The rice plant-soil-water system

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Water transport soil-plant-atmosphere

Water moves from soil through roots, stems, leaves, to atmosphere

Rate of water flow is f(potential difference, resistance)

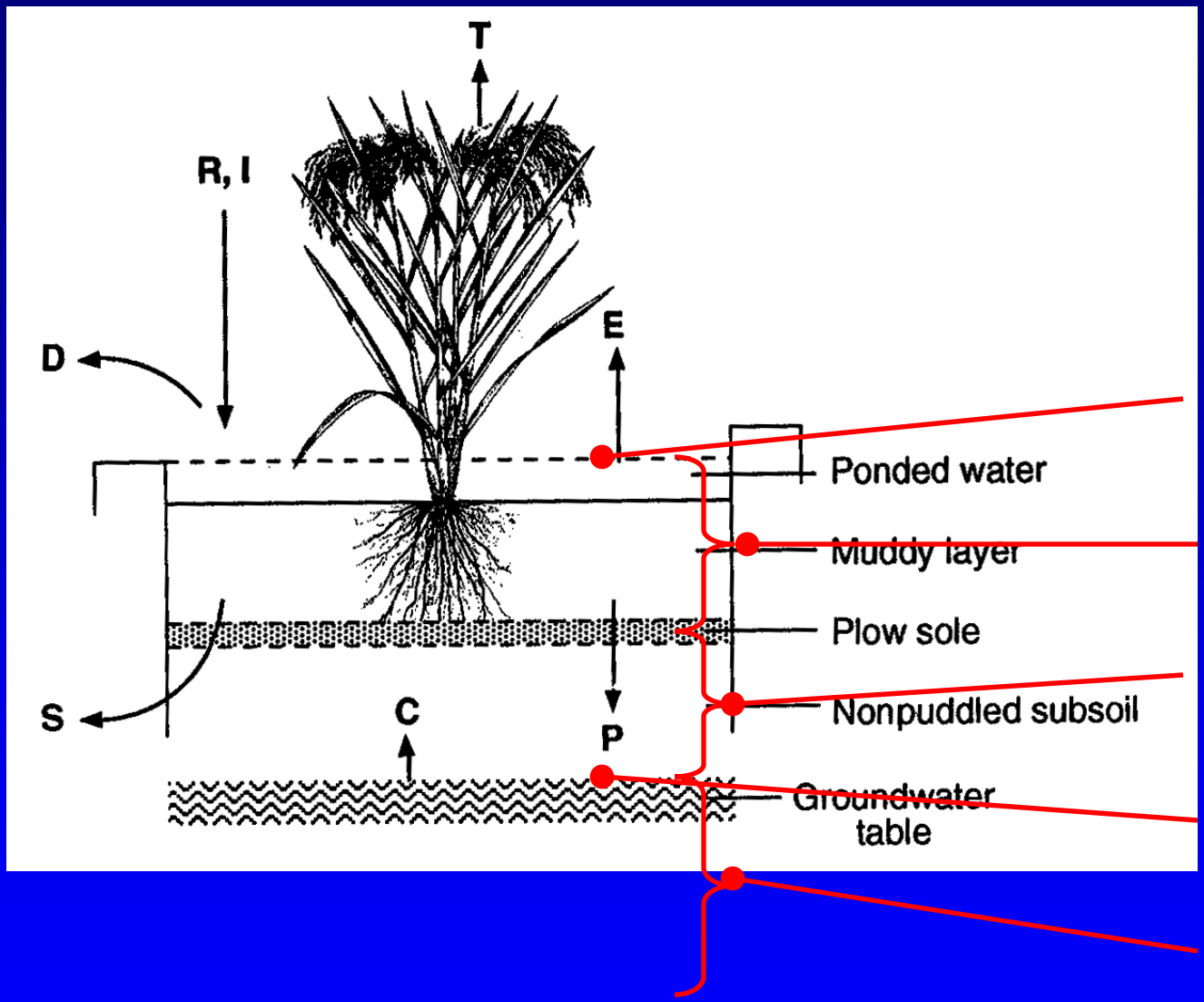
Potential unit name	Corresponding value				
Water height (cm)	1	10	100	1000	15850
pF (-)	0	1	2	3	4.2
Bar (bar)	0.001	0.01	0.1	1	15.85
Pascal (Pa)	100	1000	10000	10000	1585000
Kilo Pascal (kPa)	0.1	1	10	100	1585
Mega Pascal (MPa)	0.0001	0.001	0.01	0.1	1.585

Potential of water is positive in “free liquid water”

Potentials in the soil-plant-atmosphere are negative (in flooded rice soil, potential is positive)

Water moves from high potential (top of hill) to low potential (bottom of hill)

