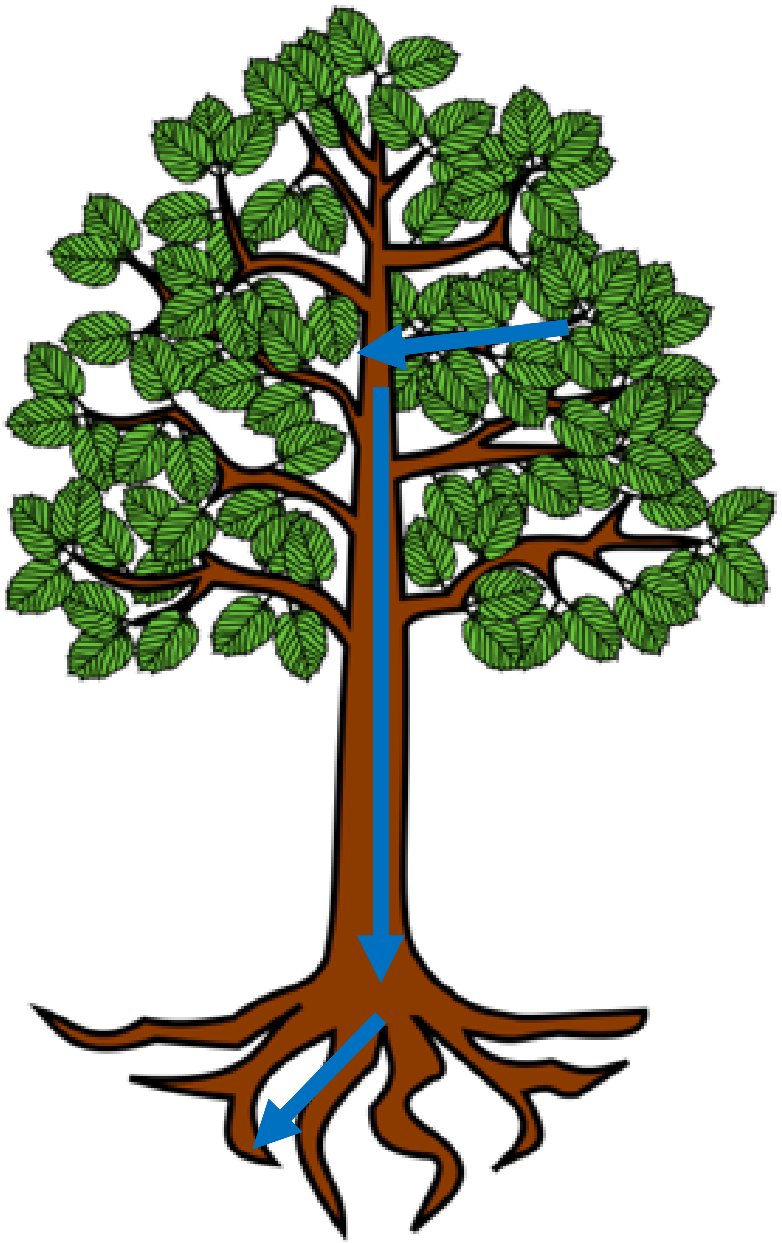
High leaf allocation



Following the carbon

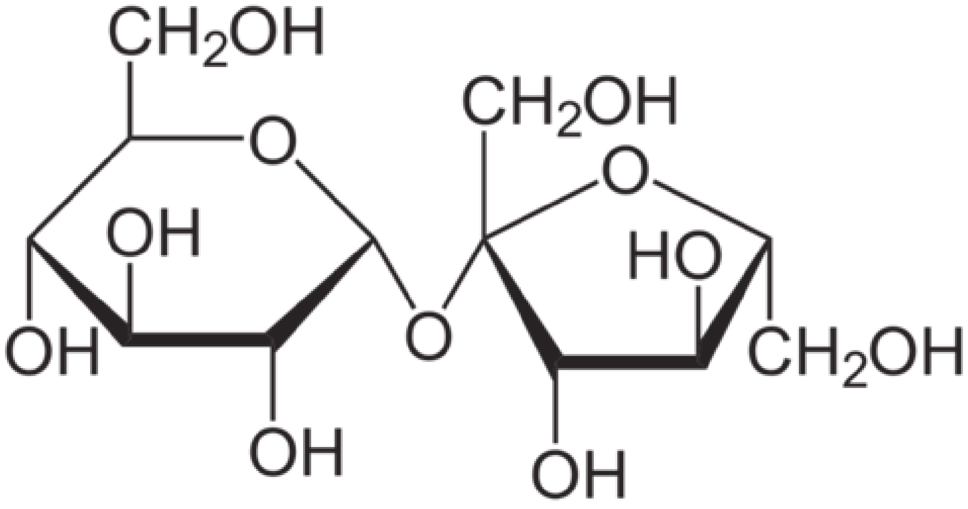


Carbon is first taken up by photosynthesis (source)

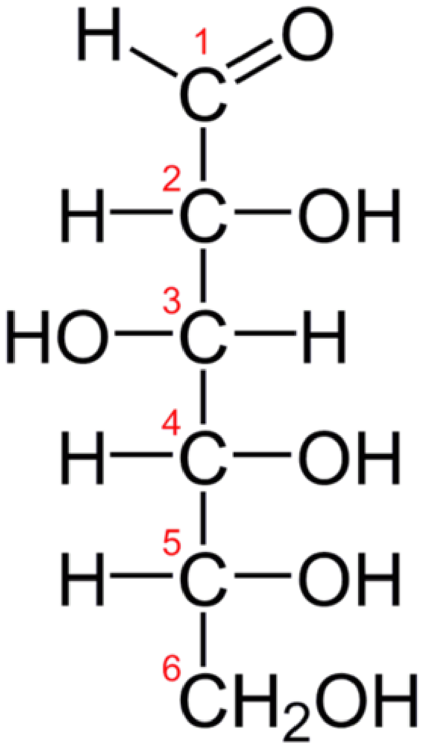


The sugars are then transported throughout the plant (sinks)

Sucrose, not glucose, is the primary transport sugar…huh?



Sucrose



Glucose

Translocation

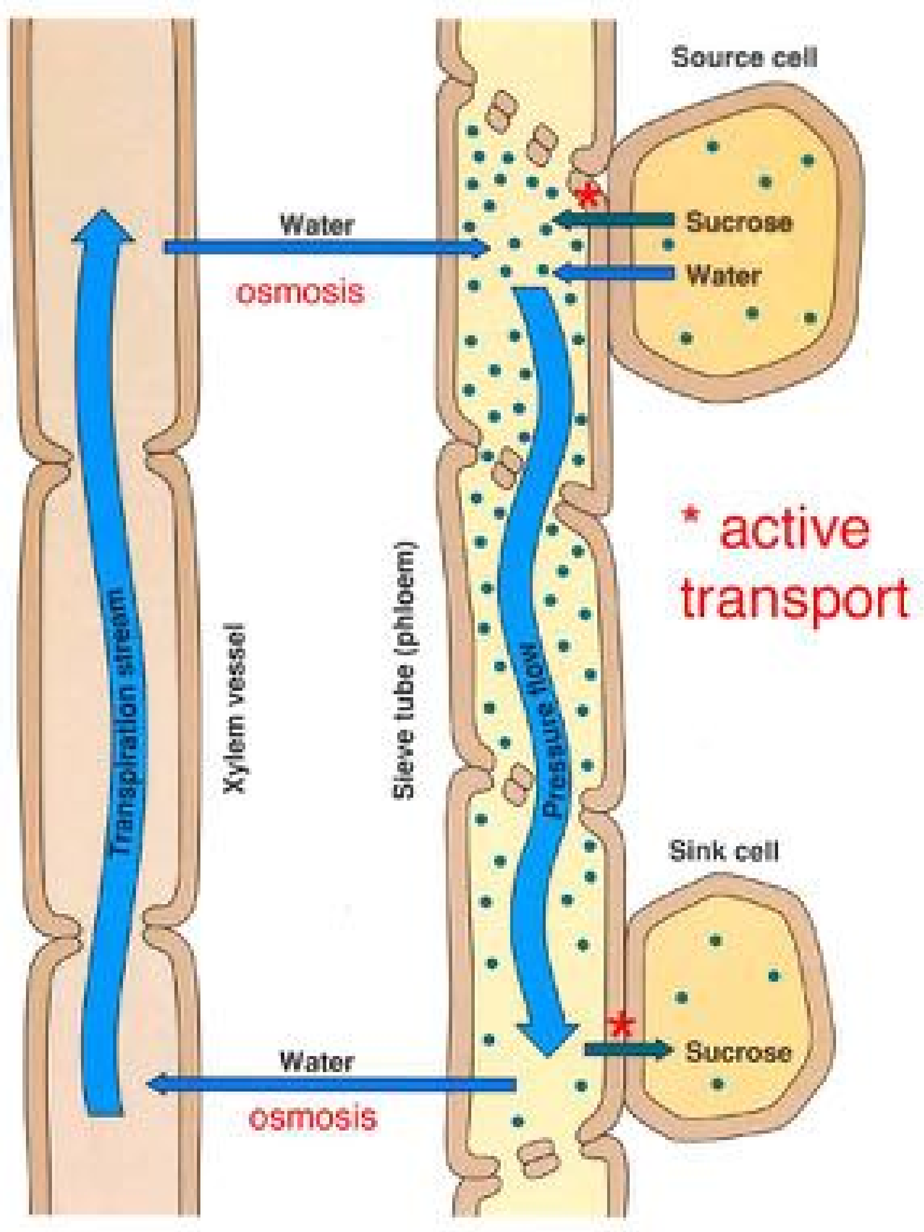
- Movement of food substances through the plant (via water)

(a) From Martin H. Zimmerman, "Movements of Organic Substances in trees" Science 133:73-79, 1961, American Association for the Advancement of Science

Translocation happens fast!
(Can't be accounted for by diffusion alone)

Pressure-flow hypothesis

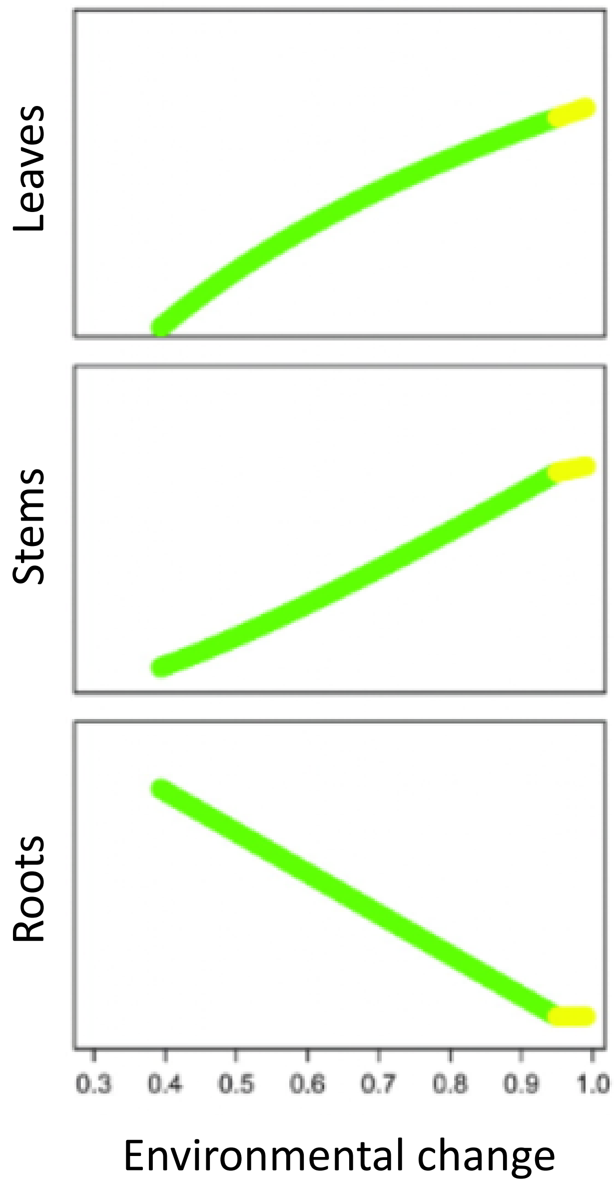
- Food is actively loaded into phloem from “source”
- Water enters phloem from xylem via osmosis
- Pressure gradient drives food to “sink”
- Food is actively removed from sink



What do the sugars from photosynthesis get used for?

(What are the sinks?)

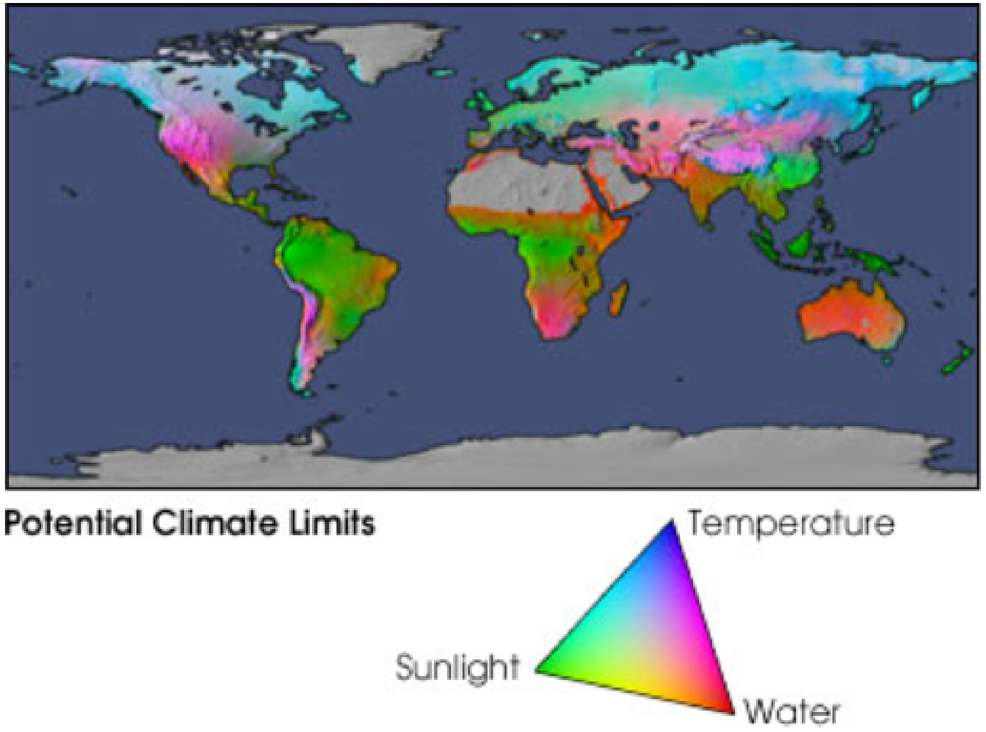
Allocation is a dynamic process that is dependent on the environment



Farrior et al. (2013)

In isolation, how would abiotic conditions influence allocation?

1. Light
2. Temperature
3. Water
4. CO_2
5. Nutrients



NASA

In isolation, how would life history traits influence allocation?

