Water absorption and transport in plants

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The importance (and properties) of water for plants

1. Water (H_2O) is an excellent solvent.
   - Covalent bond between H and O
   - Polar molecule (Dipolar molecule)
2. Water is the main constituent (part) of plant cells.

Plants	Water (%)	References
Carrot root	85	Nobel (1991)
Lettuce leaf	95	Nobel (1991)
Riceberry rice shoot (35 days old)	80-85	Chalermsuk et al. (2016)
Dry seed (Dormancy)	5	Nobel (1991)

3. Water maintains cell turgidity of plants.

6 days

Without watering

Turgid (Normal) plant

Wilted plant

4. Water has high specific heat (ความร้อนจำเพาะ)

Specific heat is the heat energy required to raise the temperature of a substance by a specific amount (Taiz and Zeiger, 2006).

ความร้อนที่ทำให้น้ำ 1 กรัม มีอุณหภูมิสูงขึ้น 1 องศาเซลเซียส มีค่าเท่ากับ 1 แคลอรี

(1 calorie is defined as 4.184 joules, Salisbury and Ross, 1992)

5. Water has high latent heat of vaporisation.

Latent heat of vaporisation is the energy needed to separate molecules from the liquid phase and move them into the gas phase at constant temperature (Taiz and Zeiger, 2006).

ความร้อนแฝงของการกลายเป็นไอ

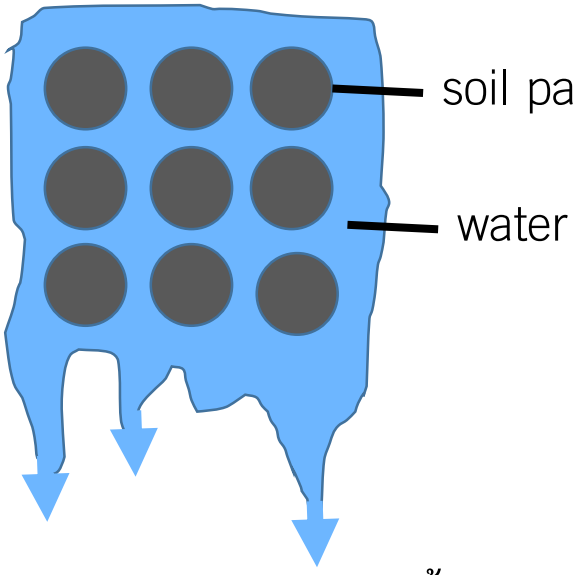
ความร้อนที่ทำให้น้ำ 1 กรัม ที่อุณหภูมิ 100 องศาเซลเซียส เปลี่ยนสถานะเป็นไอน้ำ มีค่าเท่ากับ 540 แคลอรี

6. Water has cohesive and adhesive properties.

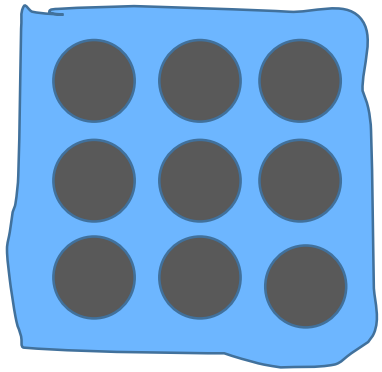
Cohesive force is force of attraction between molecules of the same substances, such as water-water.

Adhesive force is the force of attraction between molecules of different substances, such water-xylem wall.

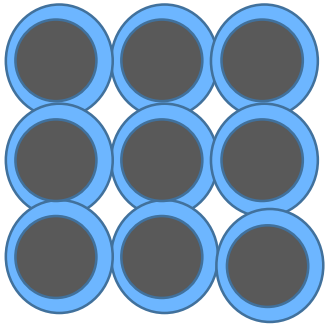
Types of water in the soil



Gravitational water (น้ำซึม)



Capillary water (น้ำซับ)



Hygroscopic water (น้ำเยื่อ)

Field capacity
(ความสามารถในการอุ้มน้ำของดิน)

Permanent wilting point
(จุดเหี่ยวถาวร)

Available water
for plant growth

ภาคภูมิ พระประเสริฐ (2550)

What are the factors that determine the direction of water movement?