Tension is –potential: water moves from low tension to high tension


T
R, I
D
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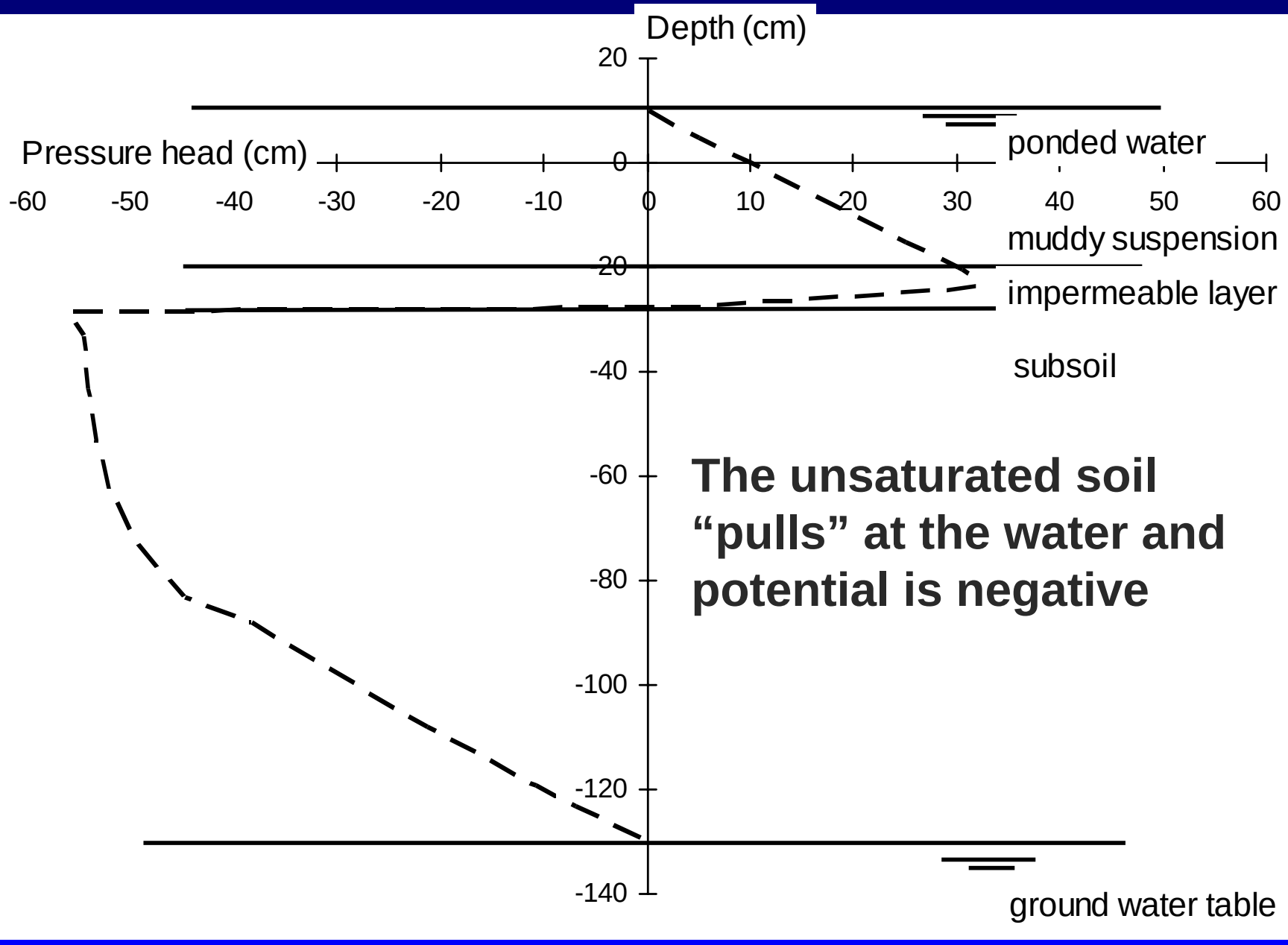
Ponded water
Muddy layer
Plow sole
Nonpuddled subsoil
Groundwater table
Potential = 0
Potential is +
Potential = -
Potential = 0
Potential = +

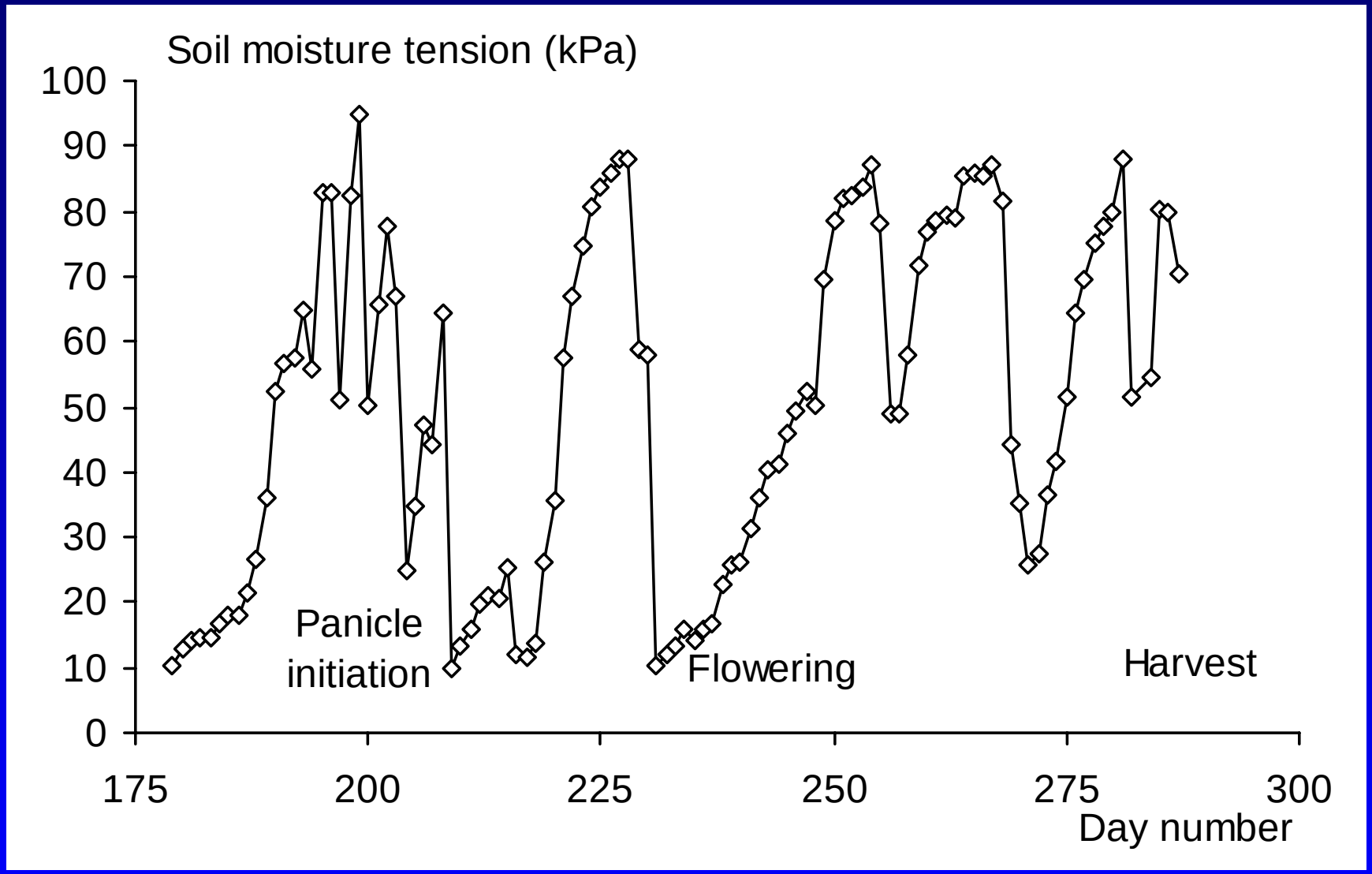


Water potential in the flooded rice soil

When a paddy rice field falls dry, the soil water potential becomes negative and decreases