1. Lifespan
2. Ontogeny
3. Photosynthetic pathway
4. Microbial symbiosis

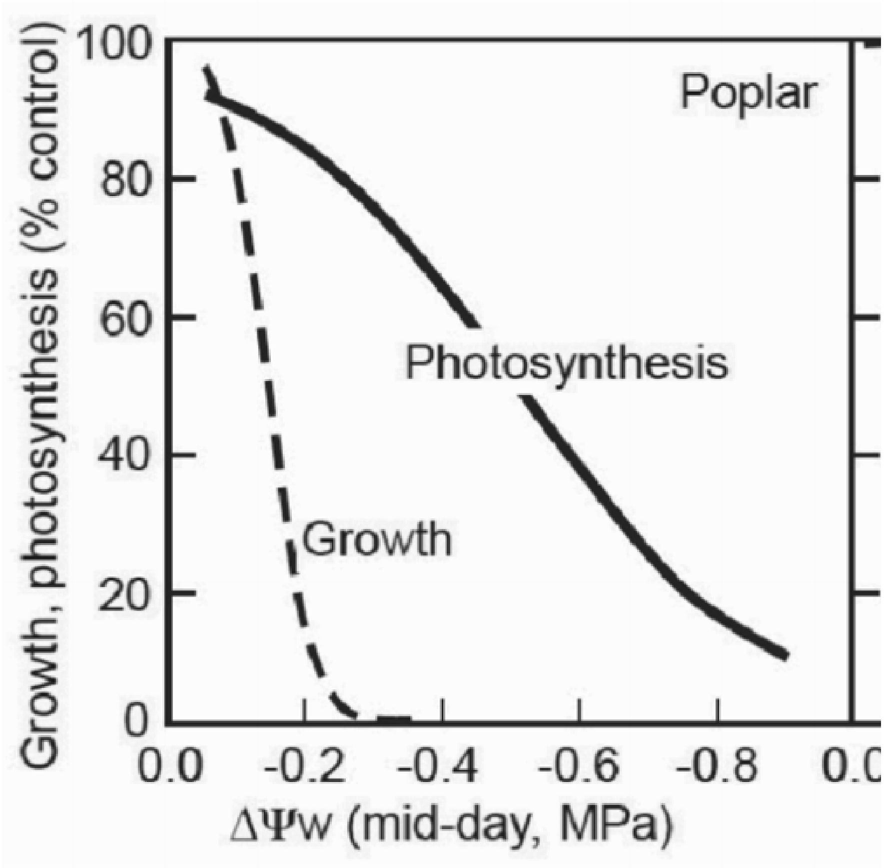
Source/sink controversy

Nova Acta Leopoldina NF *114*, Nr. 391, 273–283 (2013)

Growth Controls Photosynthesis – Mostly

Christian KÖRNER ML (Basel)

Water availability constrains growth more than photosynthesis



Körner (2003)

Low temperature constrains growth more than photosynthesis

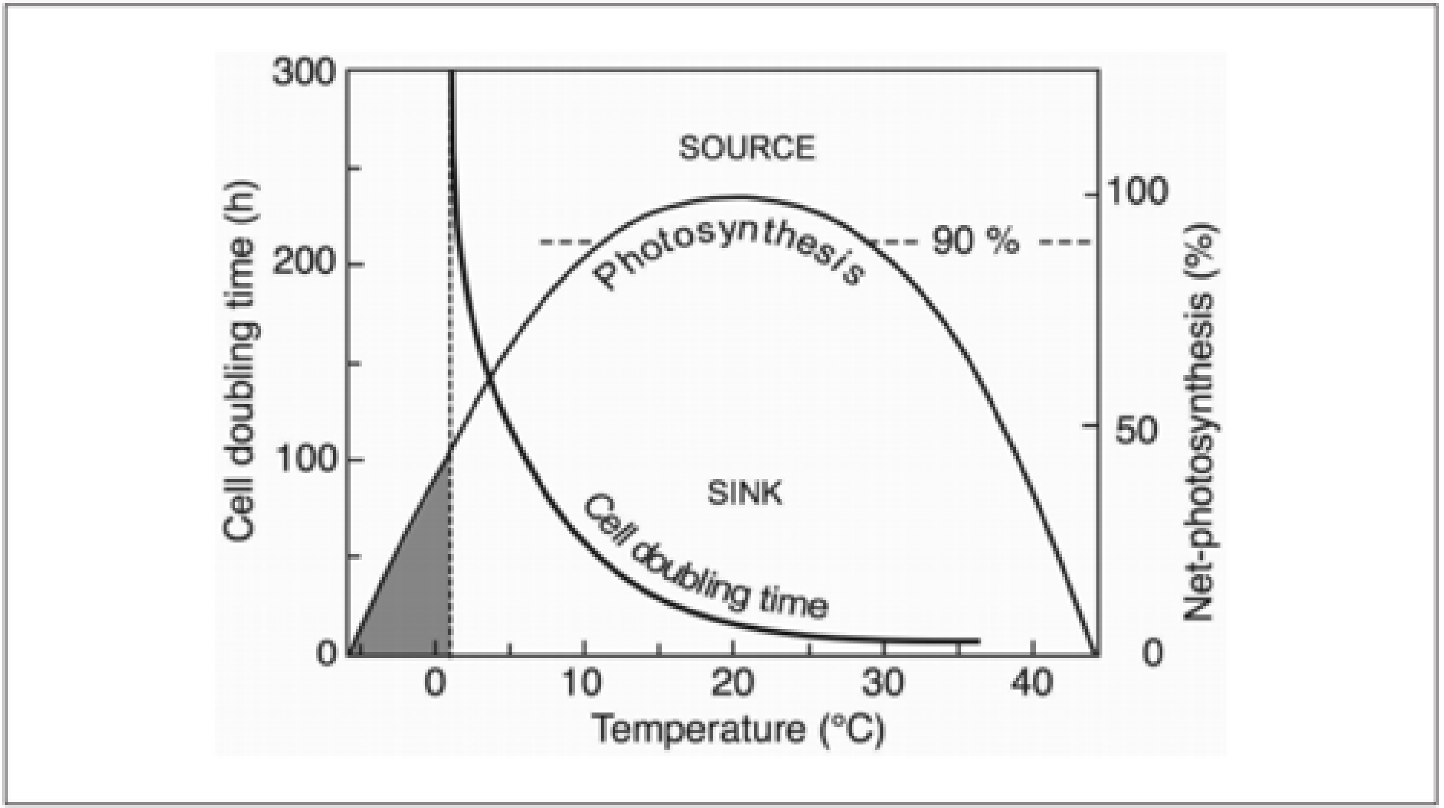


Fig. 3 The discrepancy between temperature dependency of source activity, i.e. net photosynthetic CO_2 uptake (relative scale) and sink activity, i.e. meristematic activity (tissue formation expressed as cell doubling time).

Körner (2003)

So under low resource availability, we might expect low growth to result in reduced photosynthesis, as more photosynthesis would be wasteful

Overarching thesis – photosynthesis matches sink strength

Overarching thesis – photosynthesis matches sink strength

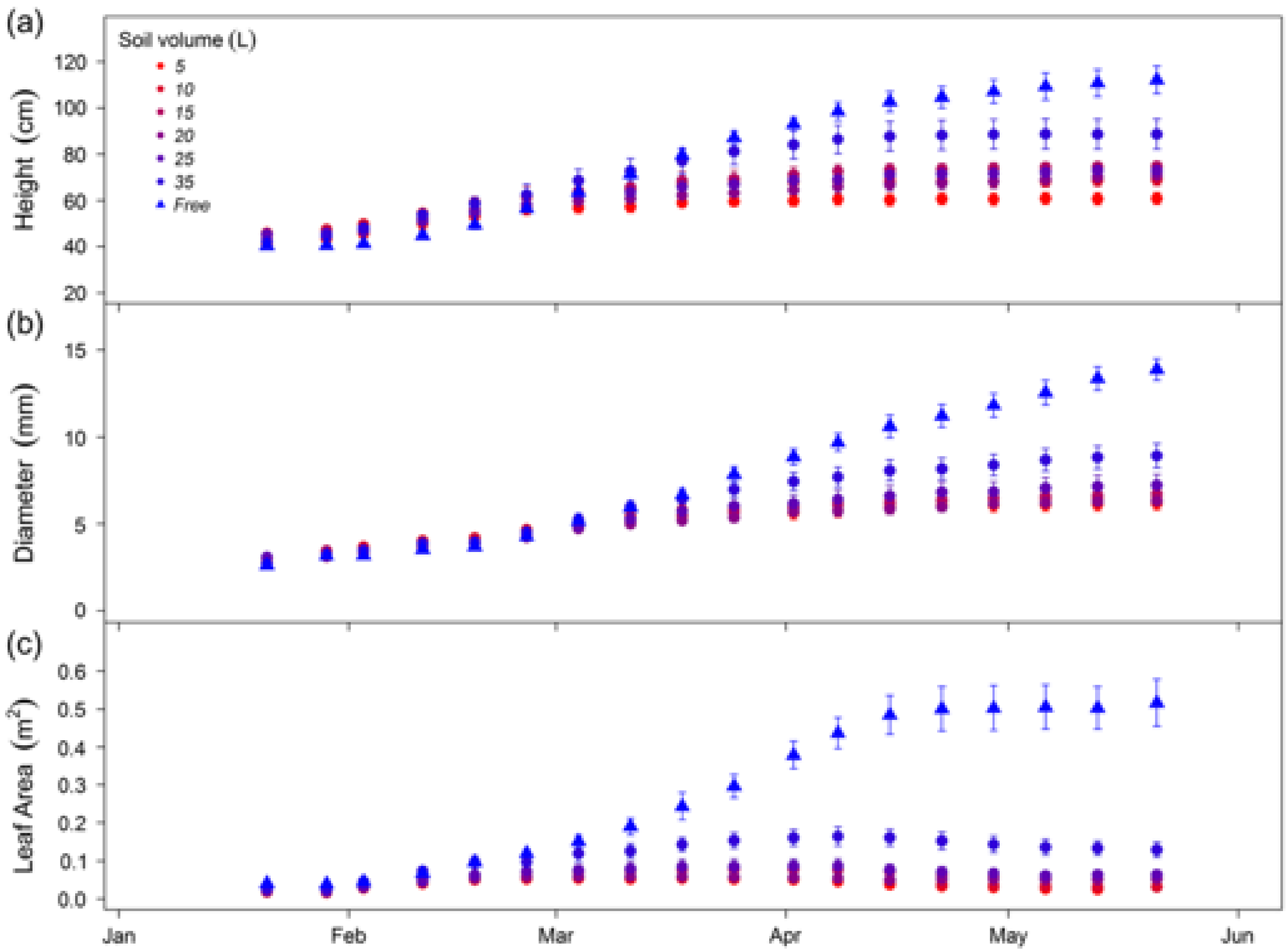
How could you test this??

Reduced growth due to belowground sink limitation is not fully explained by reduced photosynthesis FREE

Courtney E. Campany, Belinda E. Medlyn, Remko A. Duursma

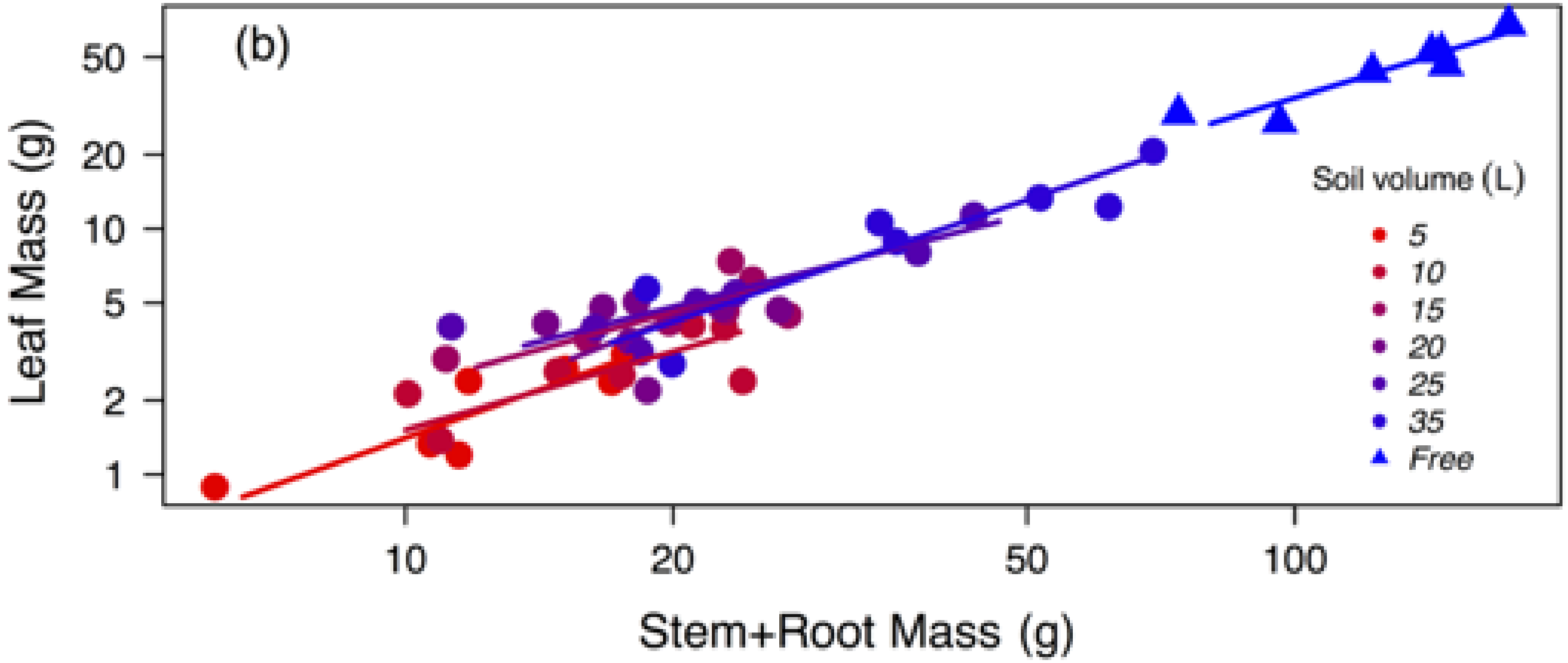
Tree Physiology, Volume 37, Issue 8, 1 August 2017, Pages 1042–1054,
https://doi.org/10.1093/treephys/tpx038

