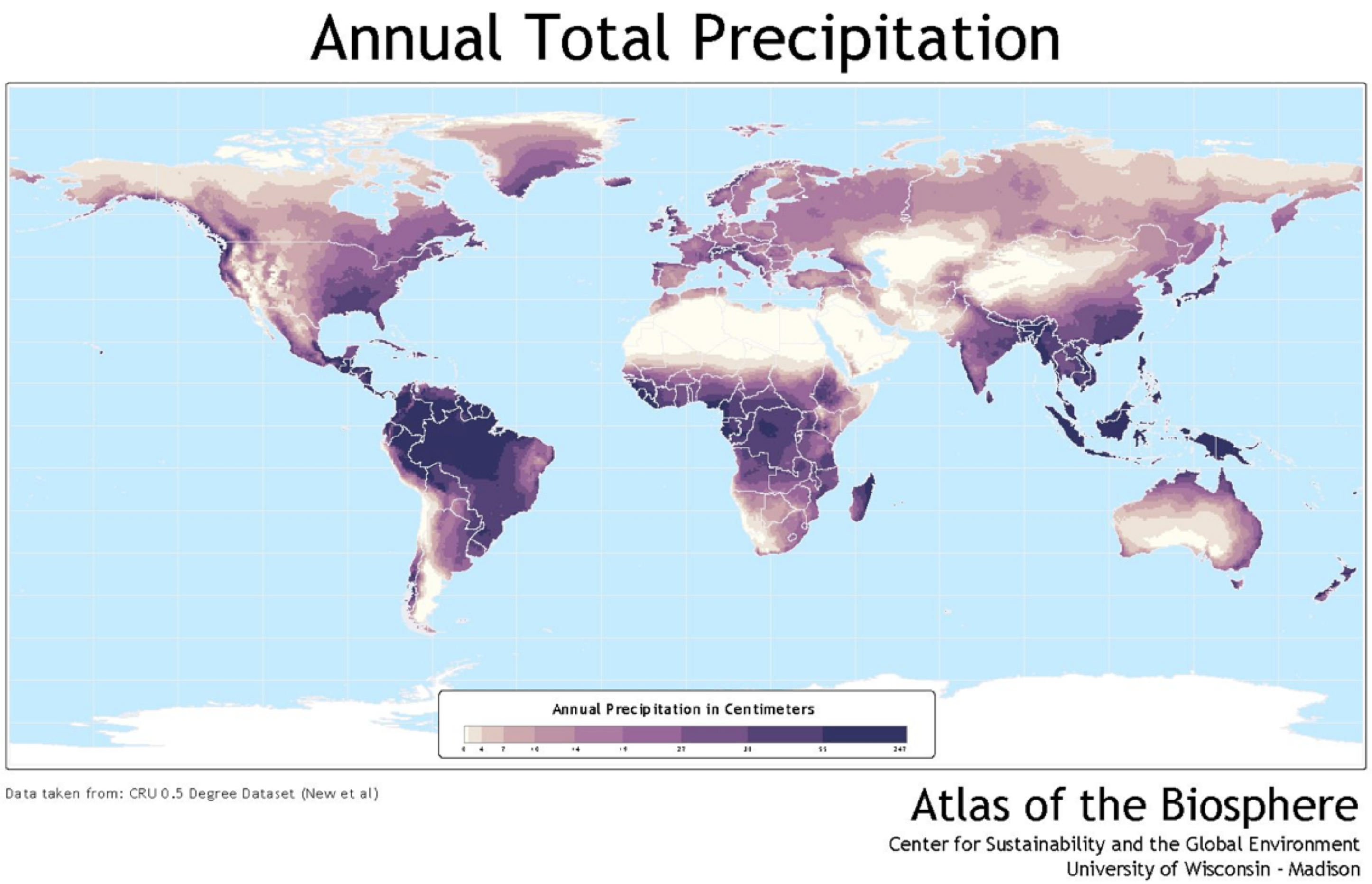
Plant-water relations

What do plants use water for?

How does water availability change in natural environments?

Water availability is not just about rainfall



Lubbock averages ~500 mm of rainfall a year.

Why might this have a different effect on different regions?

Reminder: Plants take up water in soil

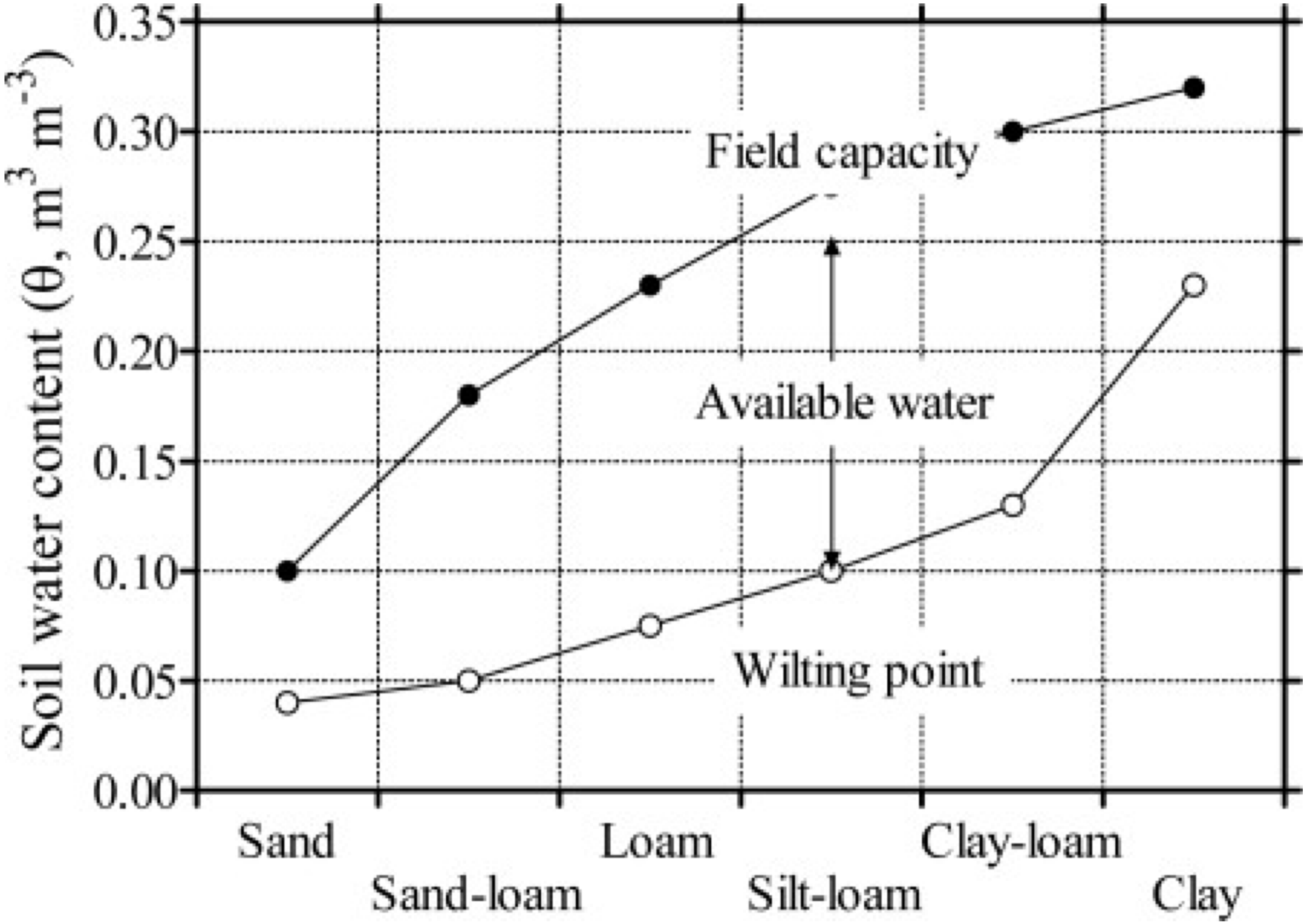
How much water in the soil is actually available to plants?