Positive water potential

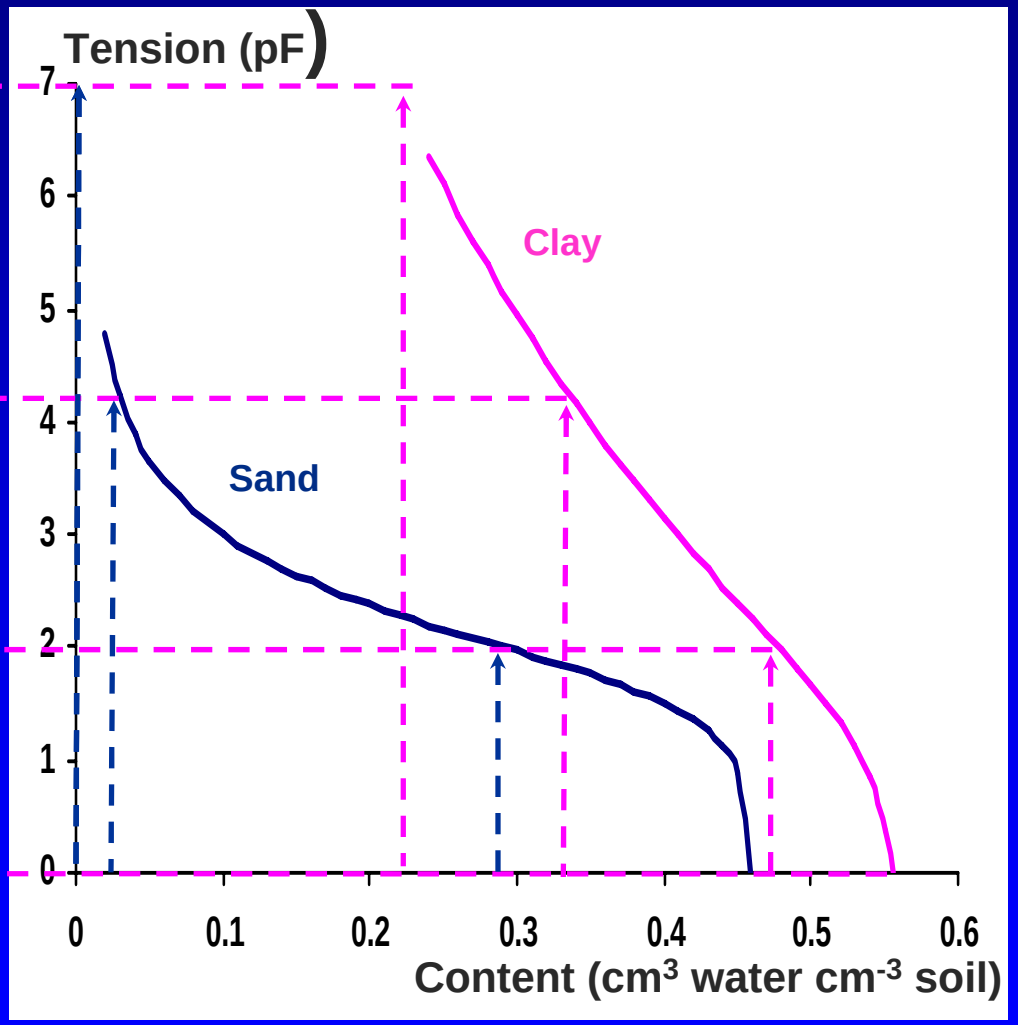
Negative water potential



Potential during the growing season in an aerobic soil (aerobic rice, Changping, China, 2002)

Each soil type has a specific relationship between the content and the potential of water: the pF curve

	Sand	Clay
Air dry (pF = 7)	0.001	0.22
Wilting point (pF = 4.2)	0.03	0.34
Field capacity (pF = 2)	0.30	0.48
Saturation (pF = 0)	0.46	0.56



A clay soil stores much water, but at a high tension, so it is difficult for the roots to extract

A sandy soil holds little water, but at a low tension, so it is easy for the roots to extract

A medium-textured, loamy soil, holds intermediate levels of water at intermediate tensions, so there is relatively much water for extraction by roots

No issue for flooded rice soil, but becomes an issue when a soil falls dry during a dry spell

