# Trees and drought

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Water availability, primarily from rainfall, irrigation or a high water-table is among the most critical environmental factor affecting tree establishment, growth, health and longevity. Prolonged or severe drought reduces growth, photosynthesis, and water-content of tissues. Depending on severity, this can cause decline and increase susceptibility to secondary pests, such as bark beetles, wood borers and canker diseases and root rots.

Water loss in plants is a natural and essential function. Most water in plants is lost through the stomates (tiny openings in the leaves) and the lenticels (natural openings) in the bark. When water is lost through transpiration (loss through the leaves) faster than it can be taken up by the roots, a water deficit (shortage) occurs, affecting growth and health, depending on severity. Excess transpiration typically occurs when temperatures are high, humidity is low, windy conditions persist, roots are damaged or soil moisture is too low or too high. Stomates open and close in response to environmental conditions, particularly soil-water depletion, to conserve water. Closure of the stomates can, however, limit photosynthesis by decreasing carbon dioxide uptake. Respiration (consumption of energy to maintain living cell), nonetheless, continues, leading potentially to carbohydrate depletion (plant starvation). Unless soil moisture improves, leaf wilt, leaf scorch, premature defoliation, branch dieback and death may result. Water loss from plants is influenced by heat, wind, humidity, light, leaf morphology, and leaf surface area.

Droughty conditions develop periodically over large areas, or prevail on sites where soil moisture is restricted by soil disturbances such as soil compaction, altered drainage patterns, under fill soils or by certain geological or topographic conditions (shallow, sandy and rocky soils, ridge tops, and hot, south-facing slopes).

Symptoms of water stress depend on the duration and severity of the drought. Typically, the younger leaves, depending on species, may wilt (droop), shrivel, turn brown or drop prematurely. With increasing drought, older leaves are affected. Leaves under moderate drought stress may turn yellow or develop marginal leaf scorch (brown, dead leaf margins). Symptoms first appear in the top and outer foliage and progress from the top down and outer crown inward.

Wilting—the visible drooping of leaves, can occur during the day followed by rehydration and recovery during the night. Trees that do not recover at night are said to be permanently wilted. Such tree will recover only when additional water is supplied to the soil.

Water moves into the roots through a semi-permeable membrane) via osmosis, that is—water moves from an area of high water potential (low salt concentration), typically found in the soil, to one of lower water potential (higher salt concentration), typically found in plant root cells. High levels of salts in the soil restrict uptake of water. Trees accumulate salts (dissolved mineral ions) in their roots to increase osmotic potential which facilitates water uptake. This requires the expenditure of energy (respiration).

Drought can have a profound affect on plant growth and physiology. For example, as water evaporates from the soil or is absorbed by plants, the concentration of salts in the remaining soil water increases. When the concentration of salts outside the roots exceeds that within the roots, water flows out, rather than into the roots. Salt buildup can also result from the use of saline (salty) irrigation water, reclaimed water, road salts or excess fertilizer. When water flows out of the roots, the cell membranes within the root cells shrink away from the cell wall often causing cell damage or death. Tree roots may be suberized (water-proofed) to limit water loss from the roots back into the soil, unfortunately this also reduces water uptake. Nonetheless, drought can physically damage or kill tree roots. Non-woody, absorbing roots, typically located in the upper foot of soil, are most affected. Without functioning absorbing roots to provide water to the foliage, additional water deficit injury may occur. Trees may respond by restricting growth, shedding leaves, increasing root growth, adjusting osmotic potential (increasing salt concentration within the cells,) regulating opening and closing of the stomates.

Stomates open and close in response to light, humidity and water availability. Transpiration and photosynthesis occurs as long as stomates remain open. As water evaporates from the leaf surface it creates a negative pressure that moves water upward from the roots. Conditions or injuries such as root loss that interrupt the flow of water or reduce uptake may cause wilting or branch dieback.

Trees resist excessive rates of water loss through stomatal regulation. Stomates can be controlled by growth regulators (hormones) transported from the roots during droughts. Abscisic acid, formed by the roots in reaction to soil water deficits, appears to initiate stomatal closure. Most trees respond to drought by closing their stomates to restrict water loss. Depending on the severity of the soil water deficit, stomates may take days or weeks to open and function normally, following replenishment of the soil water. Severe droughts may also cause permanent damage to the stomates. Increases in abscisic acid production also inhibit bud and leaf development and leaf abscission.

Stomatal closure, vital to restricting water loss and conserving soil moisture, has a downside. The main disadvantage is that photosynthesis ceases as carbon dioxide is prevented from entering the leaves. This can cause defoliation, dieback and ultimately tree death as stored energy is depleted. The remaining stored energy is used primarily to support the living cells. Less is allocated for defense. Initially, there may be an increase in the production of these compounds because growth is more sensitive to drought that photosynthesis, thus carbohydrate reserves build up. However, as the severity of drought persists the amount of defensive chemicals decreases and plants become vulnerable to pests that attack stress-weakened trees.

Once excess water in the soil drains by gravity, it can move by capillary action in any direction through the smallest soil pores (capillary space). It moves from moister areas to dryer areas. In this manner, soil water depleted by plant roots can be replenished, otherwise the roots would have to grow into moist area to obtain water. Capillary movement stops when the soil becomes too dry. As the available water is exhausted, the remaining water, held tightly by the soil particles, becomes increasingly more difficult for the roots to absorb. When the forces that bind water to the soil become greater than those holding water molecules together, movement stops. Furthermore, the soil shrinks as it dries, creating gaps between the soil water and absorbing roots.

Acute or prolonged drought may damage leaf enzyme systems and damage stomatal control, effectively reducing a tree's ability to recover full photosynthetic capacity. Before a plant can resume normal growth and metabolism to replace damaged tissues, it must reestablish its photosynthetic 'machinery' including regulation of the stomates. Because food reserves may be greatly depleted, recovery may be slow and affected trees may succumb to pest attack. The full impact of drought stress may not be evident for weeks, months or even years. Some trees may die back while photosynthetic capacity recovers.