Soil water content

- Water availability to plants depends on many things, e.g.,
  - Soil structure
    - Organic matter holds more water
  - Density of vegetation cover
    - Evaporation
    - Potential gradients
  - Location of ground water table

Wilting point and field capacity

- Wilting point
  - Point at which water is no longer available to plants
  - Not 0% water
  - Dependent on soil texture
- Field capacity
  - Point at which soil can hold no more water



Pardossi et al. (2009)

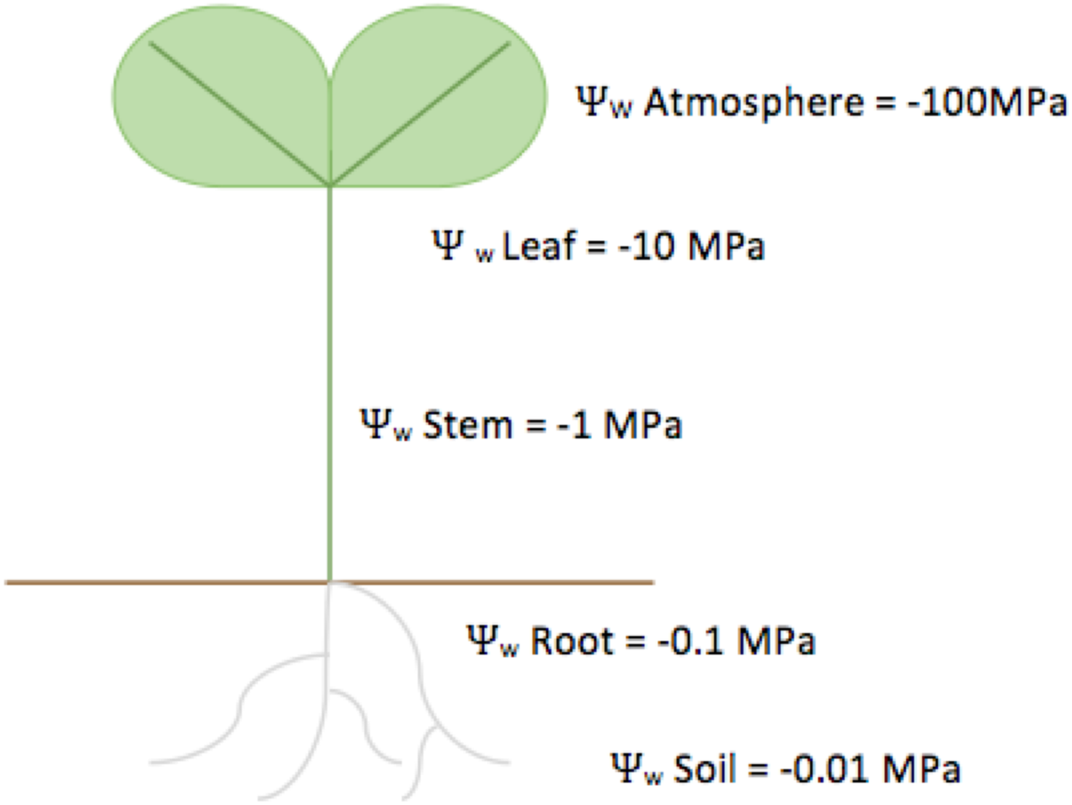
Some definitions

- Water potential: potential for water to move from one area to another (pressure units; e.g., Pa)
  - Expressed as tension relative to pure water (so is negative)
- Water conductivity: speed at which water moves from one area to another (speed units; e.g., s-1)
- Water resistance: inverse of conductance
- P50: potential at which 50% loss of conductivity is observed due to embolism

Plant-water potential

Water potential

- Tendency of water to move from one area to another
- Denoted using the Greek letter psi (Ψ)