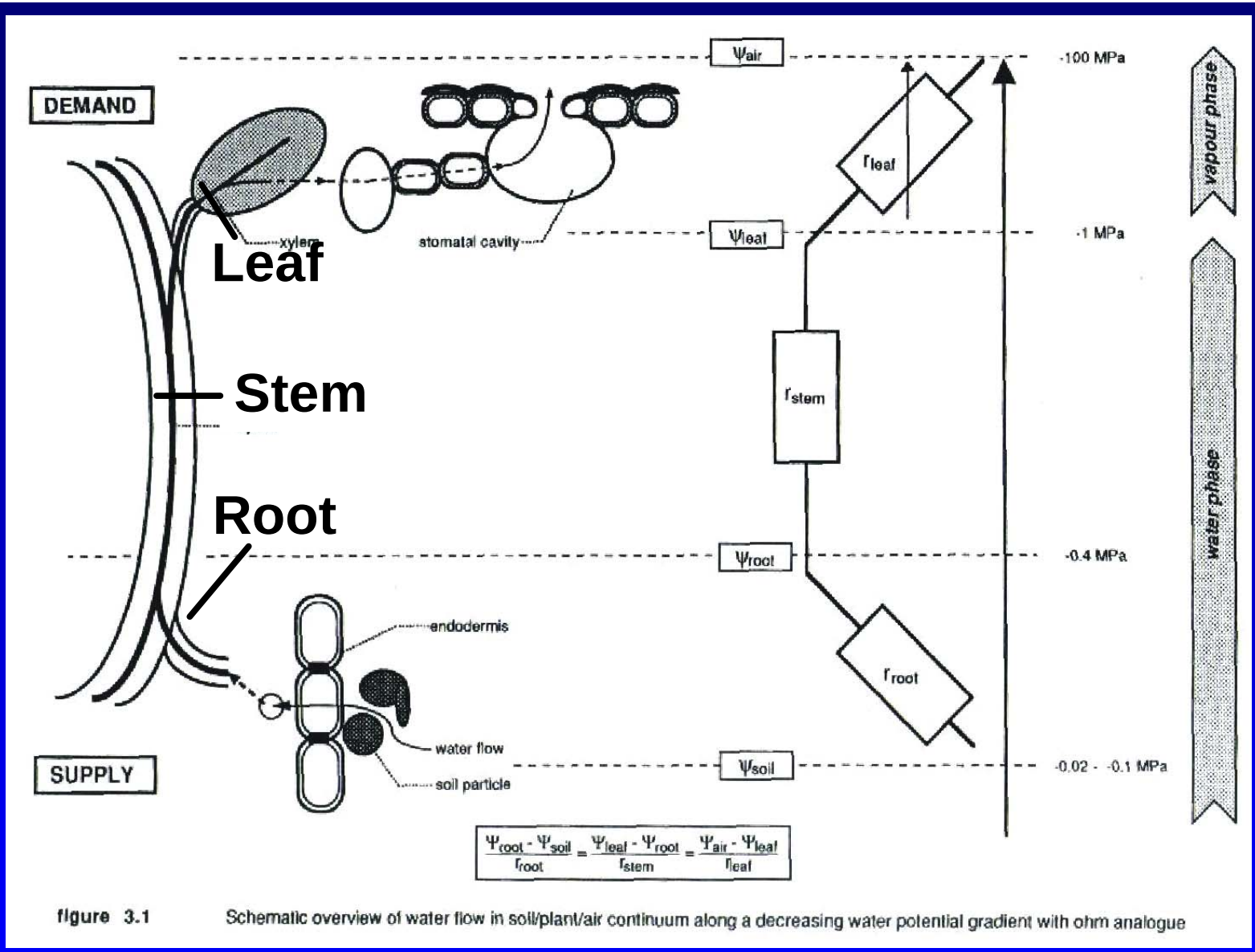


figure 3.1 Schematic overview of water flow in soil/plant/air continuum along a decreasing water potential gradient with ohm analogue

Example of potentials in soil-plant-atmosphere system
Potentials drop with each added resistance

Potential of water in the atmosphere (above leaves) drives the potential transpiration rate, which is f(radiation, wind speed, vapor pressure, temperature).
A hot sunny day => pulls hard at water from plant

Potential of water in the soil is determined by the soil properties (texture, SOM,..) and water content:

- **Clay soil pulls hard at water**
- **Sand soil pulls softly at water**
- **Much water: high potential**
- **Little water: low potential**

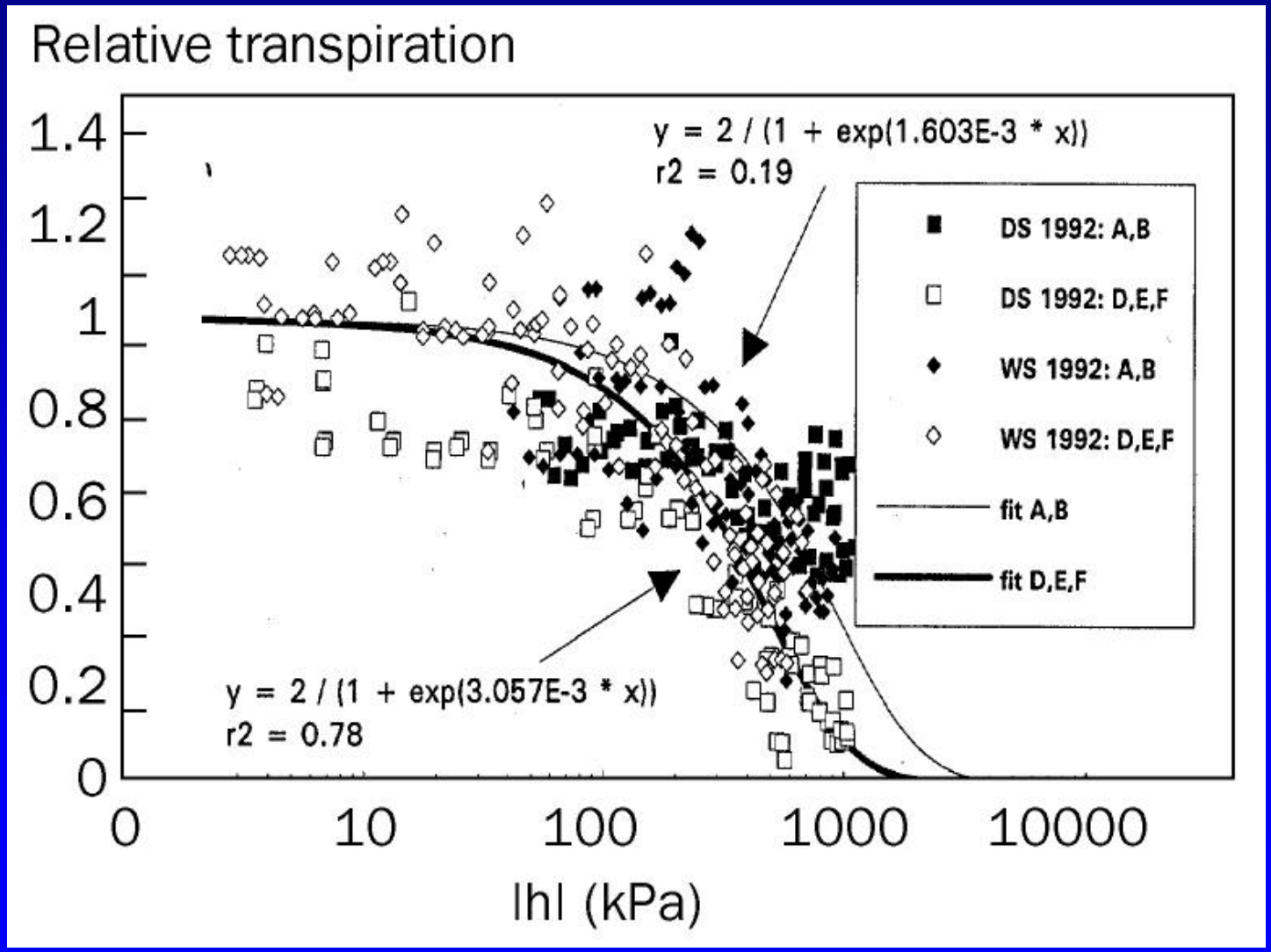
A dry clay soil pulls hard at water (difficult to take up by roots)

Drought stress

When the soil is too dry (high soil water tension), it becomes too difficult for roots to take up water and water flow in the plant gets reduced:

- Reduced transpiration
- Reduced photosynthesis
- Reduced leaf area expansion
- Leaf rolling
- Accelerated leaf death
- Spikelet sterility

Reduced transpiration as function of soil water tension (IR72)