Water potential: ชลศักย์ (Ψ or Ψ_w ; the Greek letter called " psi")

= the free energy of water to move (or to perform work)

(water potential is a measure of the free energy of water per unit of volume, J/m^3 , equivalent to pressure units such as the Pascal)

$$\Psi_w = \Psi_s + \Psi_p + \Psi_g$$

Where Ψ_s is solute potential (osmotic potential, Ψ_π)

Ψ_p is pressure potential

Ψ_g is gravitational potential

Ψ_w of pure water = 0 MPa

I. Solute potential

- When solutes are added to water, solutes bind water molecules, reduce the number of free water molecules and reduce the capacity of water to move (or reduce the Ψ_w)
- Ψ_s is always negative (-)

$$\Psi_s = -RTC_s$$

where R is the gas constant (8.32 J mol^{-1} K^{-1})

T is the absolute temperature in degrees Kelvin (K)

C_s is solute concentration (osmolality, mol L^{-1})

Taiz and Zeiger (2006)

II. Pressure potential (Ψ_p) is the physical pressure on a solution or is a hydrostatic pressure of a solution.

Ψ_p can be negative (-), zero or positive (+)

Taiz and Zeiger (2006)

III. Gravitational pressure (Ψ_g) depends on the height (h).

$$\Psi_g = \rho_w g h$$

where ρ_w is the density of water

$\rho_w g = 0.01$ MPa m^{-1}

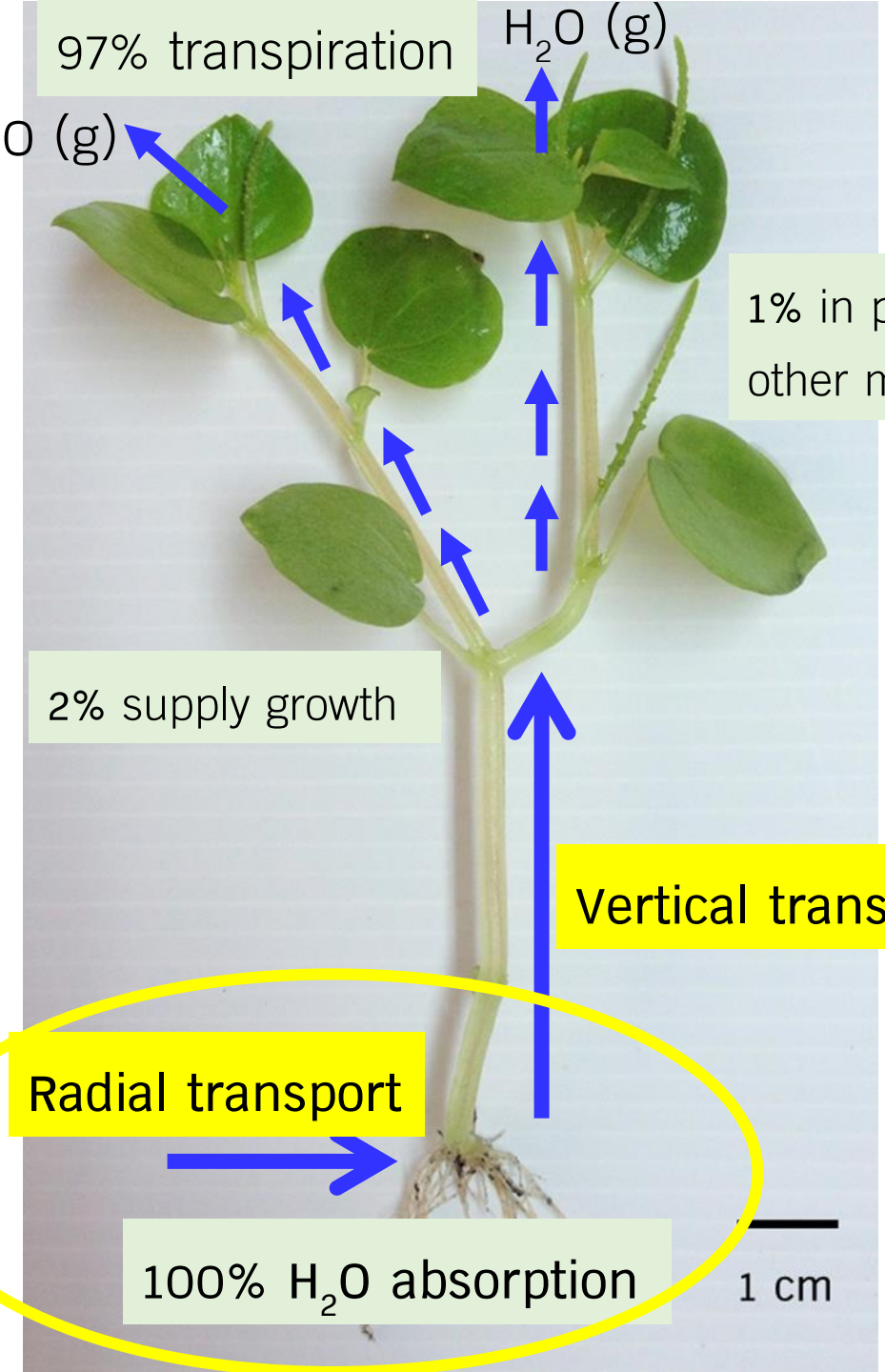
Taiz and Zeiger (2006)