Published: 04 April 2017 **Article history** ▾



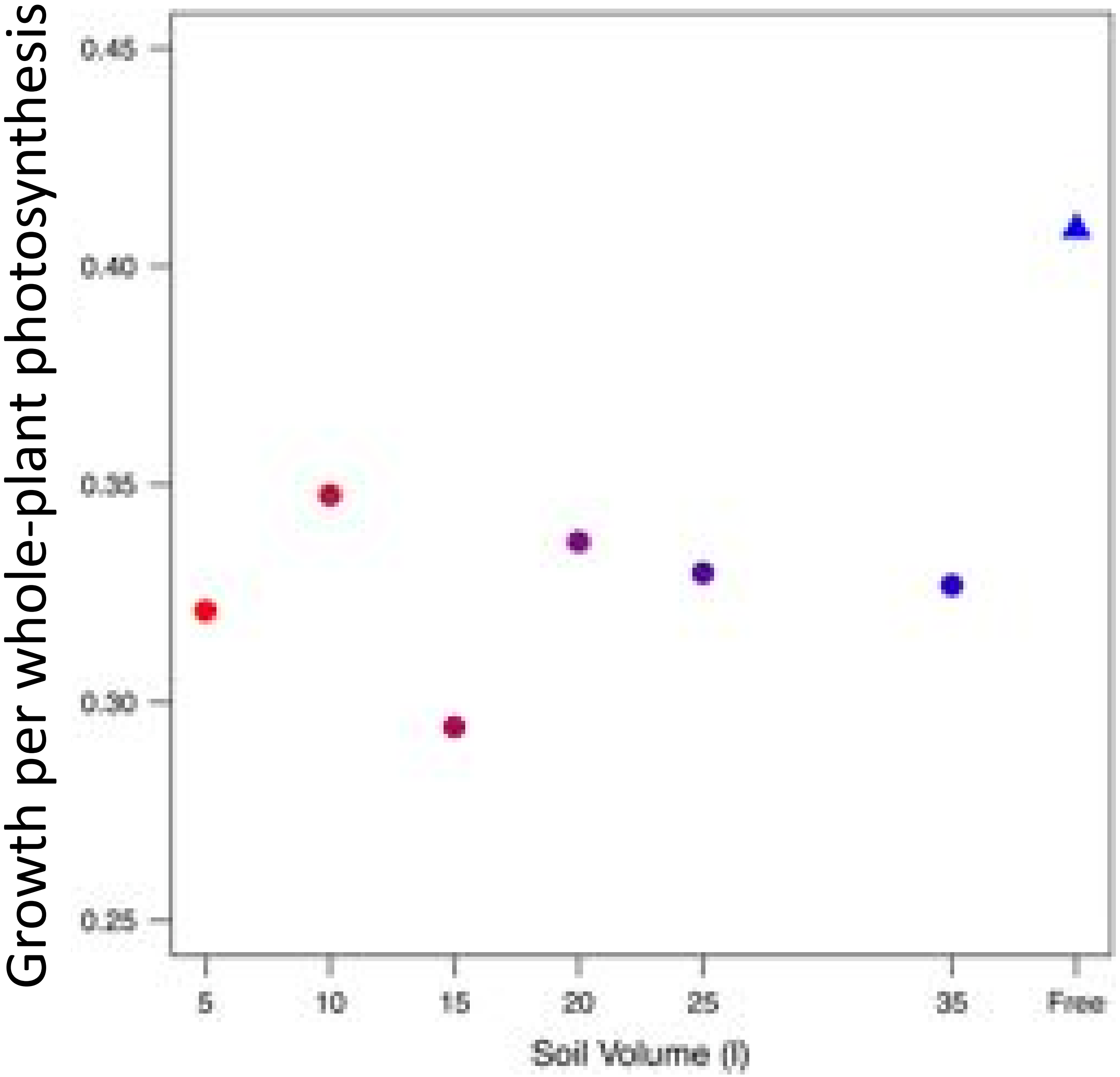
Plant growth decreased by 84%

Campany et al. (2017)



Allocation was similar

Campany et al. (2017)



Photosynthesis only decreased by 26%, but there was a big change in carbon use efficiency

Campany et al. (2017)

Conclusion: sink strength does influence photosynthesis, but this does not fully explain sink-limited growth reductions

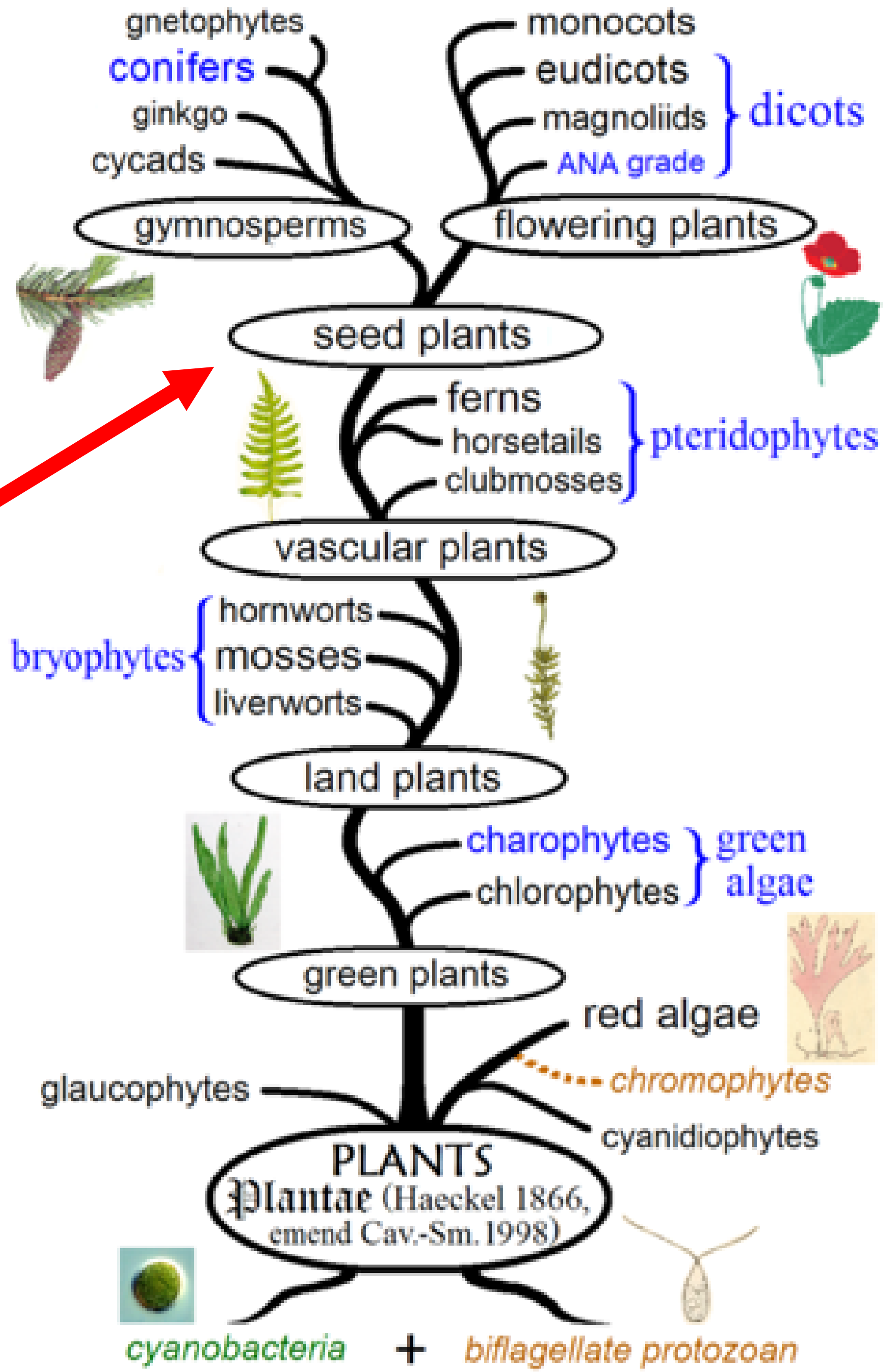
Some things that need considered

- Photosynthetic acclimation
- Whole-plant- versus leaf-level photosynthesis
- Within-leaf and whole-plant allocation of nutrients

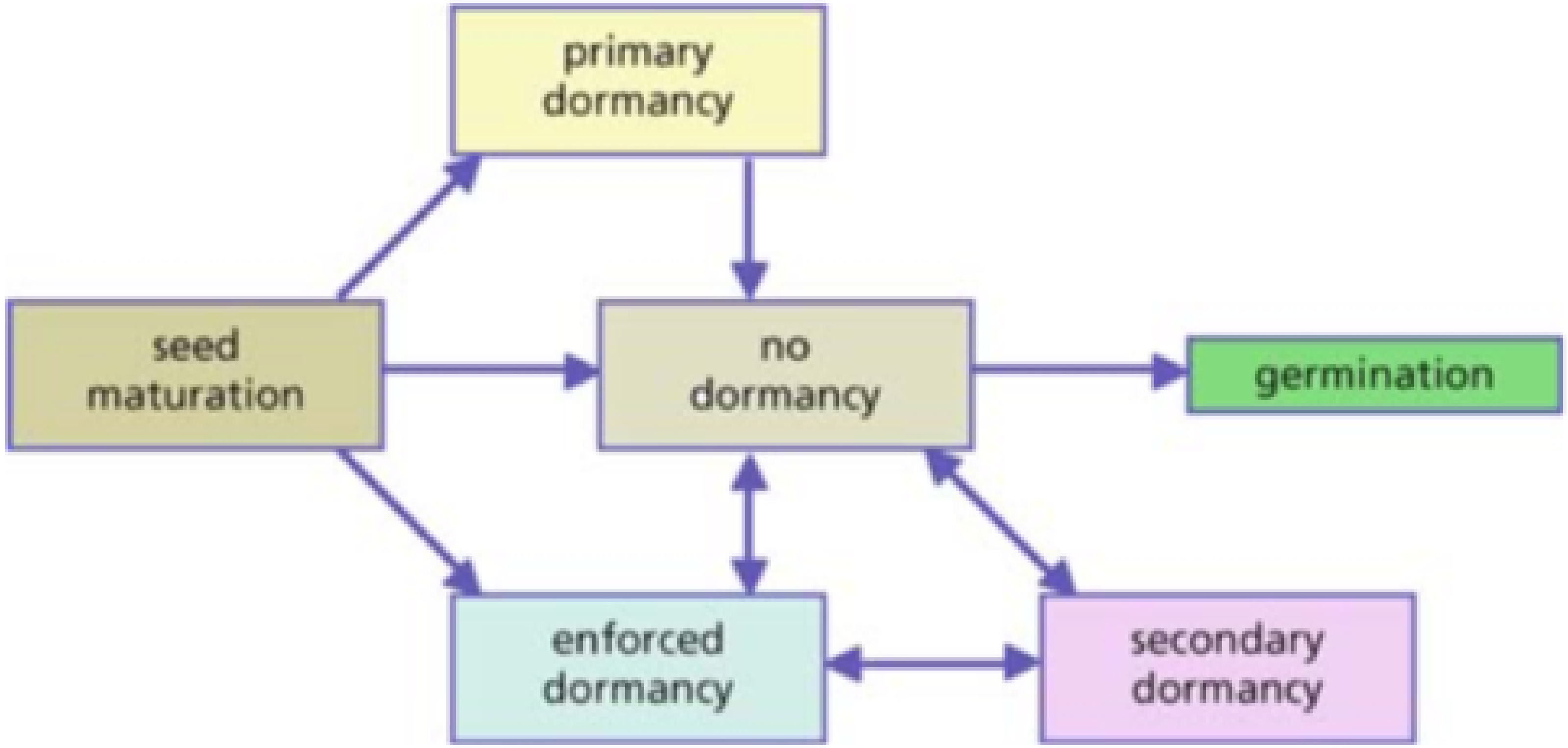
Life cycles

Seeds and germination

Not all plants have seeds! What’s the benefit?



Dormancy - not all seeds germinate immediately



Two primary benefits of dormancy

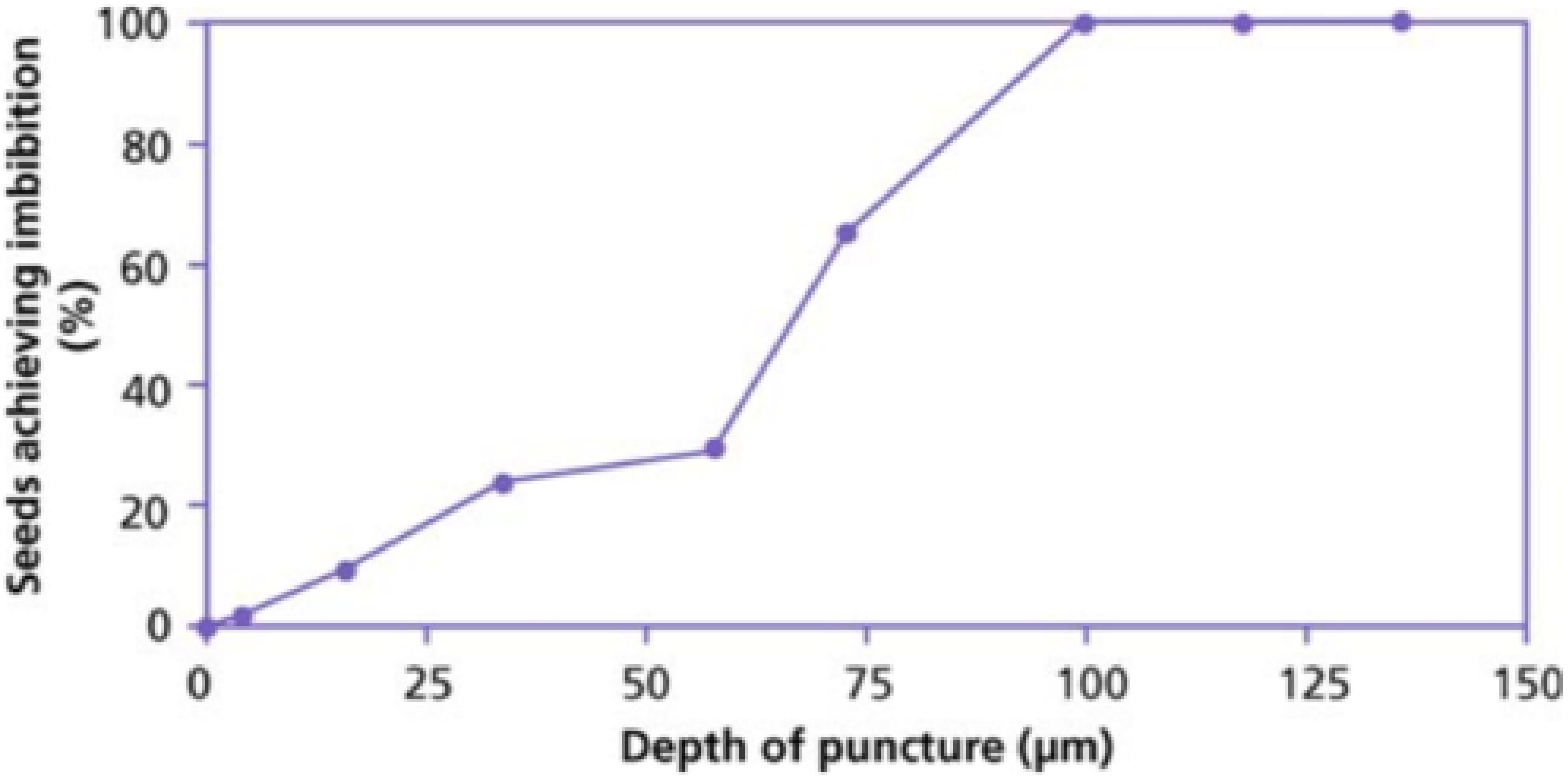
1. Avoid poor growth conditions
2. Avoid competition