Link between transpiration and photosynthesis

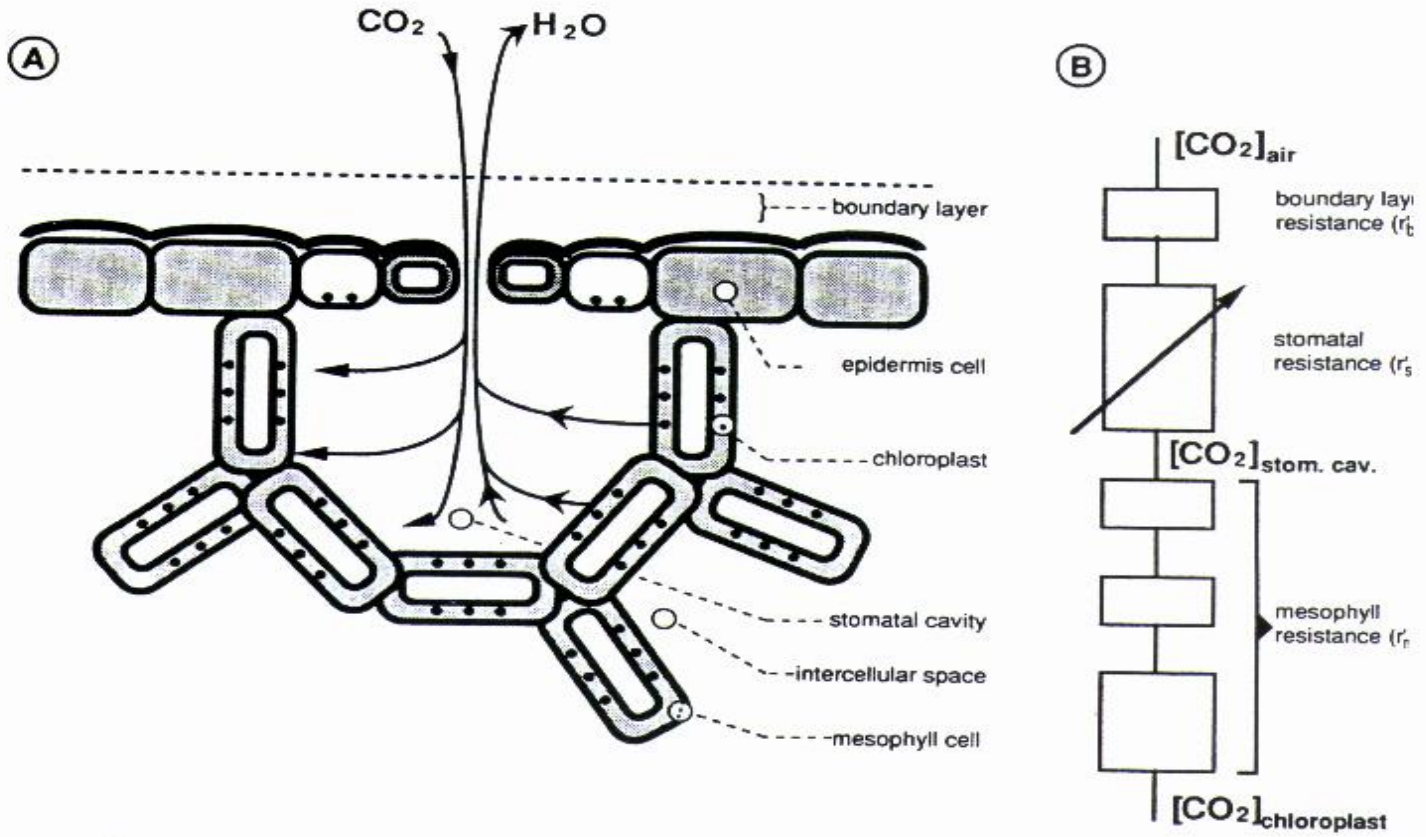
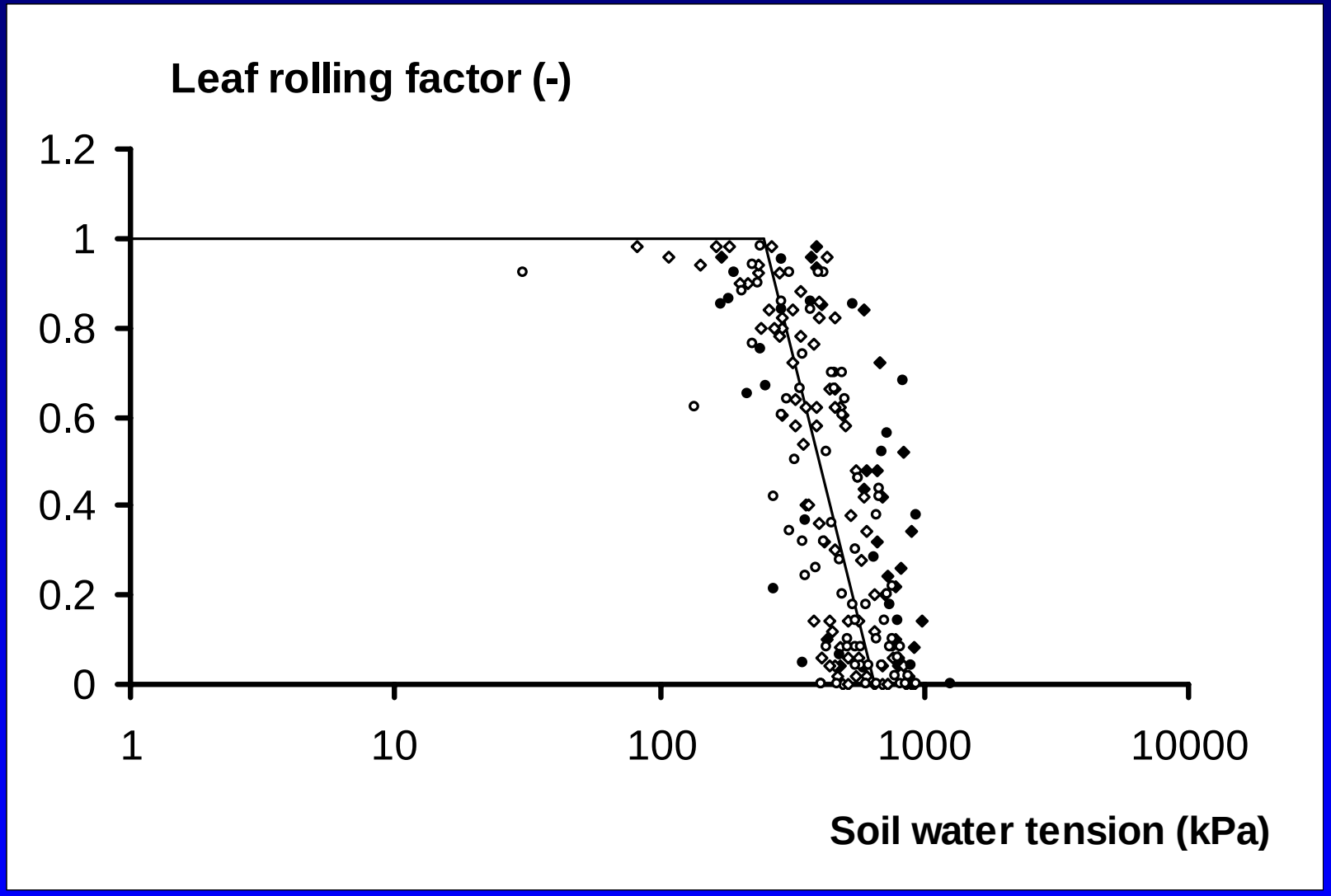


