PART II OF IV

TURFGRASS DROUGHT RESISTANCE

Turfgrass managers need to understand the difference between water stress and drought stress. In the second part of LANDSCAPE MANAGEMENT's four-part water series, we look at what it takes for plants to adapt to drought.

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To gain understanding of drought resistance in plants, turfgrass managers must realize that no single factor is responsible for drought resistance. It is certainly a combination of factors that enables plants to survive conditions dry enough to kill other plants which do not have these characteristics.

An important issue in understanding drought resistance is to differentiate between drought and water stress. Drought is a meteorological term. It is defined as an extended period of low rainfall.

Water stress refers directly to the plant and occurs to varying degrees throughout the plant's life. Drought is always accompanied by plant water stress, but water stress may occur even when soil moisture is plentiful.

One definition of water stress—a lowering of the water potential—means that less energy is held within the tissue water due to a loss in turgor pressure or a concentration of solutes in the plant cells. Solutes become concentrated due to a decrease in water content or an active accumulation from the soil solution. Research has shown a day/night (diurnal) fluctuation in turgor and water potentials in Kentucky bluegrass (Table 1).

As plants develop more severe water stress (lower turgor and water potentials) during the afternoon hours, they are able to regain their water status—more positive turgor and water potentials—at night when conditions are less favorable for water loss. However, during drought stress, turgor and water potentials may only recover partially in the dark because soil moisture normally used to replace tissue water lost via transpiration simply isn't there in sufficient amounts. As a result, plant water stress increases as a drought continues.

Drought's damage

Drought affects the morphology or appearance of plants, especially the way plants grow. For example, leaves that develop during drought stress have thicker cuticles and fewer stomata. This growth pattern reduces the rate of water loss from the leaves and conserves plant and soil moisture.

During prolonged water stress, large cells collapse, resulting in leaf folding of most cool-season grasses and leaf rolling of warm-season grasses.

In addition, older leaves die, drop from the plant and contribute a mulch to the soil. Leaf senescence and death is accelerated by severe water stress. The remaining turfgrass leaves fold or roll up depending on action of cells located near the leaf midrib.

During prolonged water stress, these large cells collapse, resulting in leaf folding of most cool-season grasses (most fescues, bluegrasses, ryegrasses) and leaf rolling of warm-season grasses (Bermudagrass, St. Augustinegrass, centipedegrass and zoysiagrass). This reduces leaf area, so both radiative heat load and transpiring leaf surface are reduced. The net effect is moisture conservation.

Drought also influences delivery of photosynthates to the leaves, roots, tillers and rhizomes. Root-to-shoot ratios have been used to evaluate drought-resistant plants, because plants with higher root-to-shoot ratios are often more drought resistant. In addition, root-to-shoot ratios of plants increase during drought stress. This also is true of turfgrasses and is due to the differential sensitivities to water stress of different fractions of the plants. Research has shown that tillers and rhizomes are very sensitive to prolonged water stress (Table 1). This sensitivity accounts for much of the increase in root-to-shoot ratios of Kentucky bluegrass during drought.

Plants can be divided into three general categories concerning mechanisms of drought resistance. Those that:

1. escape drought;

2. avoid drought with high tissue water potential; and

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Turfgrass has developed water conservation mechanisms. Shown here is a cross-section of a tall fescue leaf blade (A).) with ridged upper surface and smooth under surface; (B) as moisture stress occurs, the leaf begins to roll; and (C) the final response, a tightly rolled leaf blade with the upper surface being protected to minimize water loss.

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3. tolerate drought with low tissue water potential.

Escaping drought

Plants that escape drought are plants like annuals that can germinate quickly and complete their life cycles (seed-to-seed) before the onset of drought. The plants escape drought by surviving those periods of little rainfall as seeds. Many desert annuals have evolved the escape strategy for drought resistance.

In some ways, *Poa annua* (annual bluegrass) is like that. It germinates during the fall when there is plenty of moisture. It sets seed profusely during late spring and early summer, before severe water stress occurs. During hot, dry summer months, poa growing under unirrigated conditions may be severely thinned because the plant itself has little drought tolerance.

