3.15 Leaf water potential as a measure of water status

Species facing soil water shortage can avoid water stress to a degree by dropping leaves, or delay the development of water stress in their tissues by rooting deeply, or by shutting stomata and losing stored water only slowly through their cuticle. Alternatively, tissues may tolerate physiological desiccation. The bulk leaf water potential ($\Psi_L$; units MPa) is a simple indicator of leaf water status; the more negative the value, the more dehydrated the leaf.

When measured pre-dawn, the plant may have become equilibrated with the soil during the night, and the $\Psi_L$ may thus represent the soil water potential in the ‘average’ root zone. However, recent work has shown instances of substantial disequilibrium between pre-dawn $\Psi_L$ and soil water potential as a result of several mechanisms, including nocturnal transpiration, cavitation in the xylem and osmolyte accumulation in the cell walls. Thus, pre-dawn $\Psi_L$ may be more negative than the soil water potential, and should be used only as a tentative index of soil water availability.

During the day, $\Psi_L$ will decline below the soil water potential as a result of transpiration into the atmosphere. When measured in the dry season, the midday $\Psi_L$ can provide a useful index of the degree of physiological drought experienced. Thus, the minimum value for $\Psi_L$ that a plant reaches, usually at midday at the driest, hottest time of year, can be used as an index of the tolerance to water shortage that the species (or individuals and populations) demonstrate (assuming that the plants are still healthy and not drought-injured).

What and how to collect

Measurement of minimum values of $\Psi_L$ is typically carried out at the end of the hot, dry season for evergreen species and in Mediterranean winter-rain ecosystems. However, in summer-rain ecosystems, the time of year at which drought stress is maximal may not be obvious. Repeated-measurements in different seasons can help find the real minimum $\Psi_L$ for each species.

Depending on the type of pressure chamber used (see below within the present Protocol), either leaves or short, terminal, leafy twigs should be collected. Samples should be collected at midday and, as previously indicated (see Section 3.1), from shoots or individuals located in the sun. Leaves should have been exposed to direct sun for at least 30 min before collection (avoid cloudy days). We recommend measuring samples as soon as possible, or at least within half an hour of collecting all samples (with the number of samples depending on the number of pressure chambers available) over a period of no more than half an hour between the first and last measurement. Samples should be collected into sealable plastic bags, into which one has just exhaled to increase moisture and $\text{CO}_2$ to try to minimise shoot transpiration within the bag. Samples sealed in plastic bags should be kept refrigerated and in darkness (e.g. in a refrigerated picnic fridge, or an insulated cooler box containing pre-frozen cooling bars or ice).

Measuring

The simplest way to measure leaf water potential is with a pressure chamber, or Scholander bomb (see diagram in Fig. 4). This consists of a pressure container into which the sample (leaf or terminal twig) is placed, a manometer or pressure gauge to measure the pressure inside the chamber, and as a pressure source, a pressure tank of liquid N, connected to the chamber through a needle valve and pressure-safe (normally copper) tubing. Many models with different characteristics are commercially available.

A leaf or shoot is placed inside the chamber, with its cut end projecting to the exterior through the sealing port. Pressure, from the N tank, is then gradually increased in the chamber. When a drop of water appears at the cut end of the specimen, the ‘balance pressure’ indicated by the gauge or manometer is recorded. Assuming that the xylem osmotic potential is very low, the balance pressure represents the equilibrium water potential of the plant material in the chamber, multiplied by $-1$. Leaf water potential is conventionally expressed in MPa. Minimum leaf water potentials usually vary from near 0 to $\pm 5$ MPa, but can be lower in (semi-)arid ecosystems. Extreme care should be taken when pressure chambers are used under high pressures.

References on theory, significance and large datasets: Hinckley et al. (1978); Ackerly (2004); Bucci et al. (2004); Bhaskar and Ackerly (2006); Lenz et al. (2006); Jacobsen et al. (2008); Bartlett et al. (2012).