Two primary benefits of dormancy

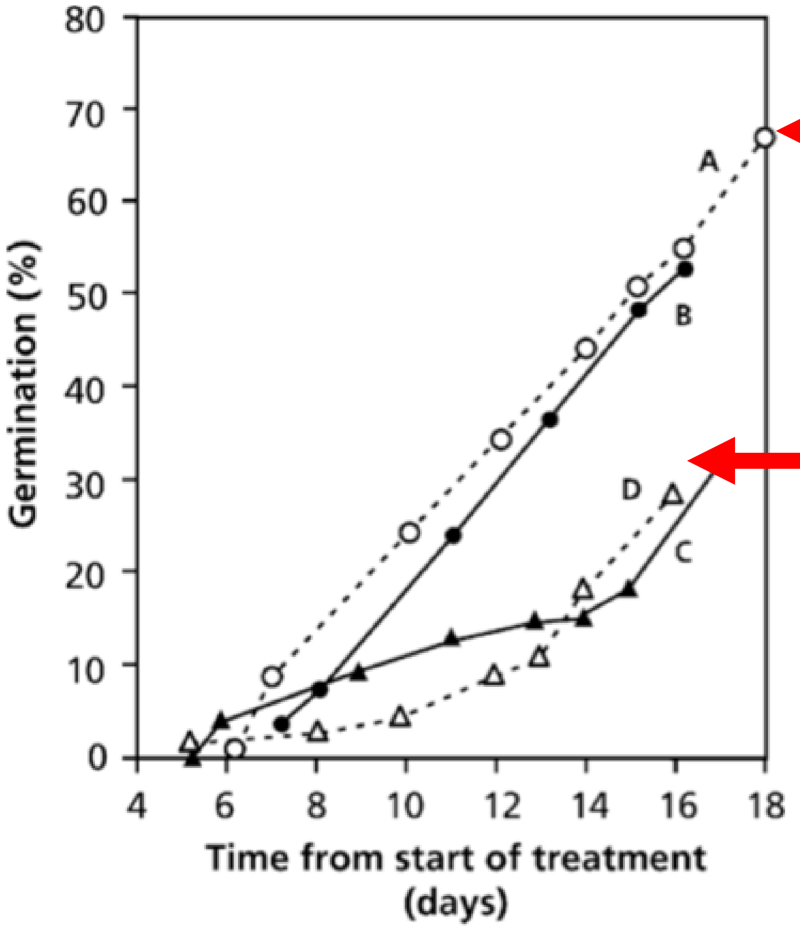
1. Avoid poor growth conditions
2. Avoid competition

Knowing this, what would be the important cues to respond to? (Let’s make a list)

Water – some plants will only imbibe after seed coat is worn down



Water soluble inhibitors can also prevent germination during dry times



93 hours of watering

24 hours of watering

Light influences germination in 3 ways

1. A total light requirement
2. Intensity and duration
3. Spectral compositions of light

Light influences germination in 3 ways

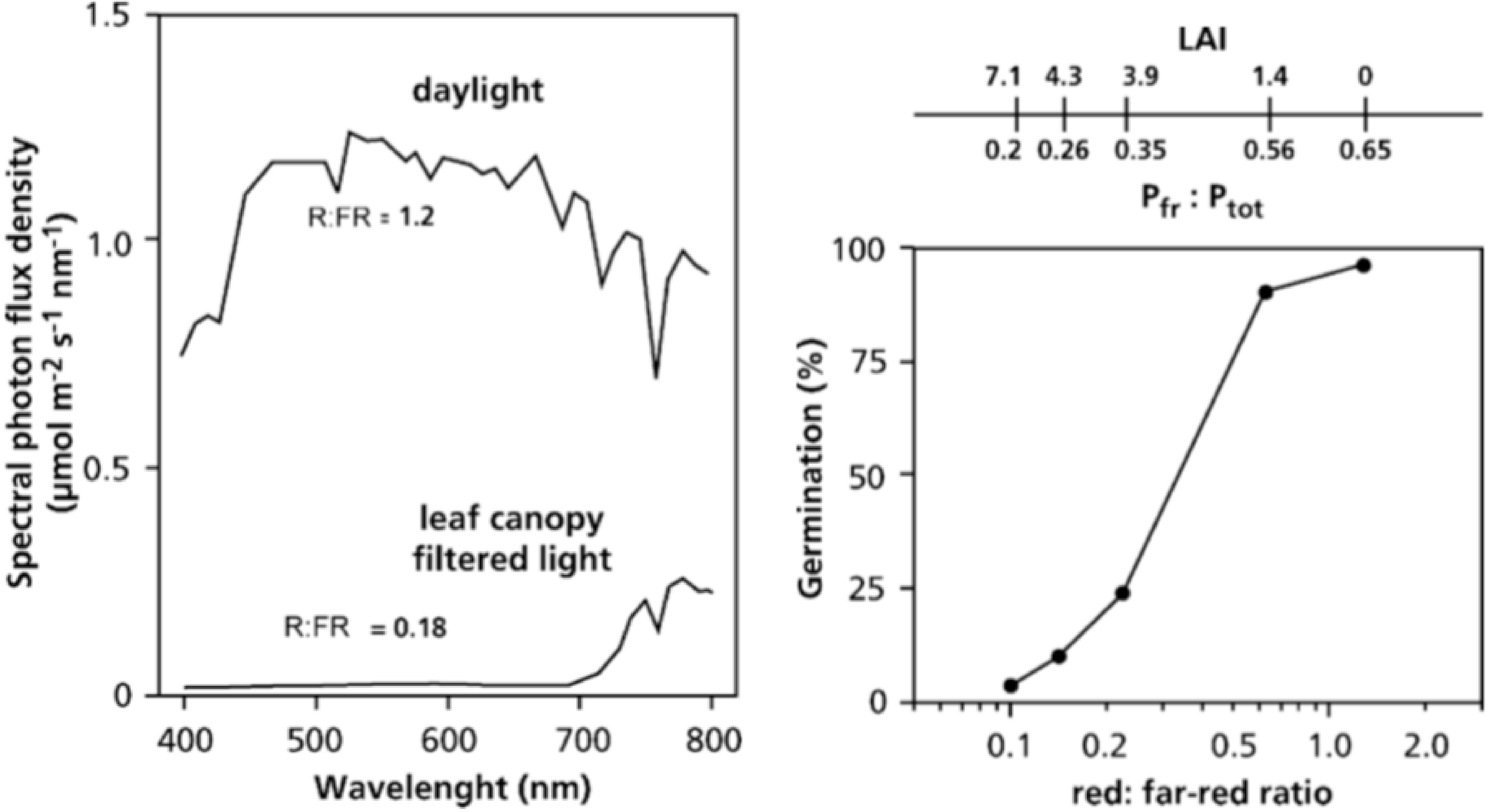
1. A total light requirement
   - Avoid being buried too deep in the soil (fatal germination)
   - When soil is turned over, seeds emerge
2. Intensity and duration
3. Spectral compositions of light

Light influences germination in 3 ways

1. A total light requirement
2. Intensity and duration
    - Take advantage of disturbance
3. Spectral compositions of light

Light influences germination in 3 ways

1. A total light requirement
2. Intensity and duration
3. Spectral compositions of light
    - Plants can sense what is happening above them!



1.5
1.0
0.5
0
daylight
R:FR = 1.2
leaf canopy filtered light
R:FR = 0.18
Spectral photon flux density (μmol m-2 s-1 nm-1)
400
500
600
700
800
Wavelenght (nm)
LAI
7.1
4.3
3.9
1.4
0
0.2
0.26
0.35
0.56
0.65
Pfr : Ptot
Germination (%)
100
75
50
25
0
0.1
0.2
0.5
1.0
2.0
red: far-red ratio

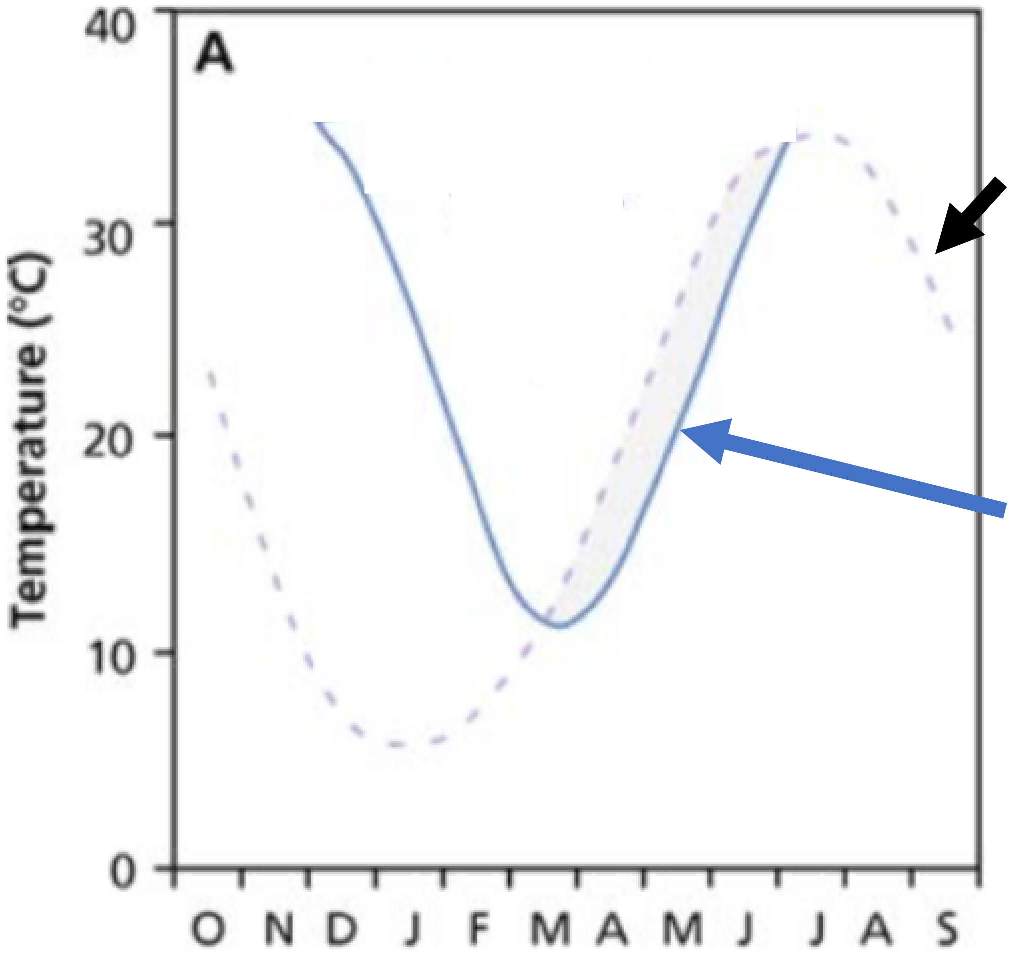
Temperature influences dormancy in two ways