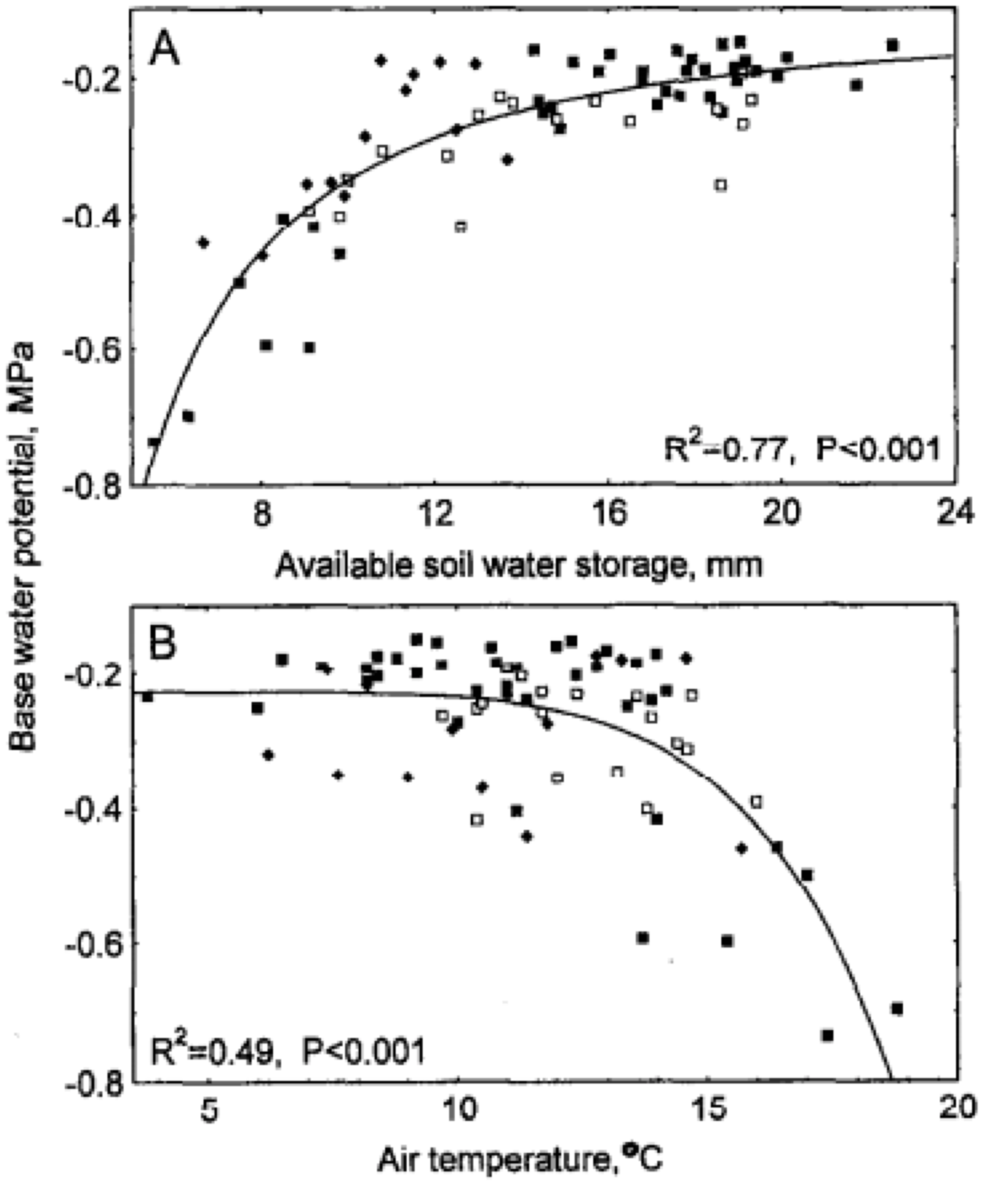


Figure 1. Base water potential of shoots as a function of the available soil water storage at the depth of 35–40 cm (A) and air temperature (B) for adult spruce trees. ■, Exposed trees; □, suppressed trees growing under the canopy shade; ◆, newly exposed trees.

Equilibrium water potential can be used as a proxy for soil water potential

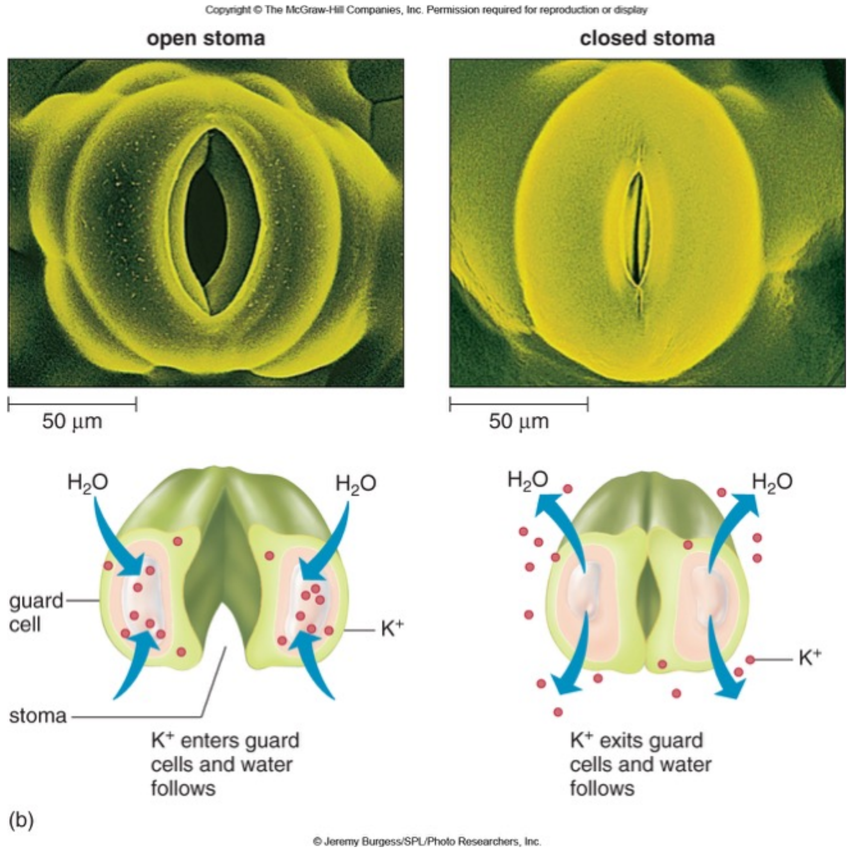
Can measure this when stomates are closed (e.g., pre-dawn)

Sellin (1999)

Plants can regulate water potential!

Water potential regulation: Guard cells

- Create open or closed stomata by changing turgor pressure



Pinon pine (*Pinus edulis*)

Plant drought strategies

Juniper (*Juniperus monosperma*)

McDowell et al. (2008). Mechanisms of plant survival and mortality during drought: Why do some plants survive and others succumb. *New Phytologist* 178: 719-739.