figure 2.1 Cross-section of a leaf through a stoma (a), indicating components of resistances to CO_2 diffusion (b).

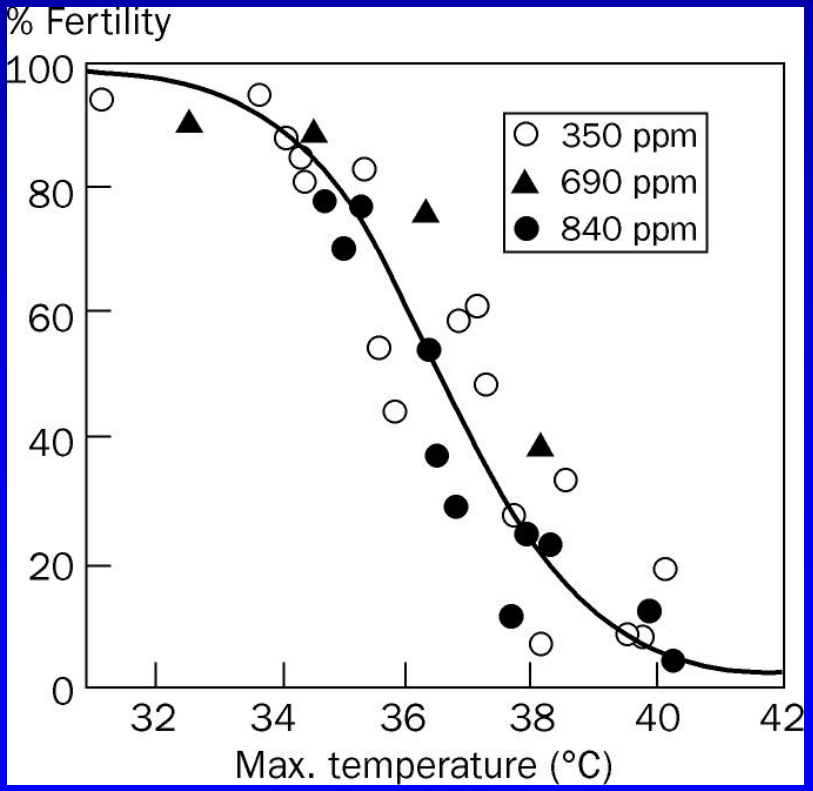
Leaf rolling



Rolled leaves => less canopy photosynthesis

Spikelet sterility

Turner (1986): relationship between leaf rolling – increased canopy temperature