1. Absolute temperature
2. Temperature fluctuations

Temperature influences dormancy in two ways

1. Absolute temperature
   - Cue to germinate at optimal time in season
2. Temperature fluctuations

Summer Annual

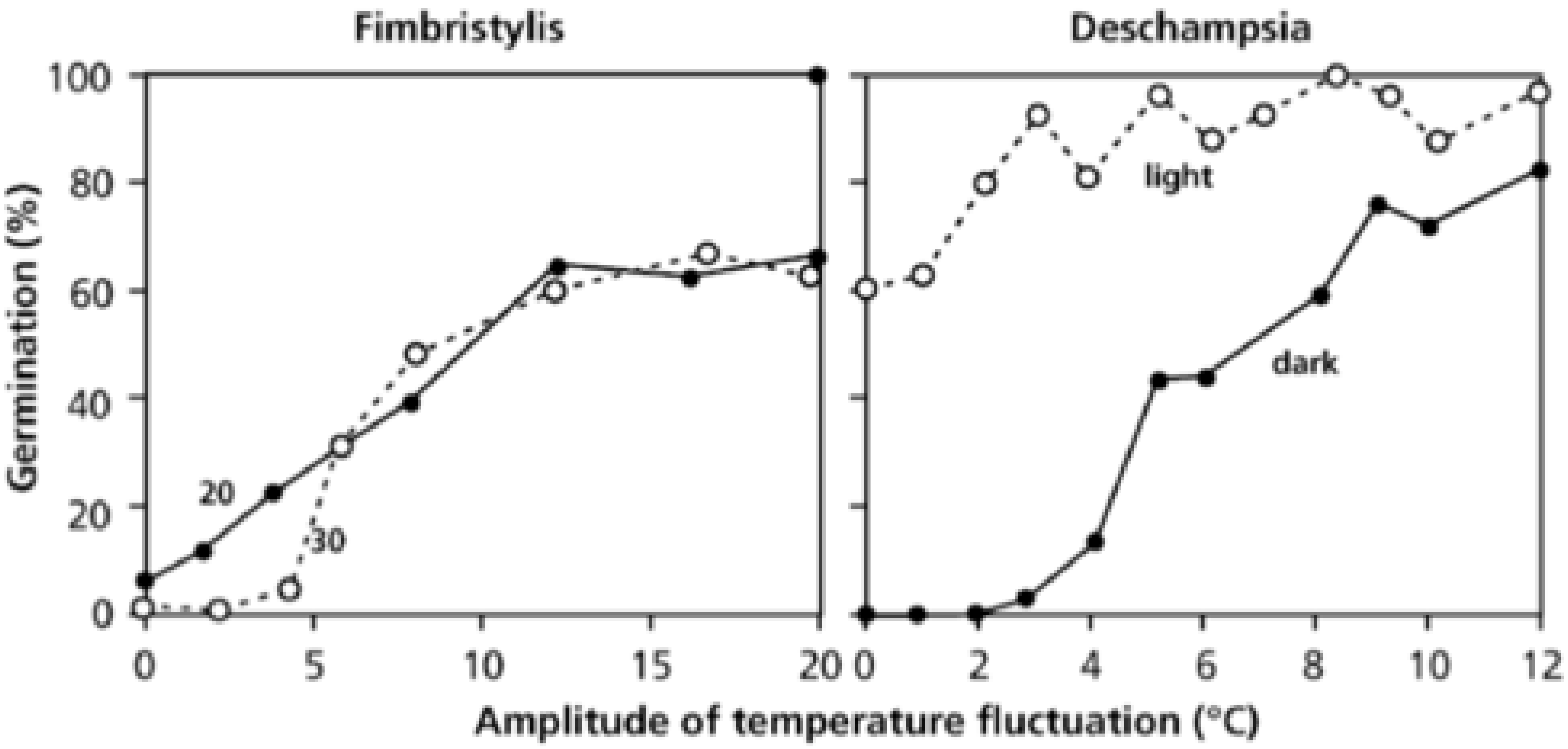


Maximum T in field

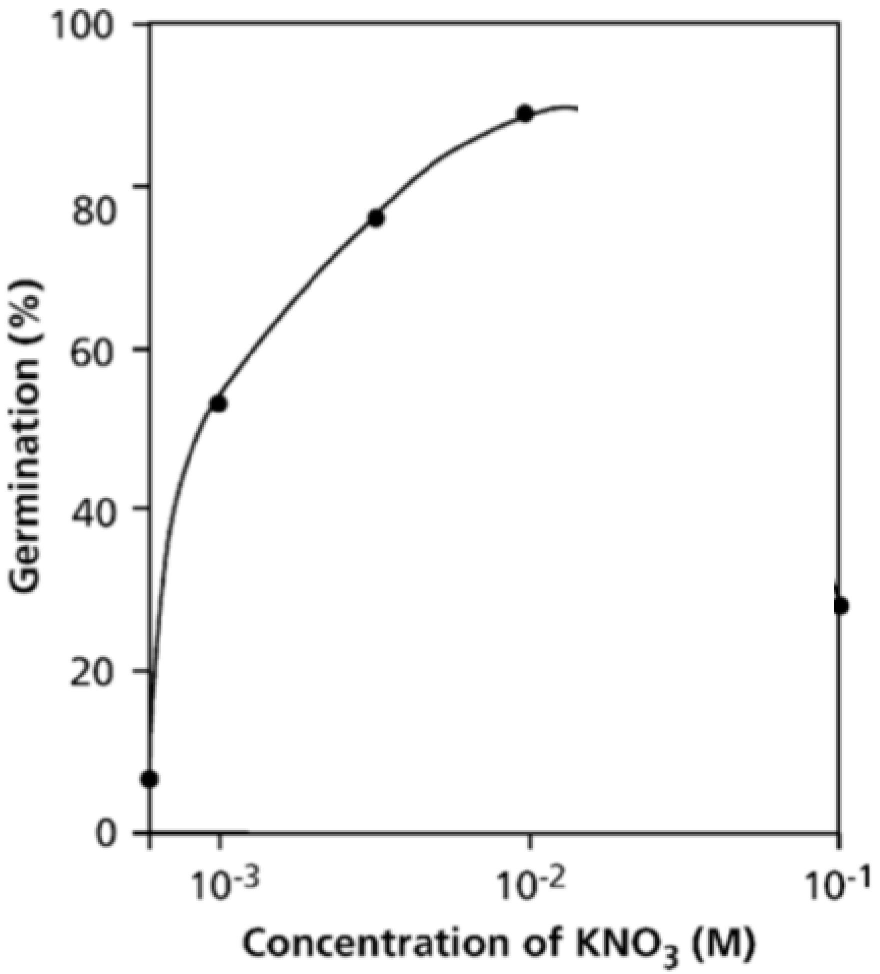
Minimum T for germination

Temperature influences dormancy in two ways

1. Absolute temperature
2. Temperature fluctuations
   - Mechanism to sense soil depth

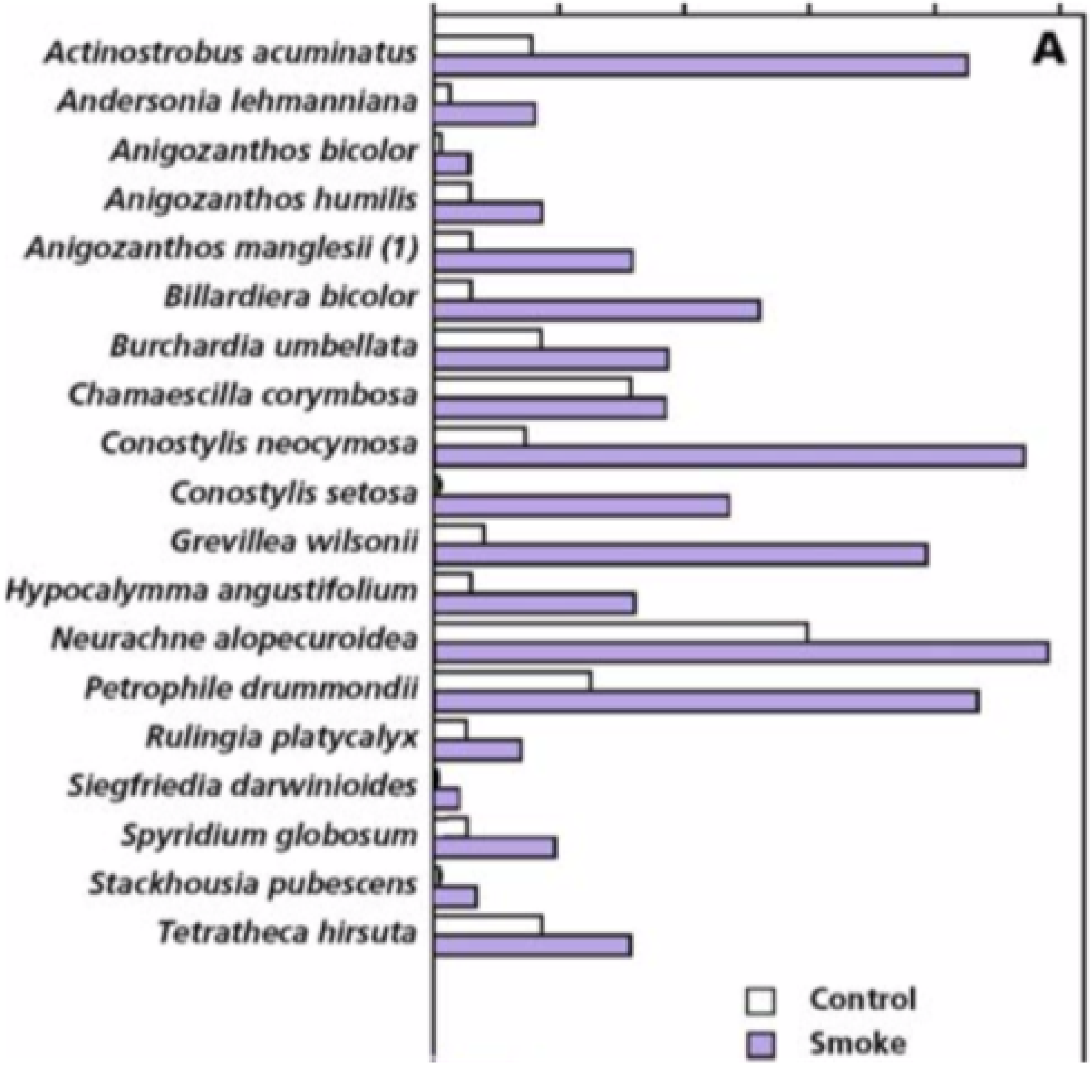

Fimbristylis
Deschampsia
Germination (%)
100
80
60
40
20
0
20
30
0
5
10
15
20
light
dark
0
2
4
6
8
10
12
Amplitude of temperature fluctuation (°C)

Presence of nitrate can signal competition



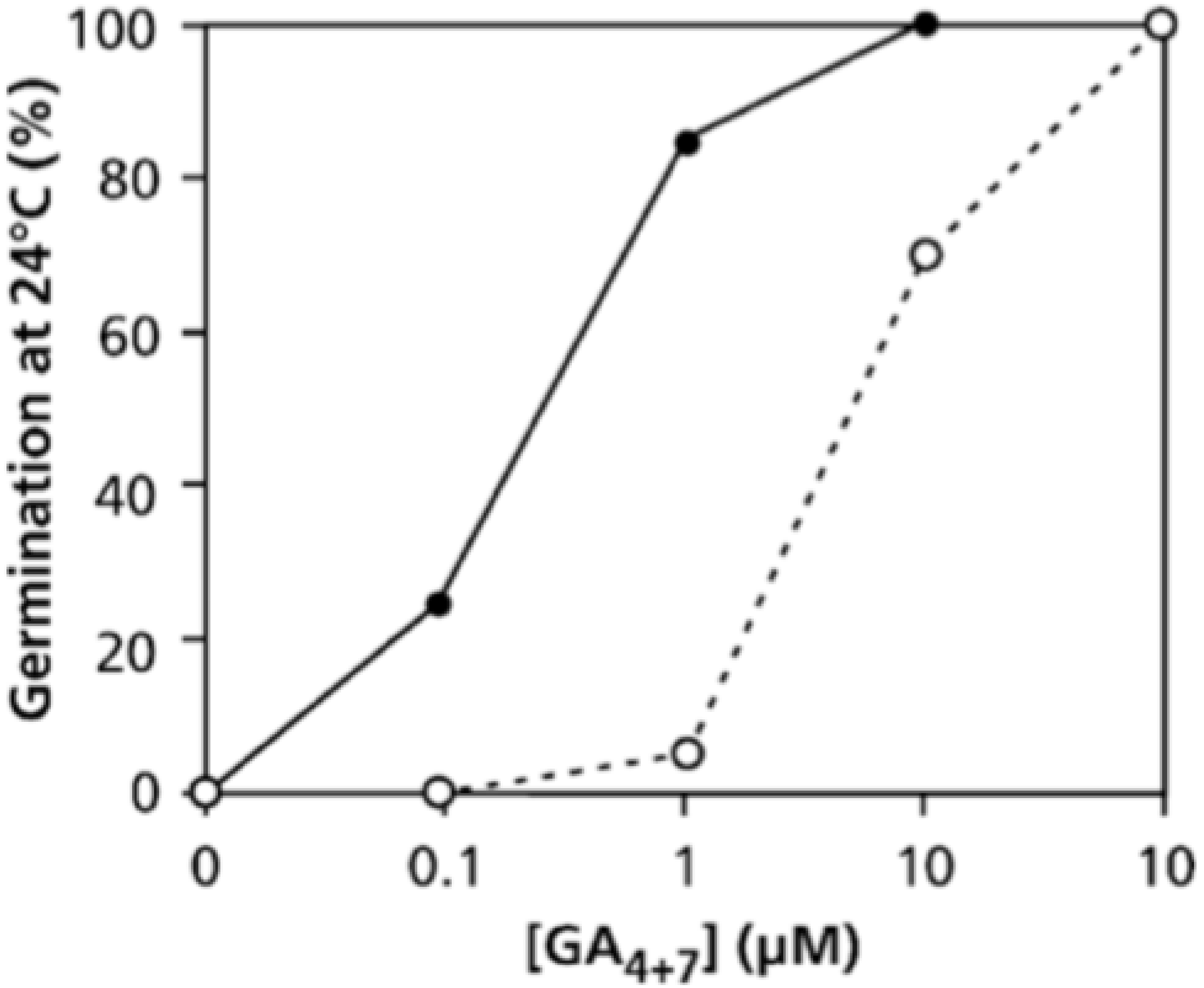
More NO_3 = less competition

Smoke can also enhance germination



Mechanism for dormancy release

Dormancy release signals: an increase in the ratio of giberrelic acid (GA) to absciscic acid (ABA)



Summary

TABLE 1. A summary of the possible ecological significance of environmental factors involved in breaking seed dormancy.

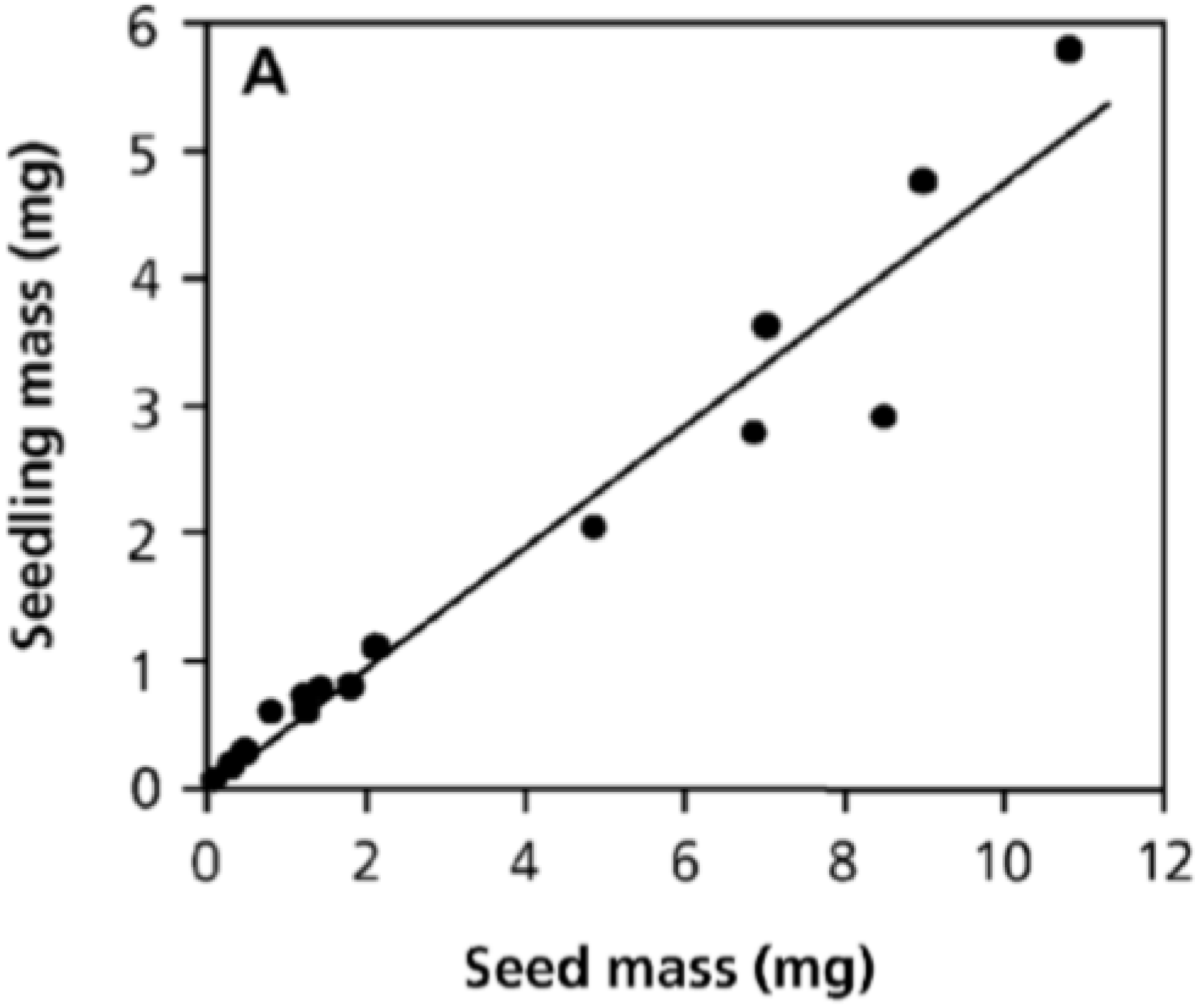
Environmental factor	Ecological role
Light	Gap detection
	Sensing depth in soil
Diurnal temperature fluctuation	Increasing longevity in seed bank
	Gap detection
	Sensing depth in soil and water
Nitrate	Gap detection
	Nutrient availability
Rain event in desert	Detection of water availability
Smoke	Response to fire
High temperature	Response to fire
Seasonal temperature regime	Detection of suitable season
	Increasing longevity in soil
Time	Avoidance of unsuitable season
	Spreading risks in time