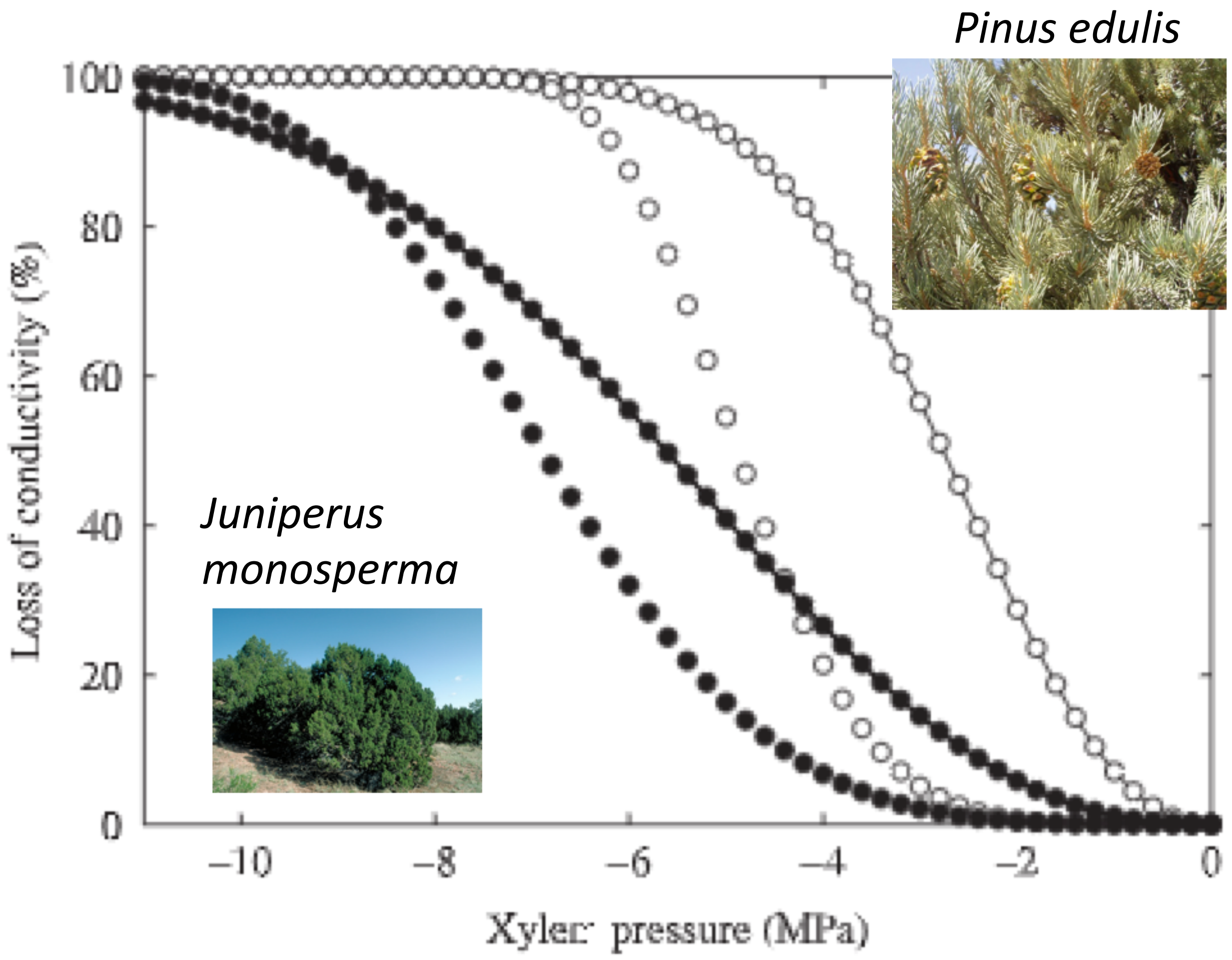


Fig. 4 The percentage loss of conductivity of excised root (connected circles) and stem (unconnected circles) segments of piñon (open circles) and juniper (closed circles) as a function of xylem pressure. These 'vulnerability curves' were obtained by the air-injection method (Linton *et al.*, 1998).

Water potentials can be used to examine different plant strategies (e.g., using vulnerability curves)

McDowell et al. (2008)

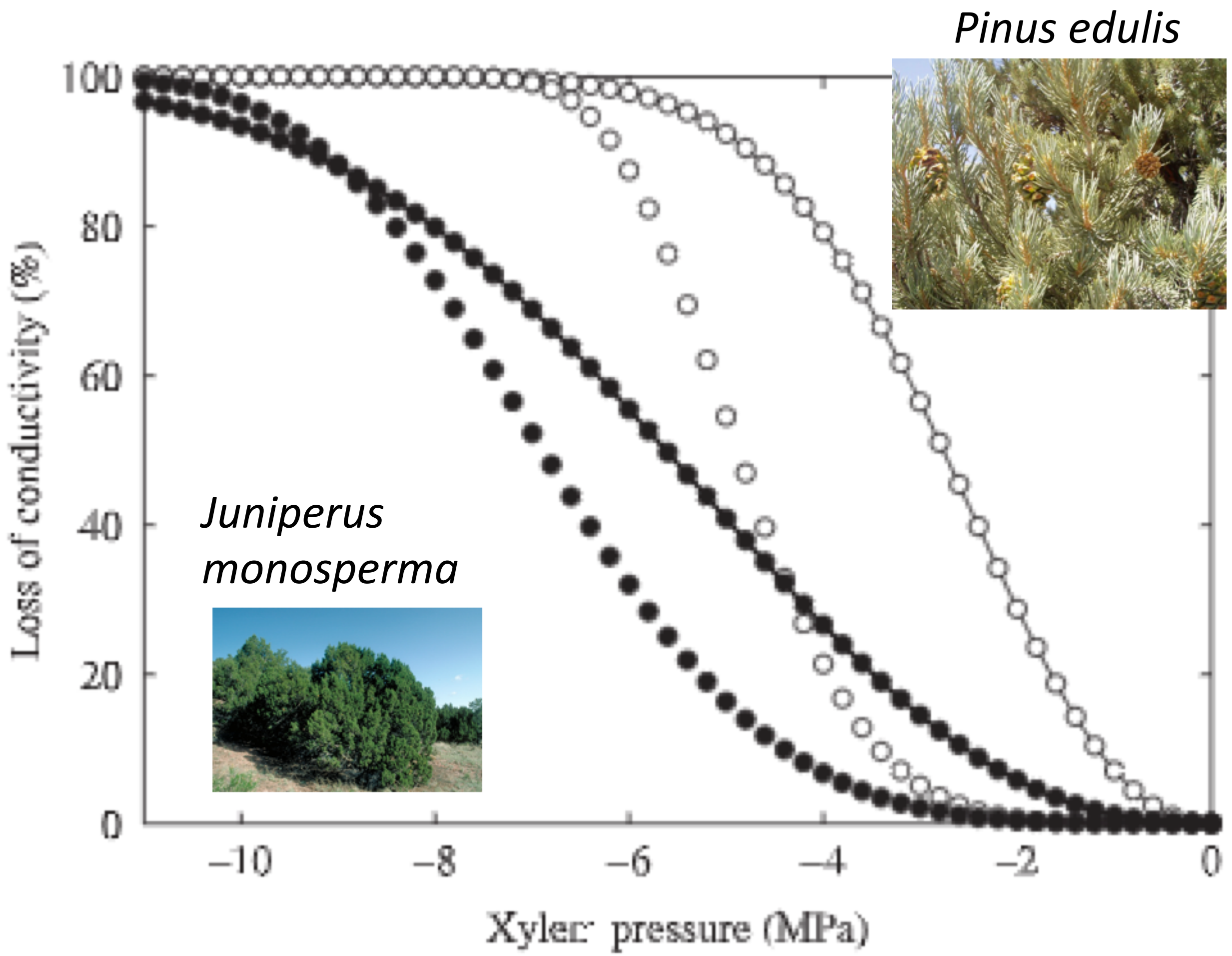


Fig. 4 The percentage loss of conductivity of excised root (connected circles) and stem (unconnected circles) segments of piñon (open circles) and juniper (closed circles) as a function of xylem pressure. These 'vulnerability curves' were obtained by the air-injection method (Linton *et al*., 1998).

