Plant Water Status

Water plays essential roles in plants as a constituent, a solvent, a reactant in various chemical processes, and in maintenance turgidity.

The physiological importance of water is reflected in its ecological importance: wherever temperature permits growth, water availability is a factor controlling plant distribution.

The importance of water is a result of its numerous unique properties, many of which arise from the fact that water molecules are organized into a definite structure held together by hydrogen bonds. Furthermore, the water bound to proteins, cell walls, and other hydrophilic surfaces has important effects on their physiological activity.

To better understand issues of soil water availability, plant water stress, and water flow in plants, it is necessary to quantify the energy status of water in the plant (or soil).

Water potential is the common way to do this. The water potential is the energy status of the water to do work. It is quantified as the amount by which its chemical potential is reduced below that of pure water.

The water potential at any point of interest can be defined by:

$$\Psi_{\text{water}} = \Psi_\pi + \Psi_p + \Psi_g$$

Where:

$$\Psi_{\text{water}}$$ is the total water potential (or just water potential). $$\Psi_{\text{water}}$$ is almost always negative, although it can be 0 in fully turgid, living cells.

$$\Psi_\pi$$ is the osmotic potential. It is the lowering of the energy of water due to dissolution of solutes in water. $$\Psi_\pi$$ is always negative.

$$\Psi_p$$ is the pressure potential (or hydrostatic pressure). $$\Psi_p$$ is positive in living cells. In living cells $$\Psi_p$$ is called ‘turgor pressure’. In xylem cells (vessel elements, fibers and tracheids), $$\Psi_p$$ is negative (xylem is under tension). $$\Psi_p$$ includes the effect of water-binding to colloids and surfaces, and the capillary effects in cells and cell walls.

$$\Psi_g$$ is the gravitational potential. This is the energy of water due to its position above a reference plane (usually the ground). $$\Psi_g$$ decreases by 0.1 MPa for every 10 m above ground.

Units: water potential is expressed in pressure units of megapascals (MPa) or bars.

From thermodynamics: Chemical potential of water = $$\mu_{\text{water}} = \frac{\mu_w - \mu_0}{V_w} = \frac{R \cdot T}{V_w} \cdot \ln\left(\frac{e}{e^0}\right)$$
Where:

- $\mu_w$ is the chemical potential of water at constant temperature and pressure (free energy per mole)
- $\mu^0$ is the chemical potential of pure water at the same temperature and atmospheric pressure
- $R$ is the gas constant (0.00832 liter MPa/degree mol at 273ºK)
- $T$ is the temperature (ºKelvin)
- $V_w$ is the partial molal volume of water (cm$^3$/mol)
- $e/e^0$ is the relative vapor pressure ($e$ is the vapor pressure of the solution; $e^0$ is the vapor pressure of pure water).

$$\Psi_{\text{water}} = \frac{cm^3}{mol K} \cdot \ln\left(\frac{kPa}{kPa}\right) = \text{MPa}$$

- Water tends to flow from high (less negative) water potential to low (more negative) water potentials.

The water potential of a leaf is influenced by three main variables: the water potential of the soil, the rate of transpiration, and the resistance of the hydraulic pathway between the roots and the leaf. This relationship can be expressed as:

$$\Psi_{\text{leaf}} \text{ is proportional to } \Psi_{\text{soil}} - [\text{transpiration rate} \times \text{(hydraulic pathway resistance)}]$$

From this relationship, we can make several generalizations, including:

1. With constant transpiration and hydraulic pathway resistance, leaf water potential will decline as soil water potential declines.
2. If transpiration is occurring, leaf water potential must be lower than soil water potential
3. With constant hydraulic pathway resistance and soil water potential, leaf water potential will decline (become more negative) as transpiration rate increases.
Measurement of leaf water potential using pressure chamber

One way to measure the water potential of a leaf is to utilize a pressure chamber, or Scholander chamber (Scholander 1965). Detailed techniques, assumptions and applications for this instrument can be found in Boyer (1975), Ritchie and Hinkley (1975) or Gonzalez (2001). In brief, the following general steps are followed to make measurements with this technique:

1) A leaf or other plant part is cut off from the tree. Since the water in the leaf xylem is usually under tension, the water column pulls back from the cut surface.

2) The leaf is placed into an air-tight chamber with only the cut surface sticking out.

3) The chamber is slowly pressurized, while the operator watches the cut end of the petiole or branch.

4) When water reappears at the cut surface, the pressure in the chamber is recorded. This is called the balancing pressure.

The balancing pressure can be thought of as the pressure it takes to exactly counteract the tension that existed just prior to the cutting of the leaf. This implies that the balancing pressure is equal (but opposite in sign) to the water potential of the xylem.

Water potential readings taken just before sunrise (pre-dawn water potentials) are often a good indication of the water potential of the soil. This is under the assumption that during the night, when the tree is not transpiring, the water potential of the tree’s tissues has come into equilibrium with the water potential of the soil.

Water potential readings taken during the day, while the tree is transpiring, give an indication of the degree of water stress the tree is under.

It should be noted that the pressure chamber reading gives $\Psi_p$ for the leaf. Osmotic potential ($\Psi_\pi$) can be measured directly on sap expressed from leaves or branches with an instrument called a psychrometer (Dixon and Tyree, 1984; Boyer, 1995). Gravitational potential ($\Psi_g$) can be calculated from the height above ground at which the sample was collected. The sum of these measurements would then give $\Psi_{water}$. Generally, $\Psi_\pi$ of xylem sap is very near 0.0 MPa, so the pressure chamber measurement is usually assumed to be nearly equivalent to $\Psi_{water}$ after accounting for gravitational effects.
**Literature Suggested**