Seedling/juvenile phase

Being a seedling is tough

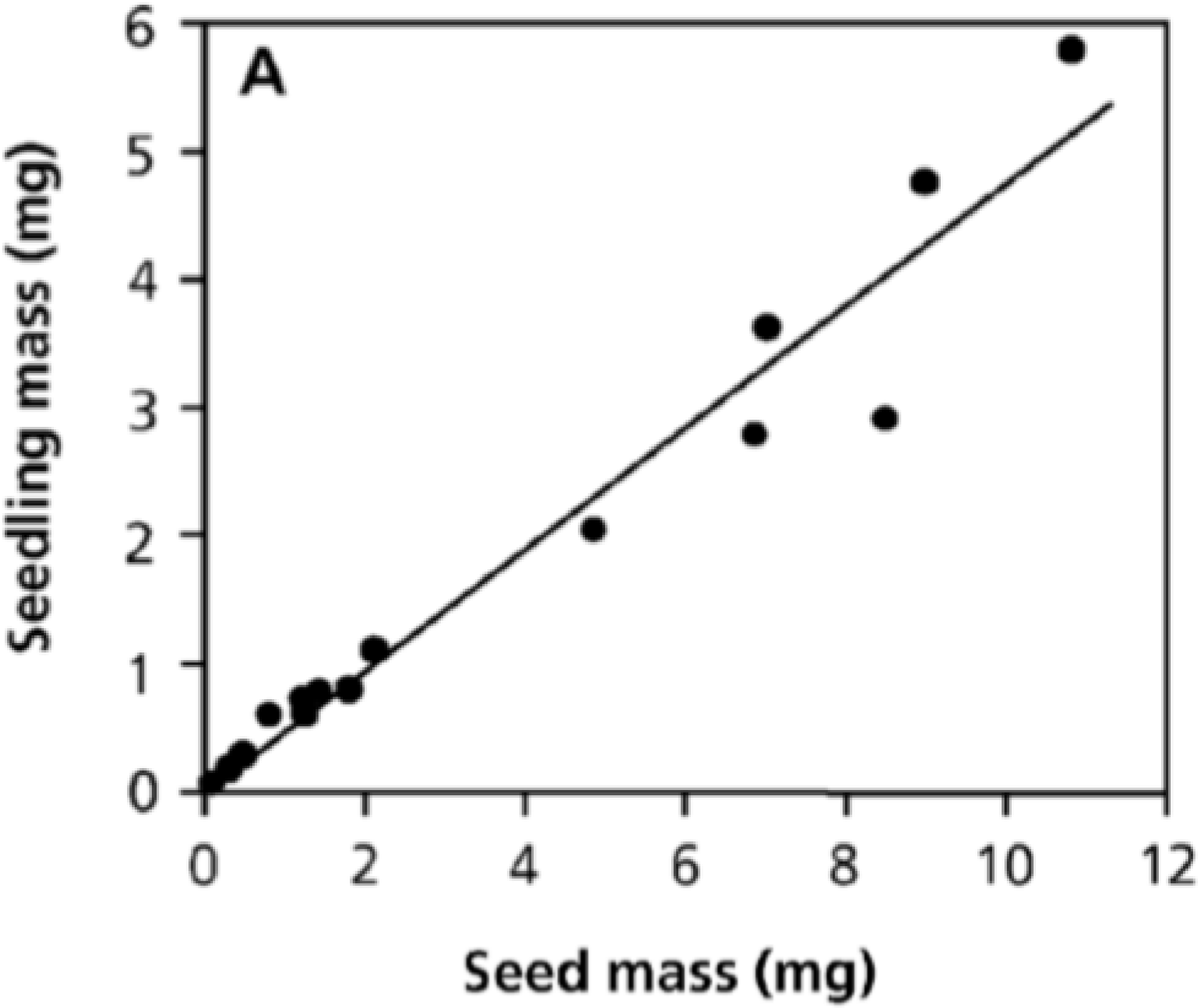
- Low light
- Prone to desiccation
- Resources determined by seed size

Seed size trade-offs

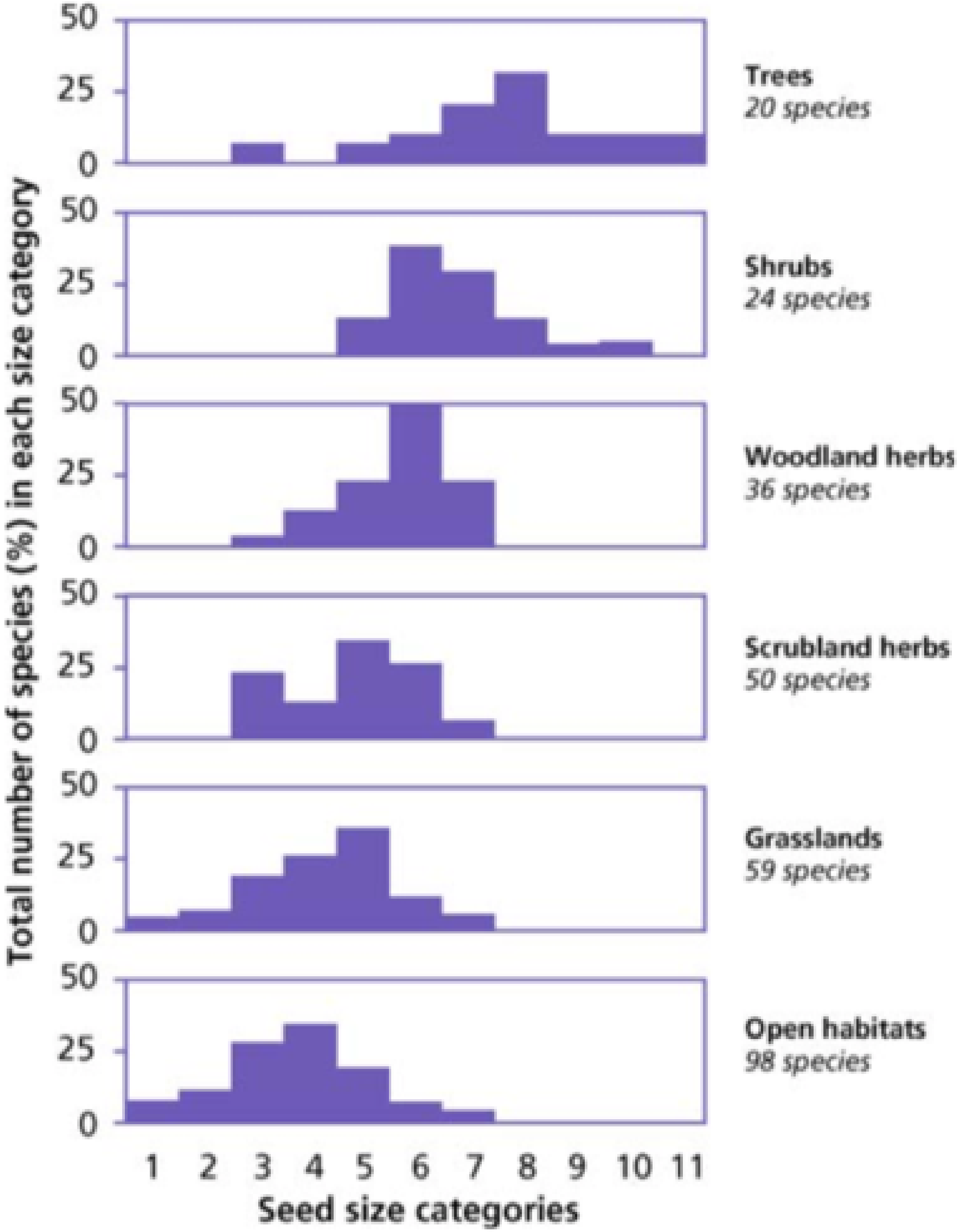


Bigger seeds = bigger seedlings

Seed size trade-offs



What's the tradeoff??



Total number of species (%) in each size category
50
25
0
Trees
20 species
Shrubs
24 species
Woodland herbs
36 species
Scrubland herbs
50 species
Grasslands
59 species
Open habitats
98 species
1 2 3 4 5 6 7 8 9 10 11
Seed size categories

Reproductive phase

Cost of reproduction

- Flowering and fruiting: up to 30% of NPP
  - Median: 10%
- In some cases, can require large storage reserves
- Trade-off between vegetative and reproductive growth

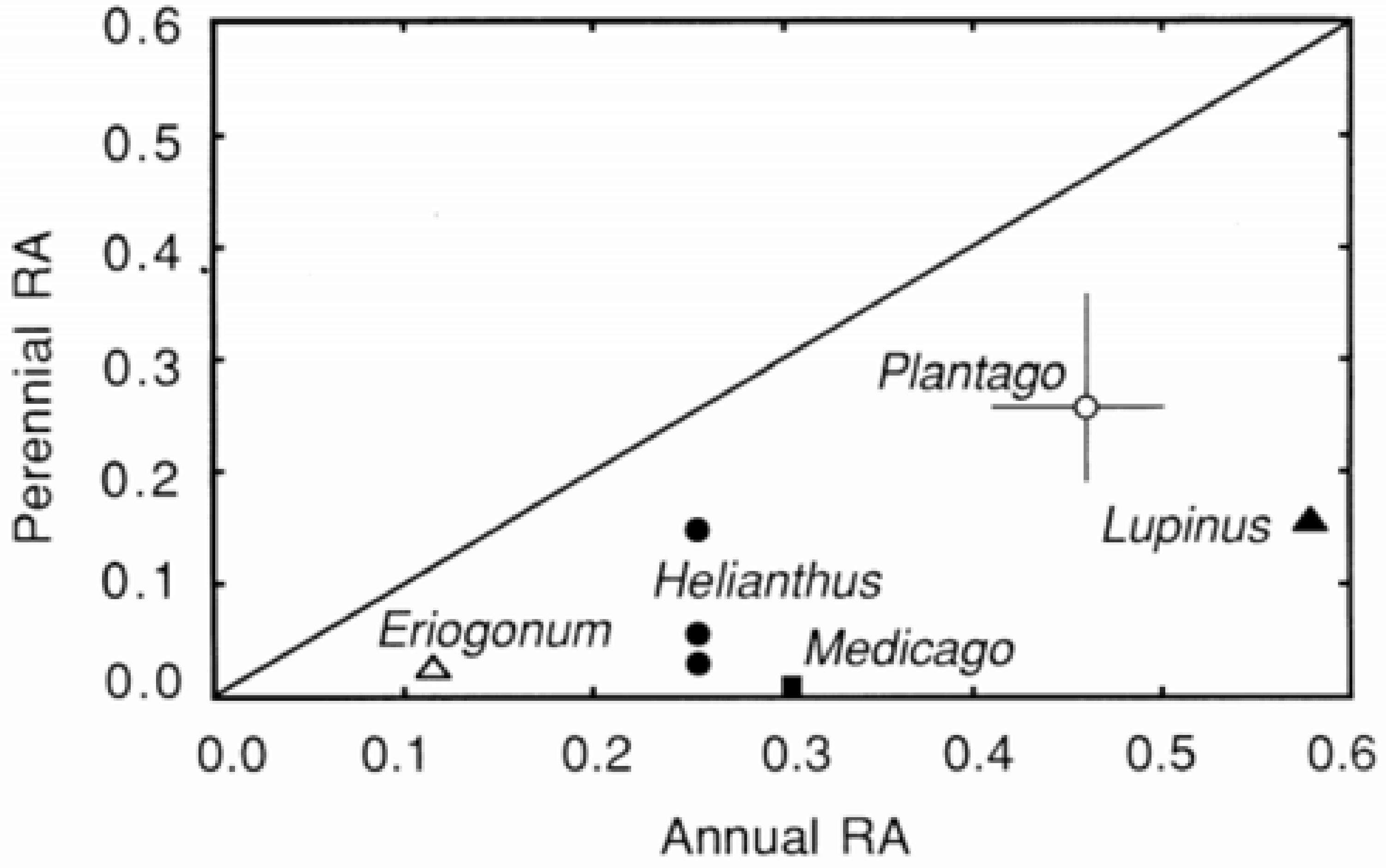


Figure 2. Relative reproductive allocation (RA) in congeneric or conspecific annuals and perennials. For *Lupinus*, *Medicago*, *Helianthus*, and *Eriogonum* the data are in units reproductive dry mass/total dry mass. For *Plantago*, the data are in units mg seeds/ 2 cm^2 leaf area. The *Lupinus* data are two-year means of naturally growing plants (one annual, one perennial species) (Pitelka 1977). The *Helianthus* data represent one annual and three perennial species (Gaines et al. 1974). The *Medicago* data represent one annual and one perennial species (Turkington and Cavers 1978). The *Plantago* data represent the mean and range of four perennial species and nine annual species (Primack 1979). The *Eriogonum* data reflect the annual and perennial subspecies of *E. inflatum*. Source: Chiariello, unpublished data.

Bazzaz et al. (1987)

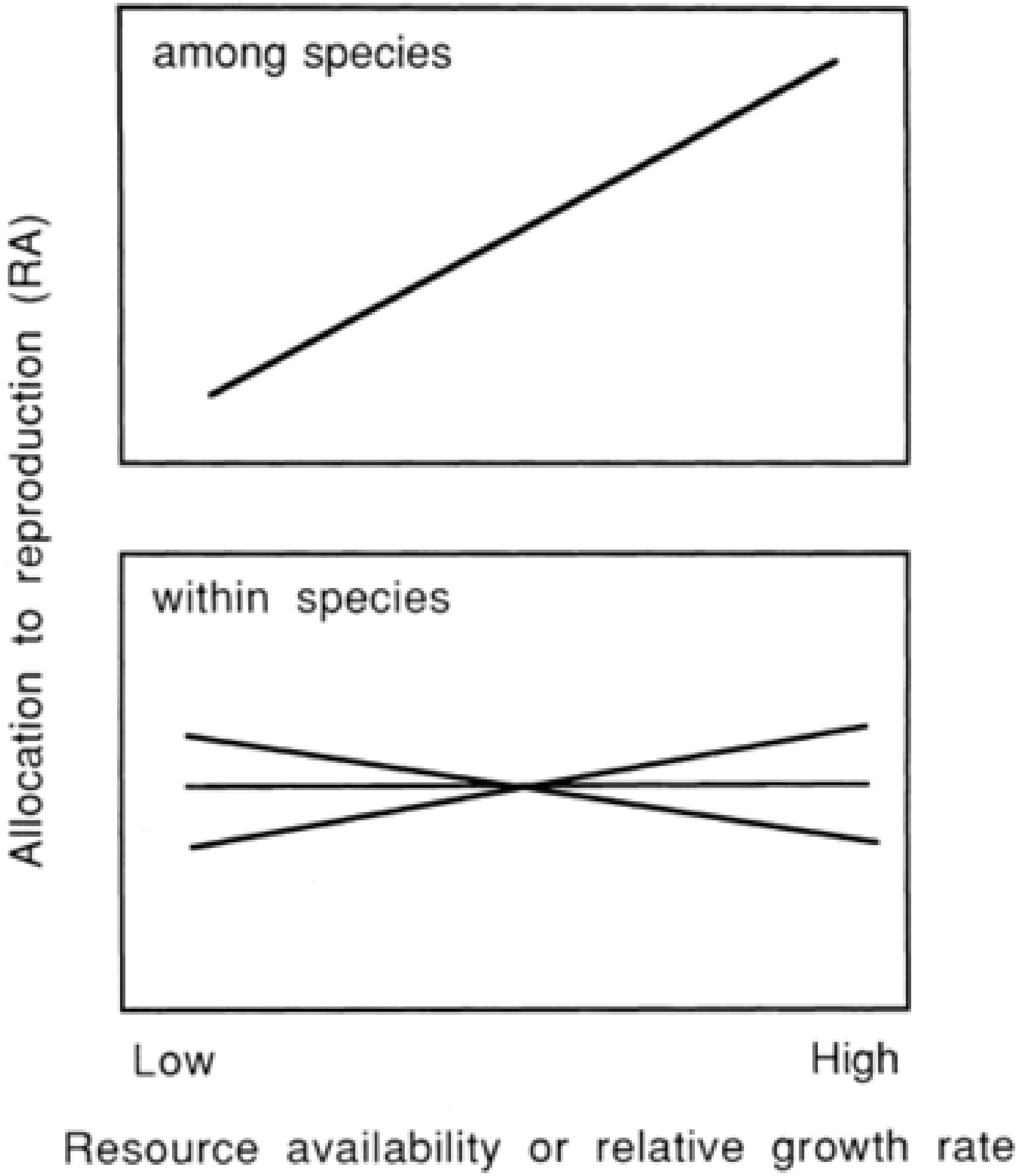


Figure 3. General trend in reproductive allocation (RA) among and within species as a function of resource availability, which we assume is related to plant relative growth rate. Among species, reproductive allocation increases with resource availability, partly because of the relationship between life history and habitat. Within species, reproductive allocation can increase or decrease with relative growth rate.