What's happening here?

McDowell et al. (2008)

Isohydry

Isohydric species are sensitive to changes in water availability, quickly closing their stomata in response to drought

- Drought avoiders
- Maintain high Ψ

Anisohydric species tend to respond more slowly to drought

- Drought tolerators
- Tolerate low Ψ

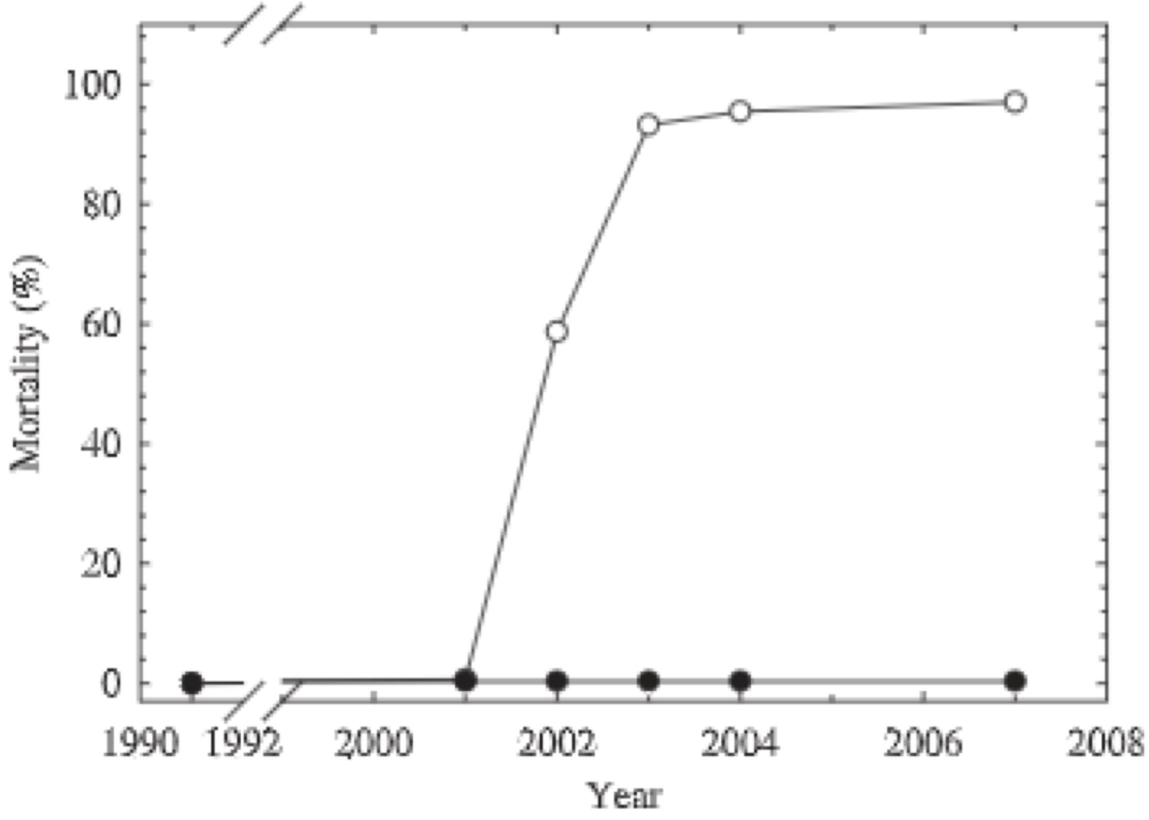


Fig. 2 Percentage mortality of piñon (open circles) and juniper (closed circles) trees at a 1.5 ha site, Mesita del Buey, near Los Alamos, New Mexico. For piñon, 16 of 484 trees survived (97% mortality), whereas for juniper, 559 out of 561 trees survived (< 1% mortality).

The poor Pinon!

What do you think happened?

McDowell et al. (2008)

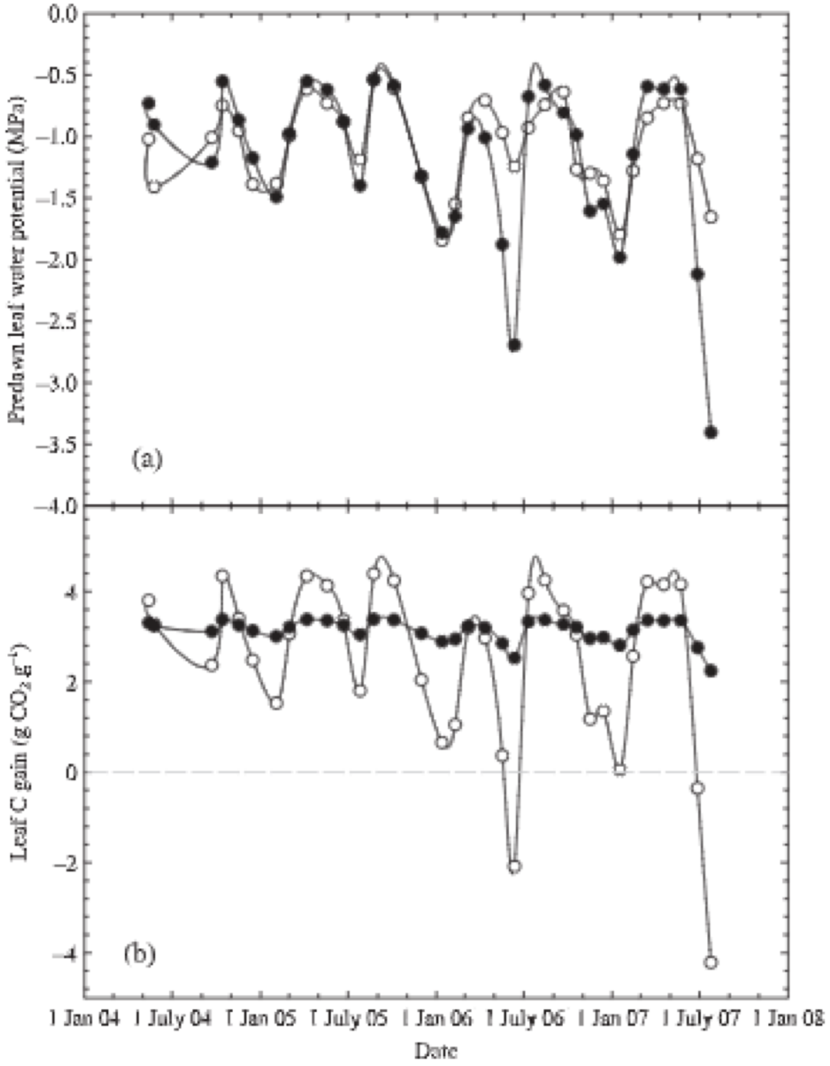


Fig. 11 (a) Three years of monthly observations of predawn water potential of piñon (open circles) and juniper (closed circles) from Mesita del Buey, Los Alamos, New Mexico. Twigs were sampled at least 20 min before sunrise and kept in plastic bags until measurement, which took place within 1 h of collection. Samples consisted of two twigs per tree and a minimum of five trees per species per time period. (b) Seasonal leaf carbon gain for piñon and juniper modeled using Barnes (1986) and the predawn water potentials from (a).