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Spikelet sterility

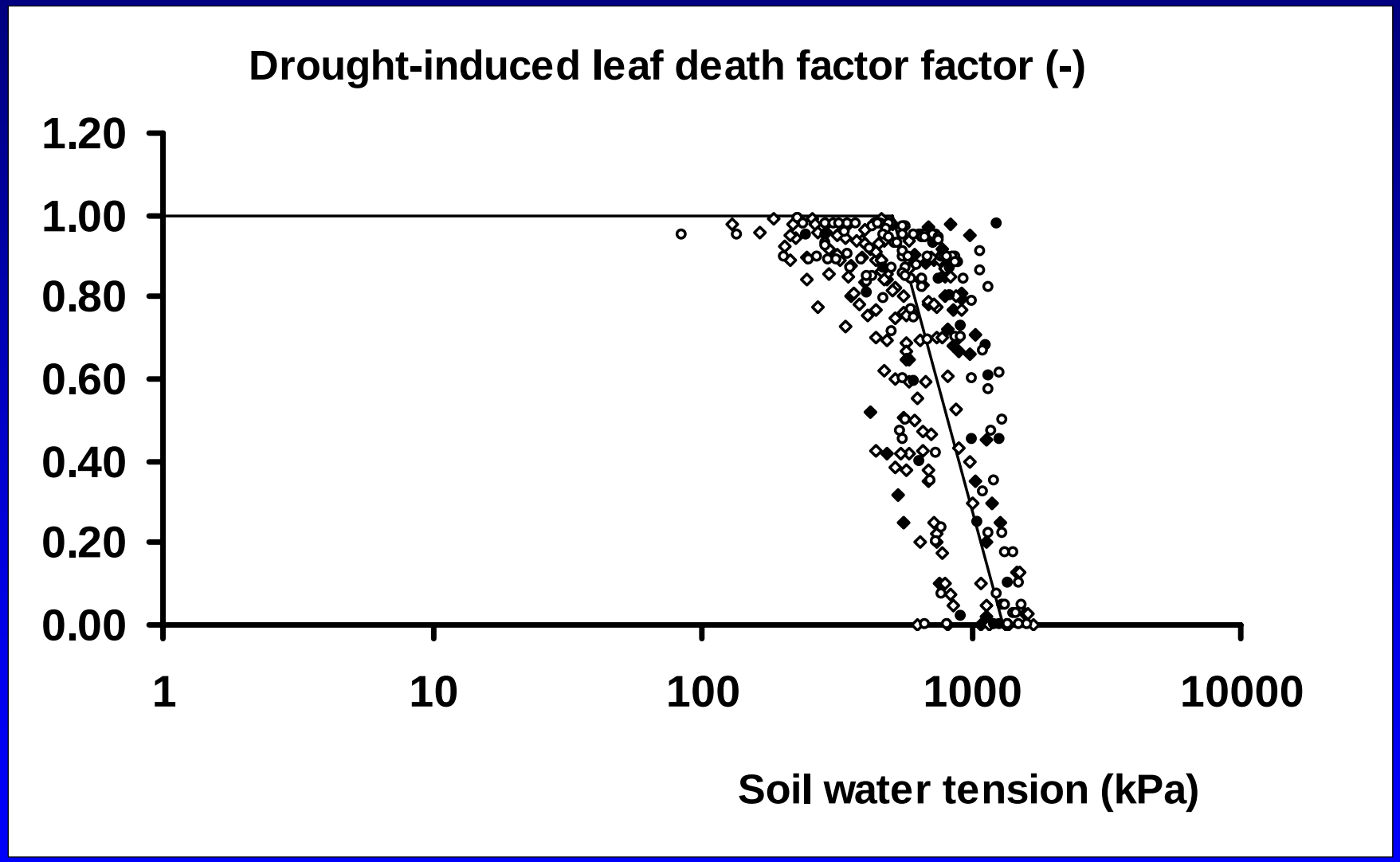
↓

Less grains

↓

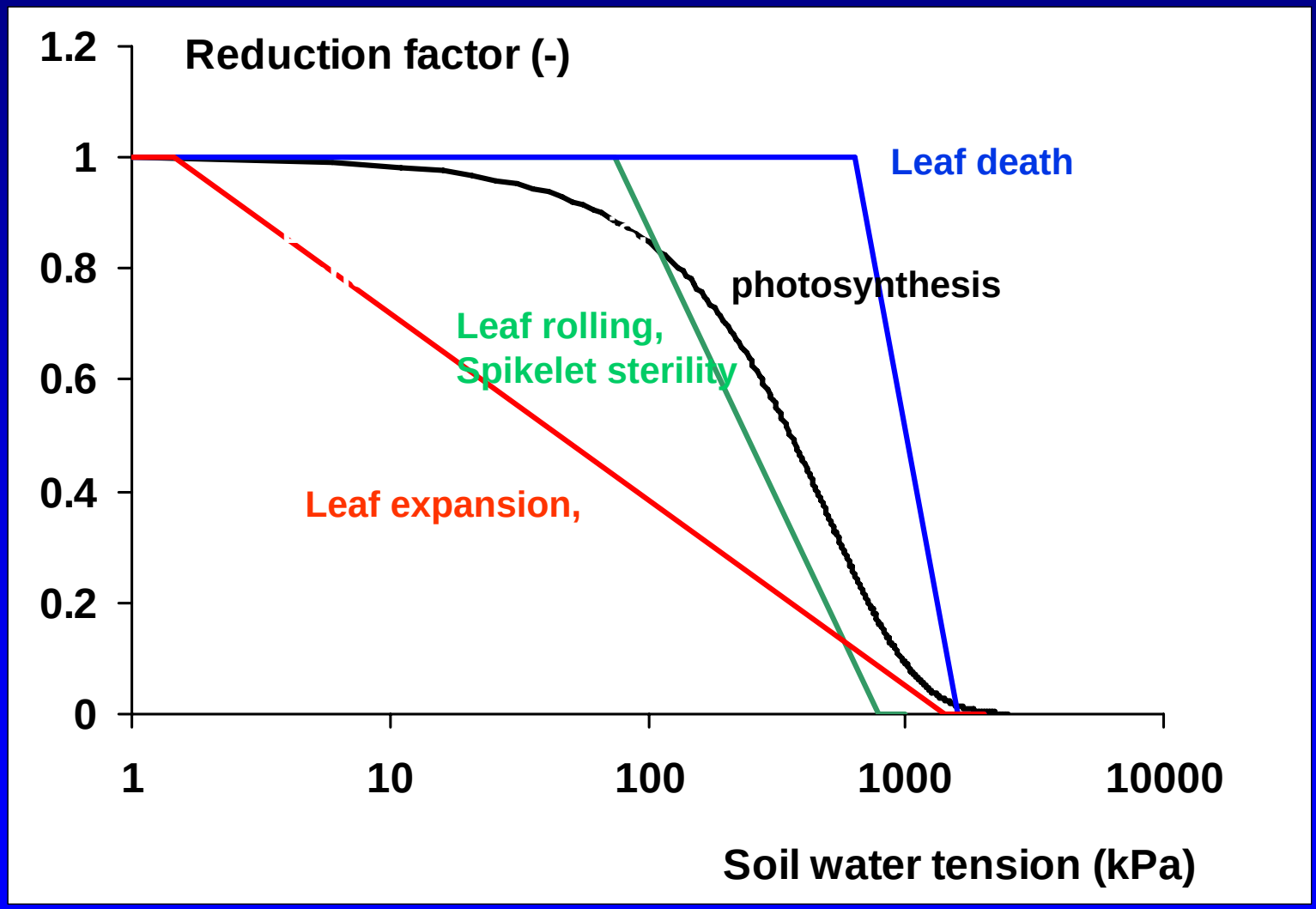
Less yield

Accelerated leaf death

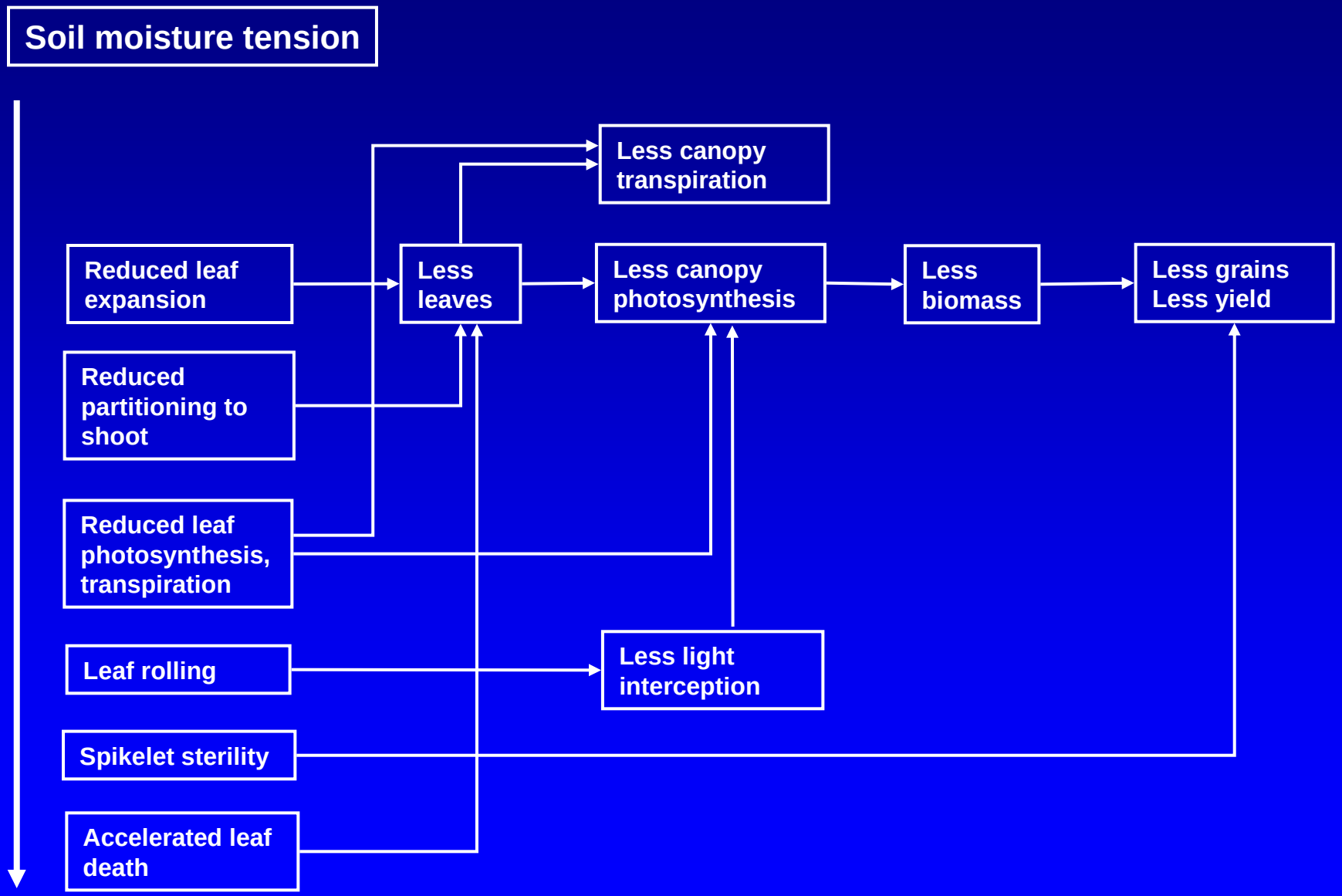


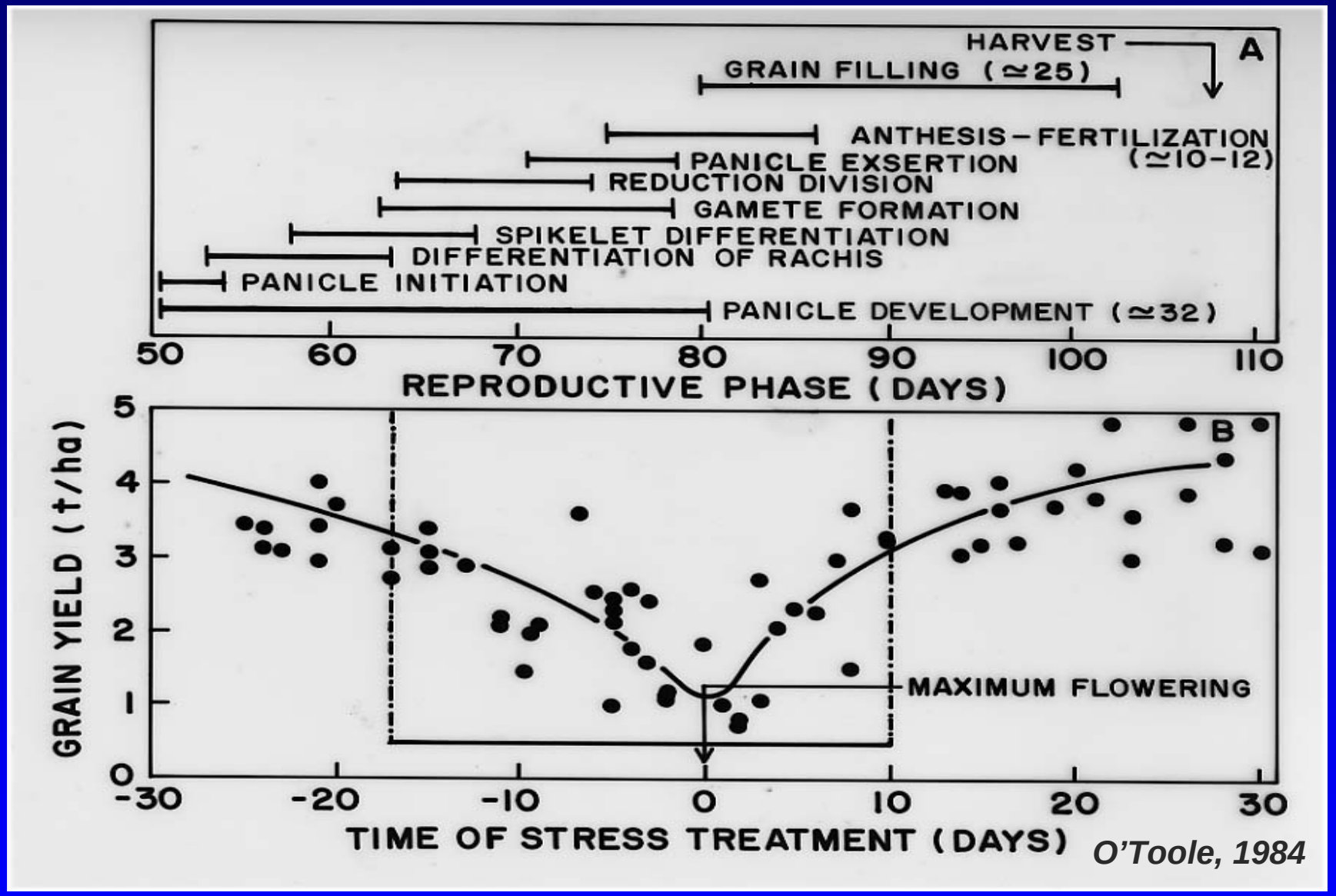
Dead leaves => less canopy photosynthesis

Summary effects of soil water tension; IR72



Summary effects of drought





Effect of timing of drought: most sensitive at flowering

Moderate drought in early growth stages

Leaf rolling in early growth stages

Severe drought in early growth stages

Severe drought in upper field near Roi Et, Oct. 2004

Severe drought