However, the survival of annual bluegrass is assured because its life cycle is completed, seed is produced, and it germinates when the conditions are again favorable in the fall. It should be kept in mind that poa exhibits a great deal of genetic diversity.

The growth habits of poa range from tufted, bunch-type annuals to perennial, prostrate creeping types. This diversity in growth habit suggests that annual bluegrasses may differ widely in the level of drought resistance.

Avoiding drought

The second general strategy of drought resistance is avoidance. Plants that avoid water loss during prolonged water stress by maintaining high water potentials (high content of relatively pure water) are classified as being drought avoidant. These are plants that most people associate with arid environments like cacti and spurges.

Drought-avoidant plants have very efficient means of rapidly absorbing water when it is available and have growth characteristics that inhibit water loss. These plants are characterized by thick, fleshy plant parts, very thick cuticles, suberized roots, low surface-to-volume ratios, and a system of photosynthesis which allows them to close their stomates during the day when evaporative demand is very high.

It is important to realize the nature of various adaptive features of these plants because some of these features may represent selection criteria for turfgrass breeders whose goals are to improve drought-resistant turfgrass.

Tolerating drought

The third general category of drought resistance includes plants that tolerate drought at low tissue water potentials (low content of relatively concentrated water). Many turfgrasses belong to this group. Plants belonging to this group react to prolonged water stress by making their tissue water quite concentrated with various salts, sugars and organic acids. This adaptation greatly increases the plant's ability to take up water. So, although there is less water available in the soil, the ability to extract that water is increased.

TABLE 1.

Relative growth of Merion Kentucky bluegrass subjected to increasing drought.

	RELATIVE PLANT GROWTH (%)		
PLANT	OSMOTIC PRESSURE		
PART	LOW		
MODERATE	HIGH		
Whole Plant	100*	52	29
Leaves	100	65	49
Roots	100	65	43
Tillers	100	41	12
Rhizomes	100	32	7

*Values are percentages of growth in low osmotic pressure or drought stress conditions.

Osmotic adjustment

The process of extracting water is called osmotic adjustment and serves an important purpose. Plants which can osmotically adjust can maintain turgor pressure to some degree. This is important, since turgor pressure is the driving force for cell expansion and plant growth. By maintaining turgor pressure, turfgrass roots can continue to grow and extract additional soil moisture. In addition, leaves can grow, increasing photosynthetic capacity, and stomates can stay open in the light when turgor is maintained. When stomates are open, evaporative cooling keeps the leaves from overheating. If osmotic adjustment does not maintain turgor, stomates close rapidly and turfgrass leaves soon overheat.

Several agronomically important grasses have been shown to have capacity for osmotic adjustment, including corn, sorghum, wheat and rice. Turfgrass research at Iowa State University demonstrated that Kentucky bluegrass can osmotically adjust under simulated drought stress conditions.

The recent interest in osmotic adjustment in response to water stress should not lead to false hope. It must be remembered that drought resistance is the result of many plant characteristics.

Osmotic adjustment is a process that may provide valuable insight in the development of drought-resistant turfgrasses. But it is only one process in many that deserves attention.

In addition, research has shown that the capacity of osmotic adjustment is clearly limited. That is, even plants with the greatest capacity for osmotic adjustment have a point at which it is useless to develop drought resistance because of high water needs.

Research at Kansas State University is investigating the relationship between water use requirement and capacity for osmotic adjustment in several Kentucky bluegrass cultivars. It is hoped that this research will yield information helpful to the development of drought-resistant turfgrasses.

Until more basic knowledge concerning drought resistance in turfgrasses is gained, however, performance of turf during drought is solely dependent upon the turfgrass manager's expertise.

Turf management

Management techniques have centered around the need to conserve water. They include limiting nitrogen use prior to drought's onset, tensiometer-controlled irrigation, and using wetting agents to improve wetting uniformity of the soil. Although these management strategies are certainly valuable, long range success may depend primarily on using drought-resistant species and cultivars.

Turfgrass species and cultivars that exhibit superior drought resistance and recuperative potential offer the best hope of ensuring quality turfgrass under non-irrigated conditions. It is gratifying to see that much recent turfgrass research is being conducted with this goal in mind. **LM**