McDowell et al. (2008)

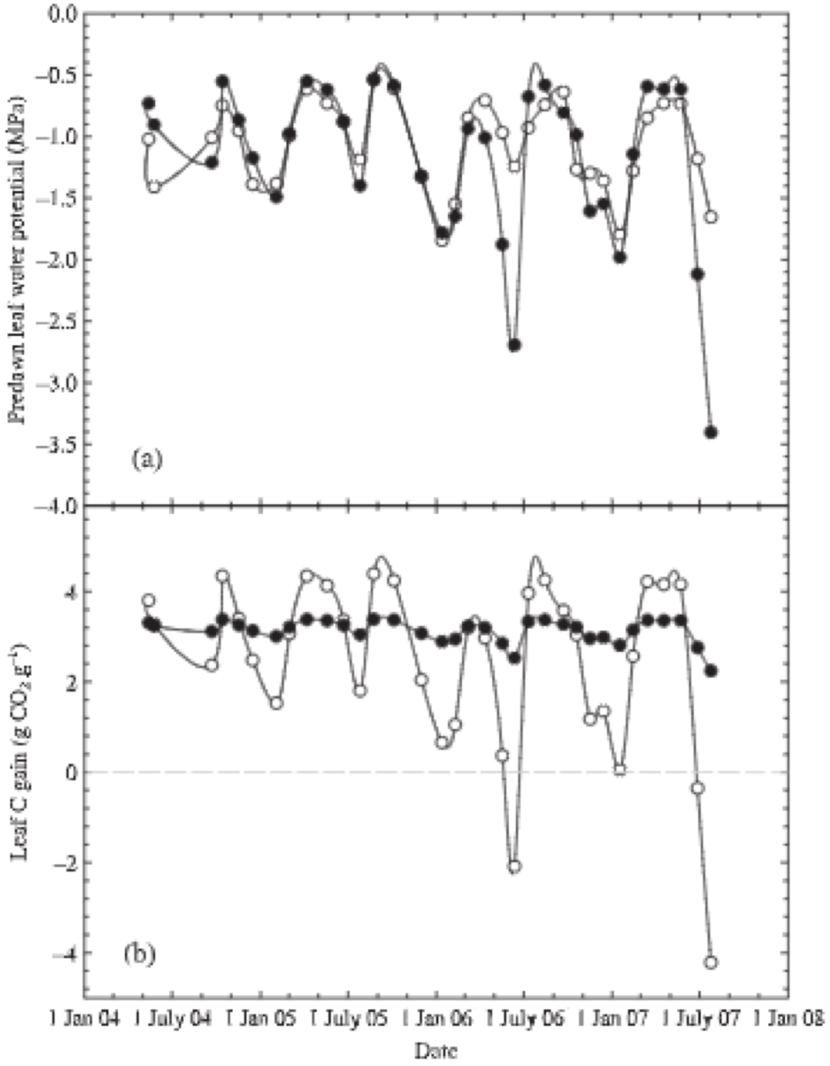


Fig. 11 (a) Three years of monthly observations of predawn water potential of piñon (open circles) and juniper (closed circles) from Mesita del Buey, Los Alamos, New Mexico. Twigs were sampled at least 20 min before sunrise and kept in plastic bags until measurement, which took place within 1 h of collection. Samples consisted of two twigs per tree and a minimum of five trees per species per time period. (b) Seasonal leaf carbon gain for piñon and juniper modeled using Barnes (1986) and the predawn water potentials from (a).