Bazzaz et al. (1987)

Generally the cost of female structures is greater than males structures

- Carbon allocation to female flowers can be 3x a male flower (Lambers book)
  - Nitrogen difference may be even greater

Some plants can reproduce vegetatively

- Carbon cost to reproduce sexually can be 10,000-fold greater than asexual reproduction in some places
- Why don't all plants reproduce asexually?

Larrea tridentata

Life cycle diversity

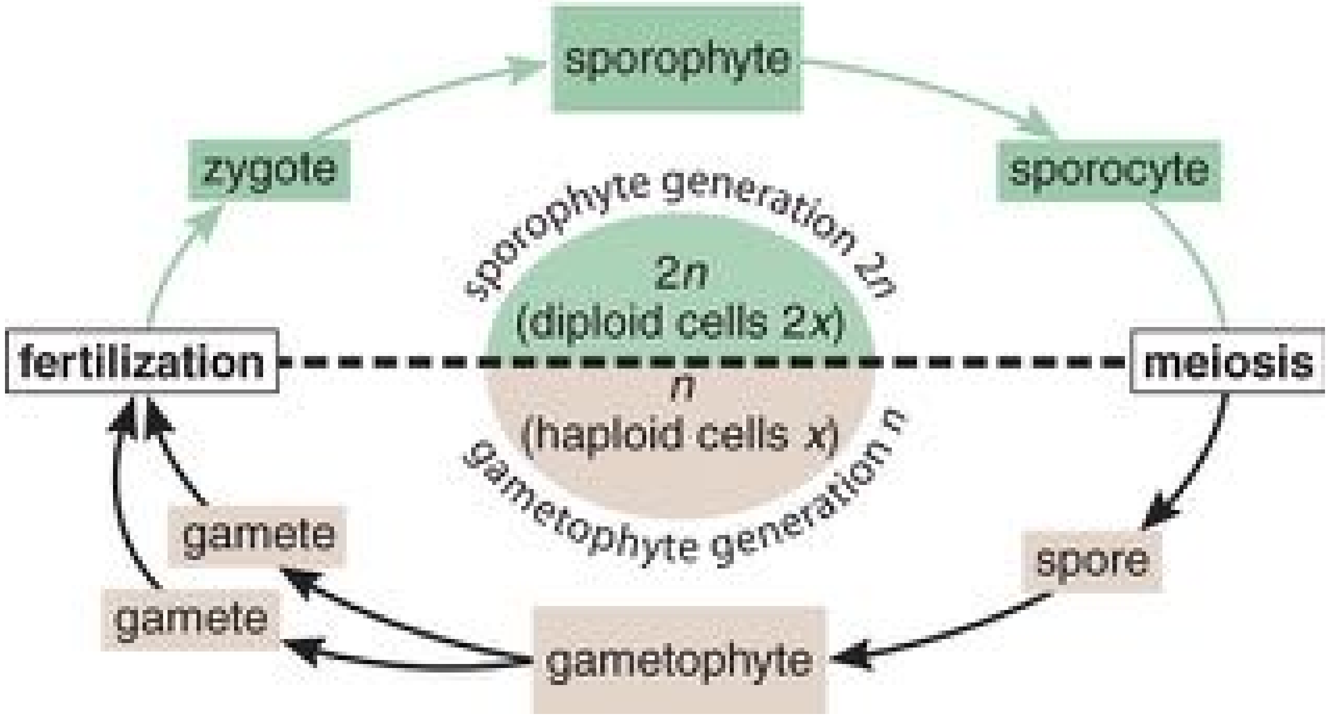
Timing of development

1. Annuals
2. Perennials
3. Bi-ennials

Where would you expect each to dominate?

Time spent as a gametophyte

- Bryophytes are gametophyte (1n) dominant
  - What's the advantage of sporophyte dominance?



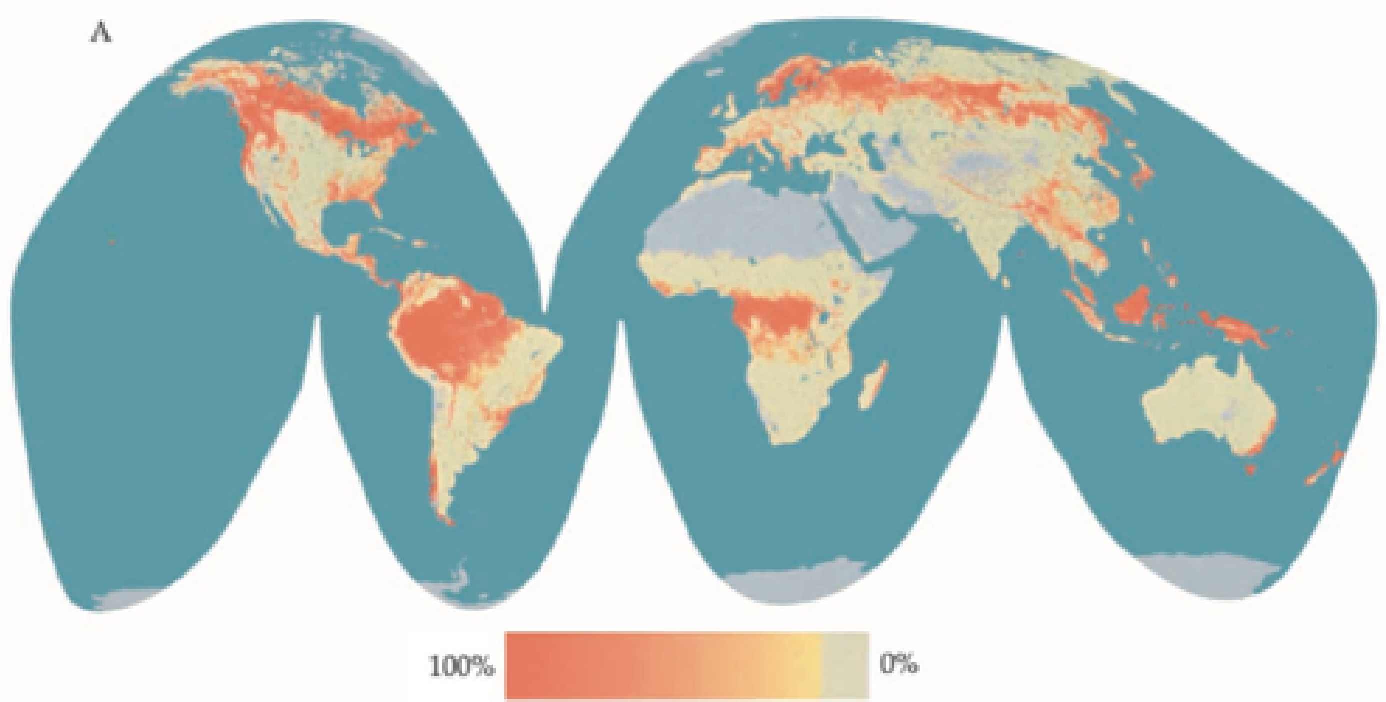
Phenology

What are the benefits of being deciduous or evergreen?

What are the costs of being deciduous or evergreen?

Bimodality of phenological strategies

- Many evergreens in high and equatorial latitudes, but not so many in mid latitudes



Evergreenness

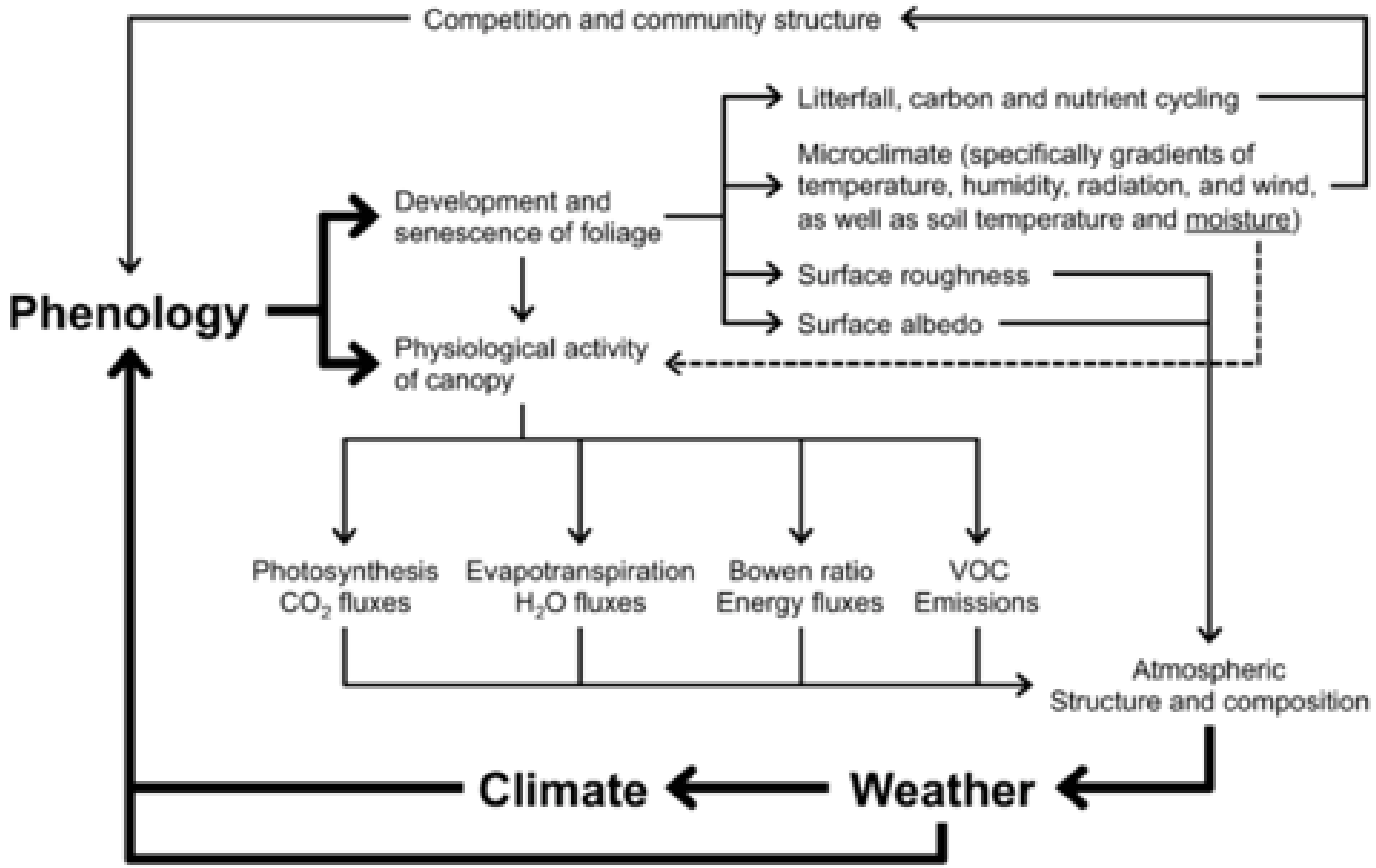
Givnish (2002)

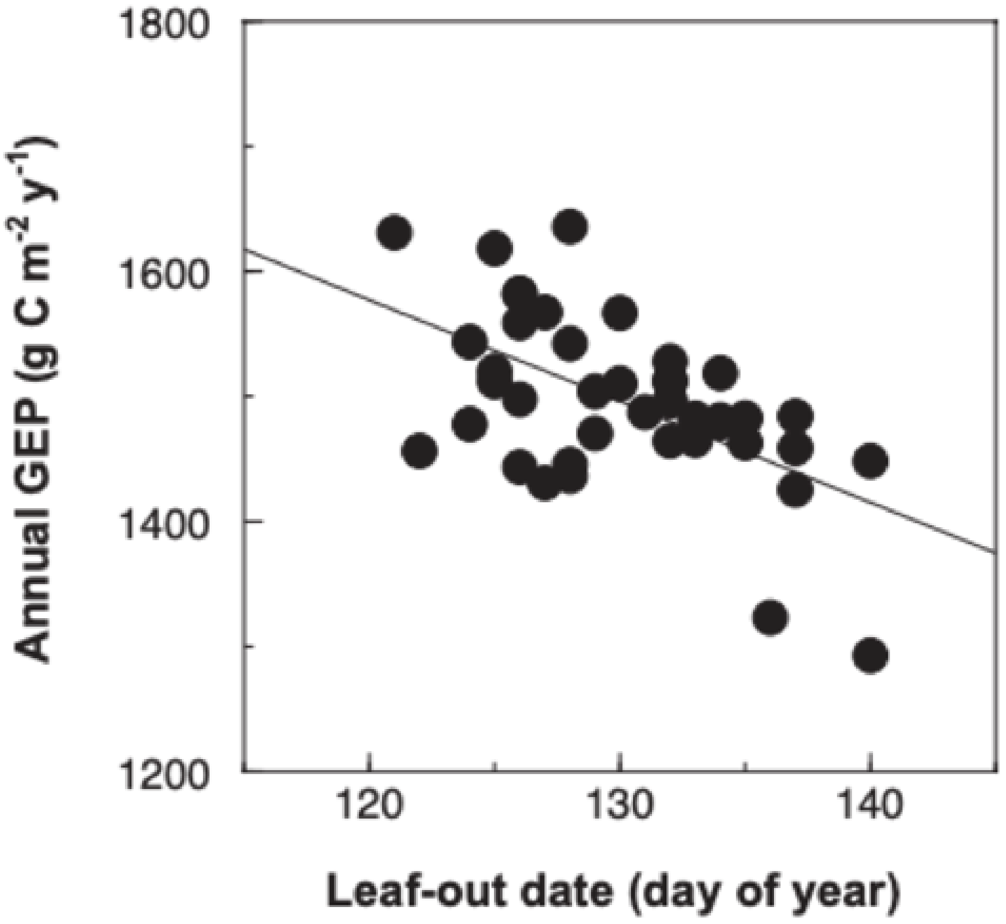
Givnish’s paradoxes

1. Why are boreal forests dominate by evergreens when they are exposed to intense thermal seasonality and winter drought?
2. Why do deciduous larches often dominate nutrient-poor bogs and swamps in the boreal zone?
3. Why do evergreen leaf exchanges dominate nutrient-poor sites in the seasonally dry subtropics?