So, it is negligible in cells and small plants, but may be significant in tall plants (trees).

To understand and remember

Ψ_w of pure water = 0 MPa

Water moves from higher water potential to lower water potential.



กระดังงา (*Peperomia pellucida*)

Taiz and Zeiger (2006)

Pathways of radial transport of water

1. Apoplastic pathway (or Bypass flow)
2. Symplastic pathway
3. Transcellular or transmembrane pathway

Orchid root

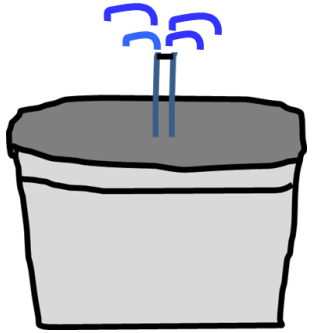
Steudle (2000) Plant and Soil, 226, 45-56.

Mechanisms for vertical transport of water

1. Root pressure (แรงดันราก)

How to check/confirm whether root pressure exists?

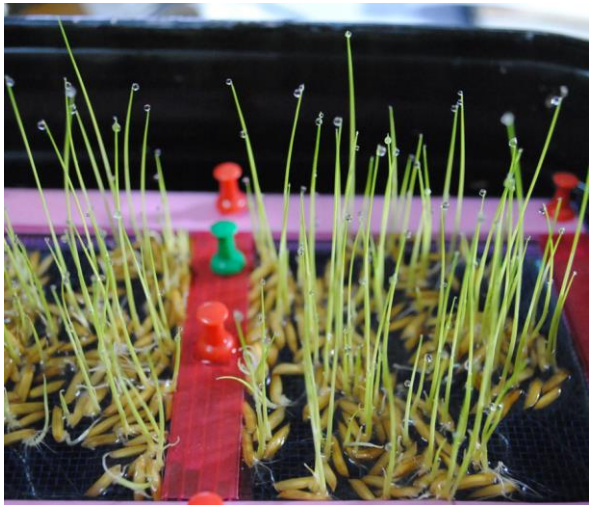
1.1 Water exudates from the cut end (stump).



Generating pressure about 0.05-0.5 MPa,

measuring by a manometer (Taiz and Zeiger, 2006, p58)

1.2 Guttation (the exudation of water droplets)



Guttation from rice (*Oryza sativa* L.) leaves

How do plants generate root pressure?

By absorbing **ions (or minerals)** from the soil solution, concentrating them in the root cells and in the xylem sap, resulting in low water potential in the root xylem.

Conditions

I. High concentration in the root

II. Low transpiration rate

Advantages of root pressure

1. Helping transport water

2. Getting rid of air bubble in the xylem

Taiz and Zeiger (2006, p 58)

2. Capillary force/ action

3. Transpiration pull