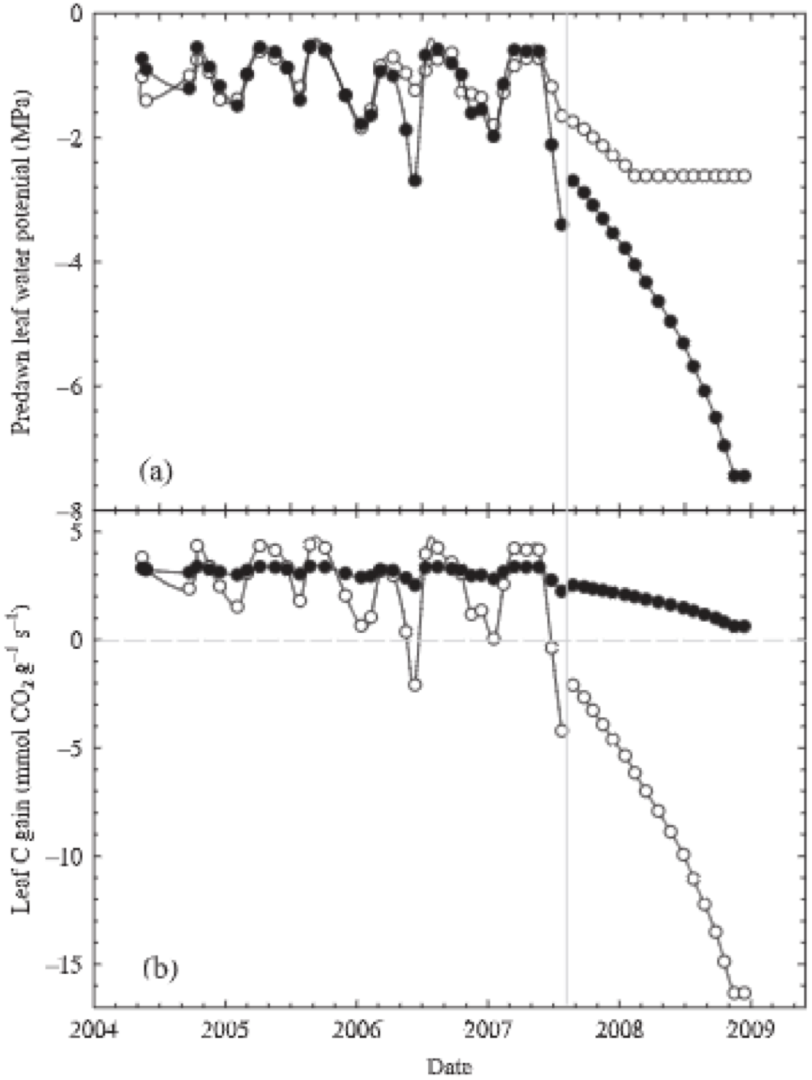
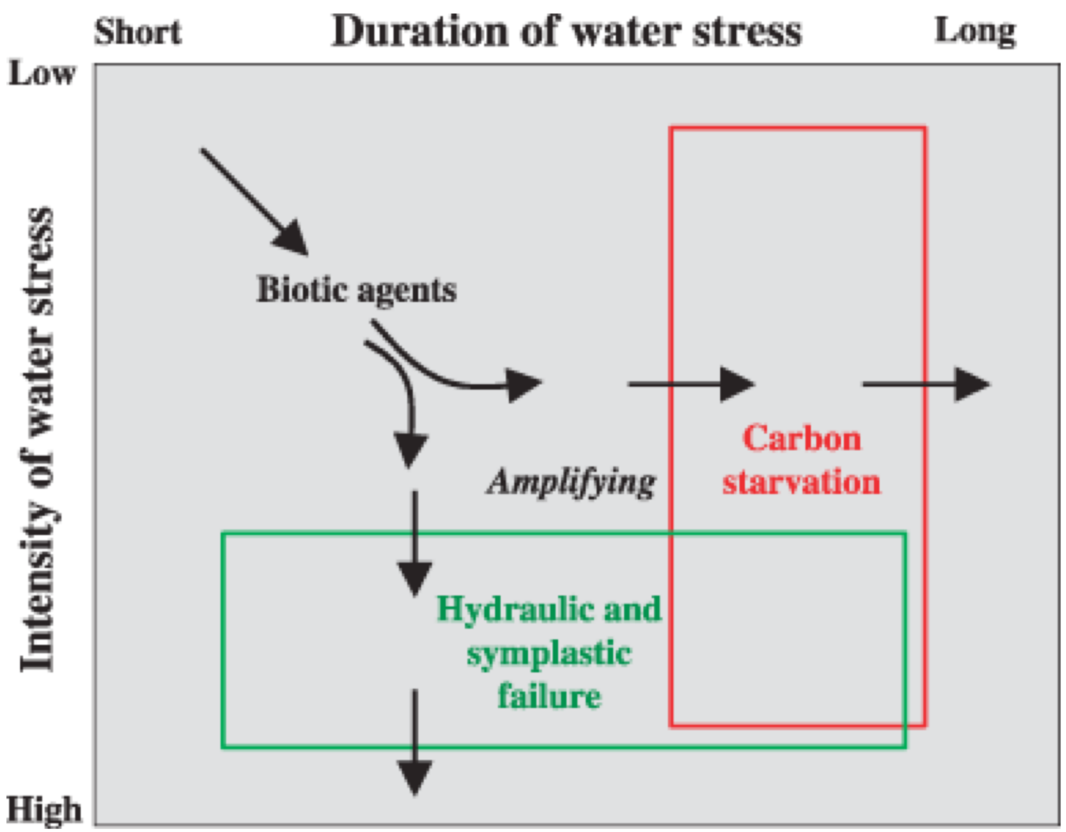


Fig. 13 (a) To the left of the gray bar are 3 yr of monthly observations of predawn water potential for piñon (open circles) and juniper (closed circles) as from Fig. 11(a), and to the right of the gray baris a simulation of the water potential response to a severe drought. A description of the simulation is given in the text. (b) Seasonal leaf carbon gain modeled as per Fig. 11(b) using values of juniper predawn water potential as observed between 2004 and 2007 (left of gray bar) or simulated for 2007–2009 (right of gray bar).

McDowell et al. (2008)

A matter of time and duration



McDowell et al. (2008)

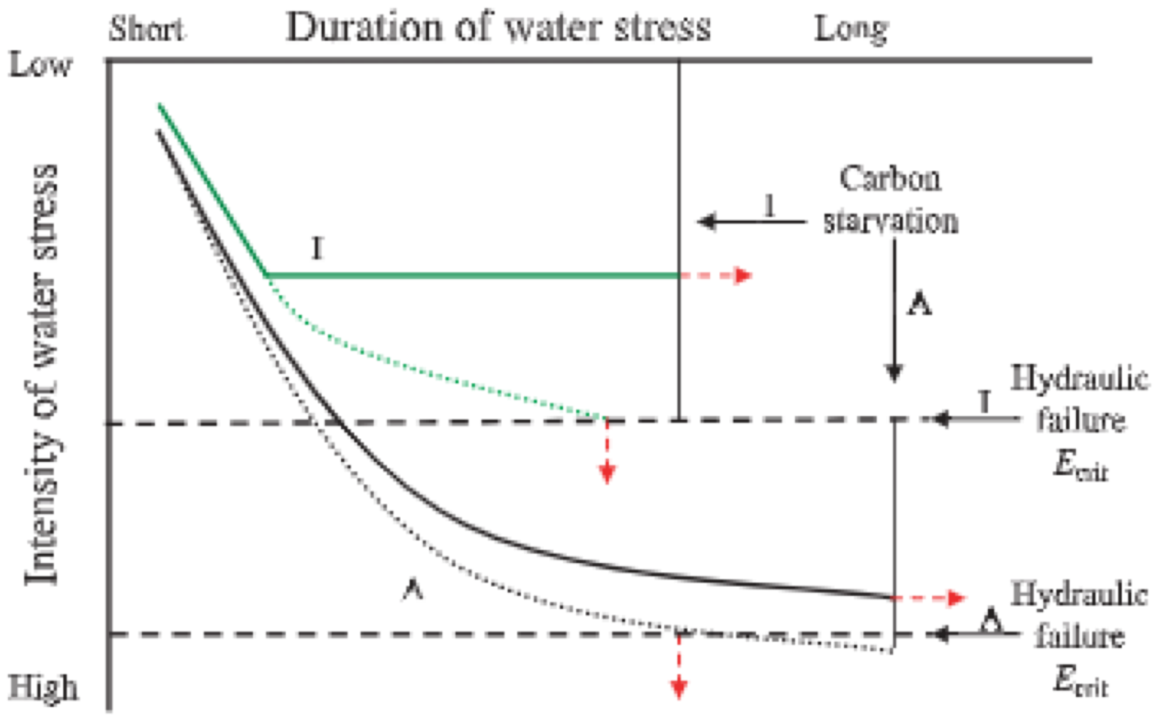
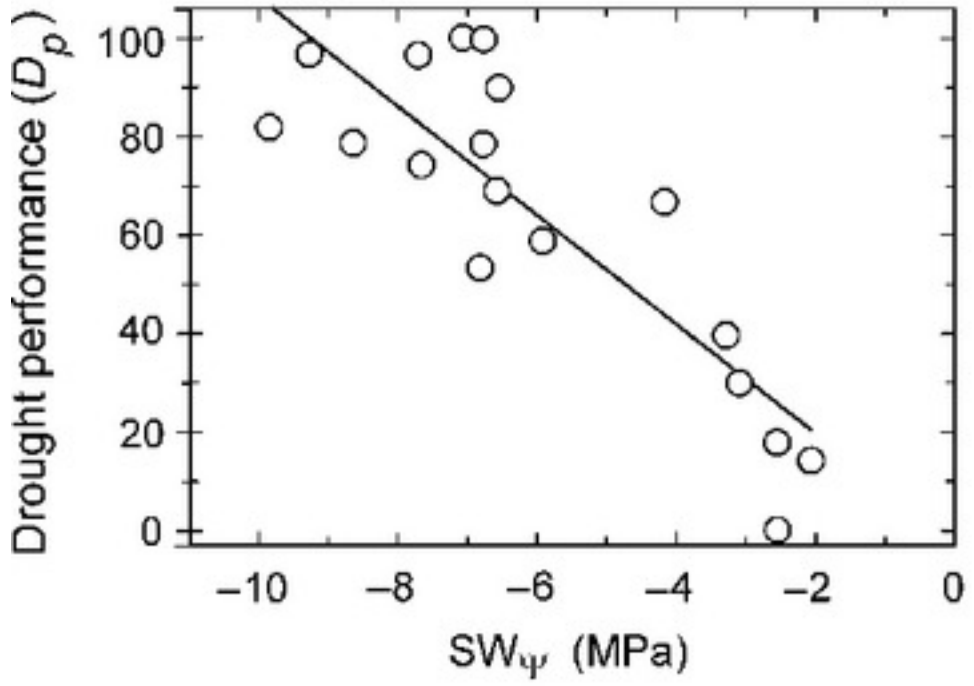