Givnish (2002)

The importance of leaf phenology

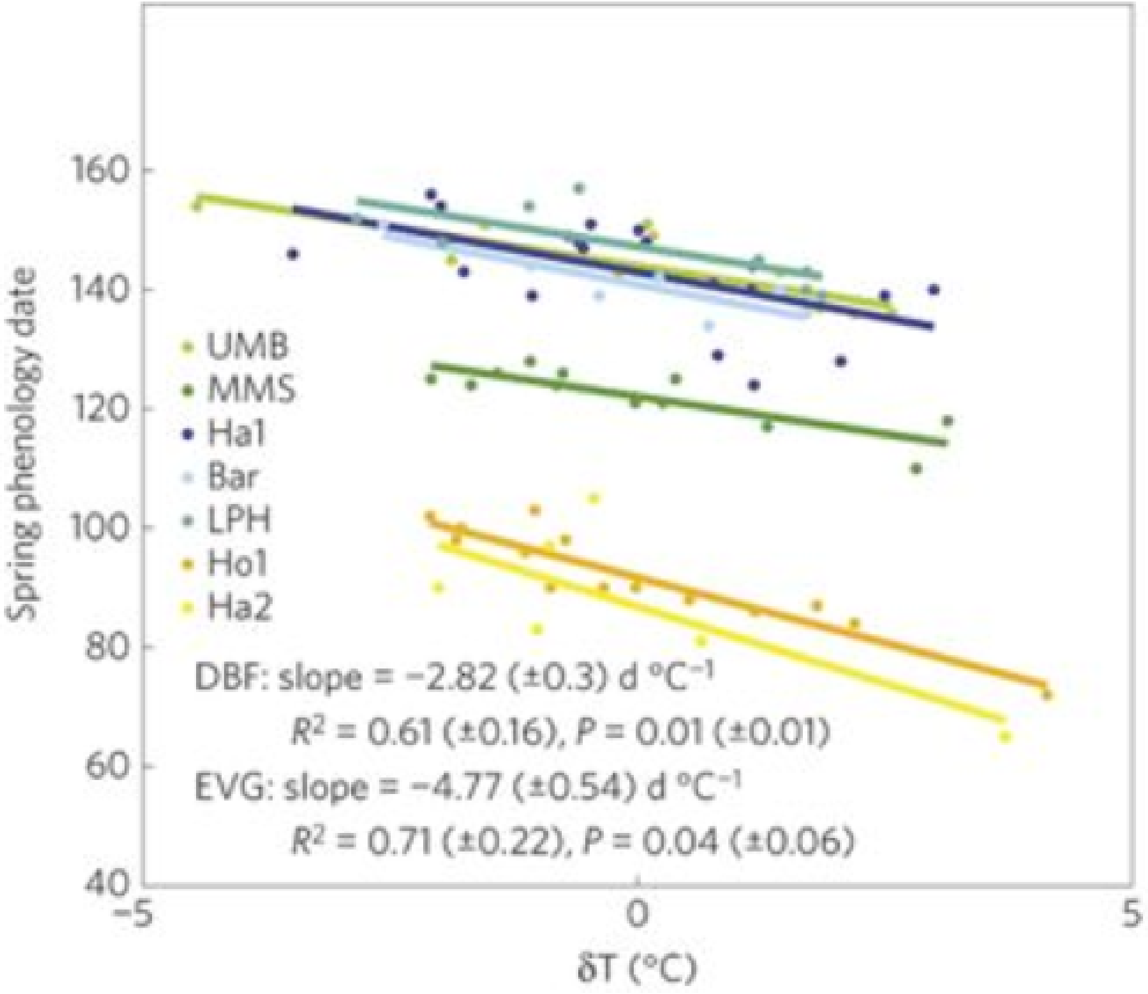




Richardson et al. (2013)

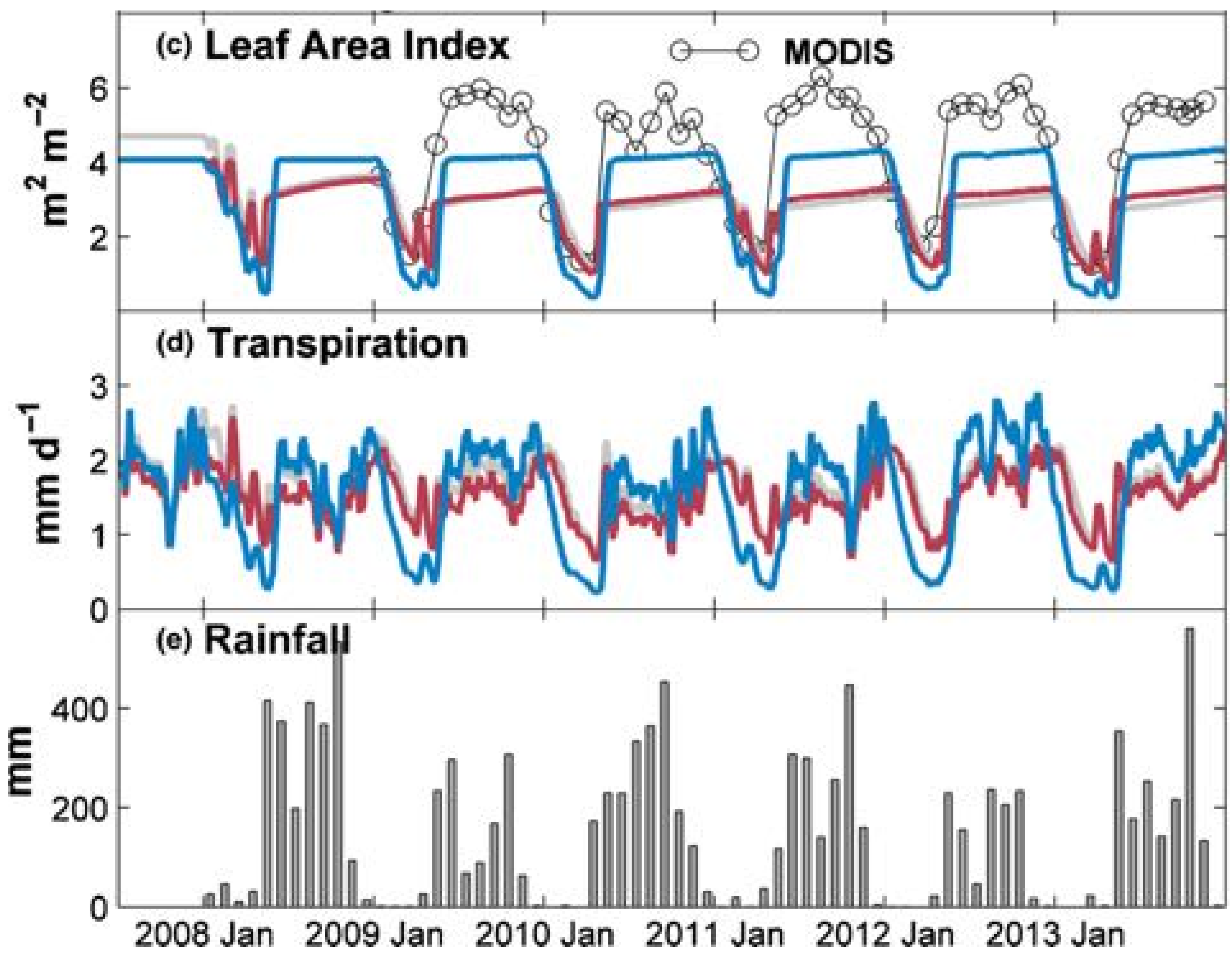
The timing of leaf phenology

In temperate regions, temperature determines Spring leaf out



Keenan et al. (2014)

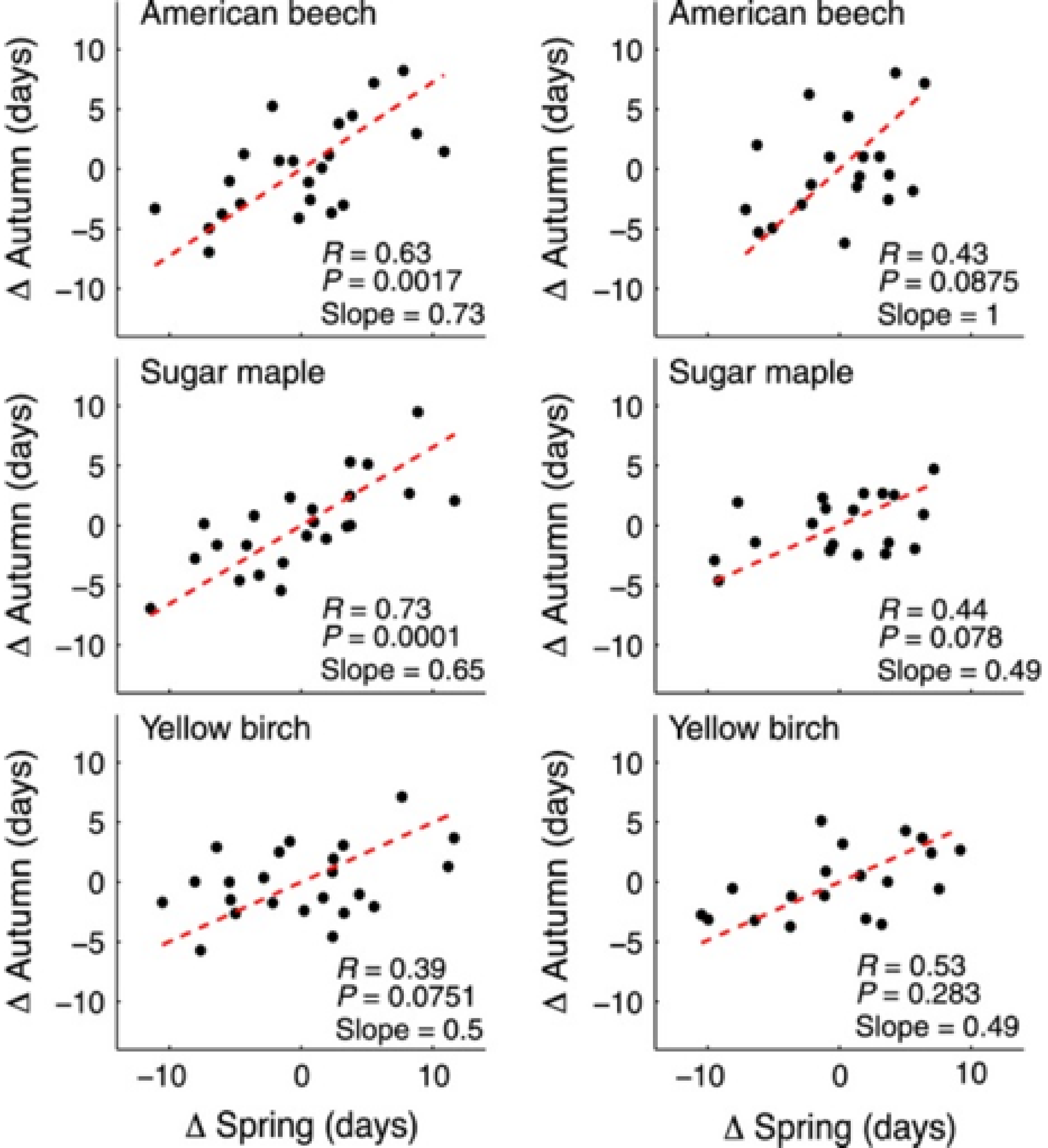
Water is more important in tropical climates



Xu et al. (2016)

Autumn phenology is much harder to predict…

maybe determined by spring phenology?

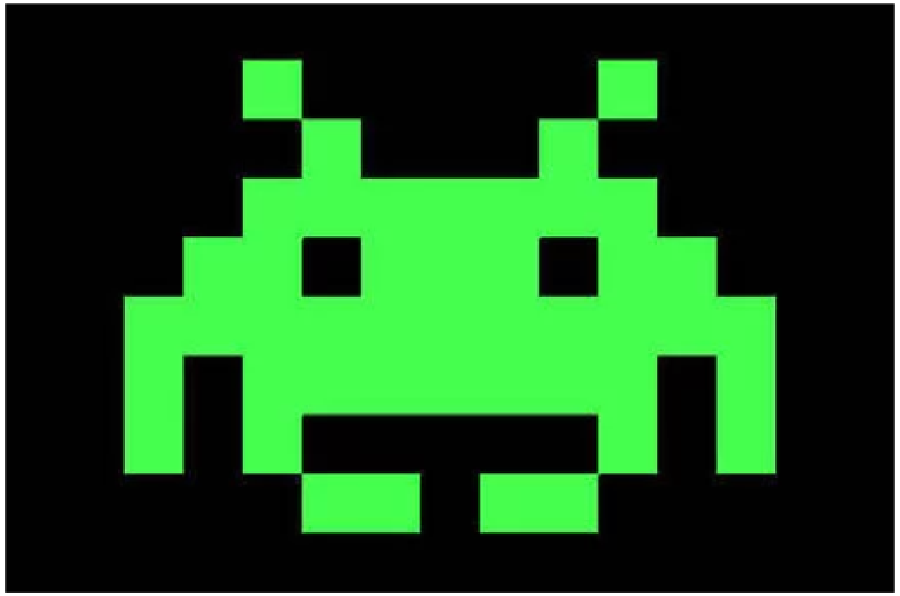


Keenan et al. (2015)

Class activity: the Invader

1. Pretend you are a species of plant
2. Dr. Smith will give you a place to invade
3. What growth and reproductive strategy will you adopt?
4. What would your allocation pattern be like?

Miniquiz question



Things to think about:

- What is the environment like?
- Natural enemies?
- Competitors?
- What kind of flowers/seeds?

Joshua Tree NP (CA)

Big Bend NP (TX)

Congaree NP (SC)

Everglades NP (FL)

Smokey Mtns NP (TN)

Badlands NP (SD)

Rocky Mountain NP (CO)

Sequoia NP (CA)

Acadia NP (ME)