Fig. 10 Theoretical predictions of the mechanisms of drought-related mortality for species utilizing isohydric vs anisohydric regulation of water potential. This figure is a more detailed representation of the hypotheses exemplified in Fig. 3, highlighting differences between isohydric (I) and anisohydric (A) functional types. The dashed horizontal line represents the point of hydraulic failure for each functional type. Carbon starvation is hypothesized to occur primarily for isohydric species that close stomata relatively early in a drought (solid isohydric line), initiating the phase of reliance on carbohydrate reserves earlier than anisohydric plants (compare solid isohydric and anisohydric lines). Isohydric species may experience hydraulic failure in cases of severe intensity of drought (dotted isohydric line). Anisohydric species have a more curvilinear response (similar to Fig. 9) and are predicted to maintain positive carbon gain for a longer period than isohydric species, thus prolonging the duration of drought they can withstand before carbon starvation (solid anisohydric line). However, anisohydric species have a smaller margin of safety, thus increasing their likelihood of mortality via hydraulic failure (dotted anisohydric line).

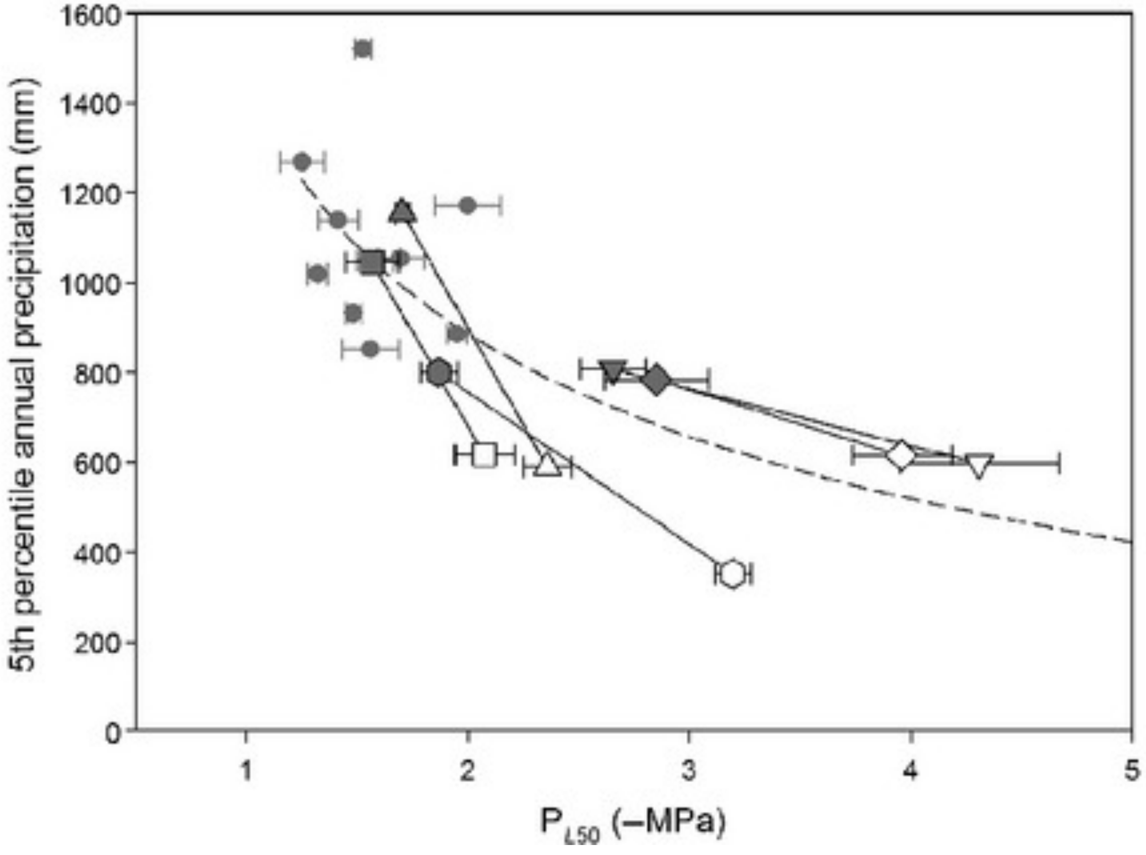
McDowell et al. (2008)

How else would you expect anisohydric versus isohydric species to differ?

Trees in Panama



(Leaf wetness)



(Point of 50% conductivity loss; note: scale is backwards)

Reich et al. (2014)

Other drought adaptation traits: plants in your own backyard!

Other drought adaptation traits: plants in your own backyard!

Bouteloua gracilis

Prosopis glandulosa

Opuntia phaecantha

Interactions with other conditions in the field: Chaves et al. (2002)