DROUGHT STRESS ON TURF

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Drought is a water stress that diminishes plant turgor causing wilting (a symptom of drought) that limits or prevents plants from normal growth. The degree of drought injury (and wilting) depends upon the growing medium (soil), plant and atmospheric factors. One aspect cannot be studied alone; all must be considered simultaneously.

When dealing with the phenomenon of wilting, we are, in essence, dealing with availability of medium-water (soil-water) to the plant. Hypotheses concerning the availability of soil-water to the plant are: (1) Soil water is equally available to the plant from field capacity to permanent wilting point, (2) Soil water availability to the plant gradually decreases as soil moisture decreases from field capacity to permanent wilting point, and (3) is a compromise that attempts to divide the available range of soil-water into readily available and decreasingly available.

Although all of these theories were based on research and observation, none are appropriate under the entire dynamic array of the soil-water-atmosphere phenomena.

The more recent view of soil-plant-water relation is a concept of a unified and dynamic system. The amount and rate of water uptake is affected by the roots absorption ability and the soil's ability to supply water at a rate sufficient to meet the transpiration requirements. Water availability to plants is dependent upon physical aspects of soil, plant and atmosphere. In this soil-plant-atmosphere continuum water flow occurs from wet to dry throughout the soil, plant, and atmosphere continuously.

Flow encompasses the water transportation through the soil to the roots, absorption by the roots, movement to the leaves, evaporation in the intercellular air spaces of the leaves and vapor diffusion through the stomatal cavities to the air boundry to the external atmosphere.

Water movement occurs along a path of increasing suction (decreasing potential energy). Not only the water content and potential soil-water, but also the flow rate in the soil, influence the water supply to the plant. The water flow in the various parts of the system is proportional to the resistance of flow. Factors such as soil aeration, nutrients, plant age and genetics, as well as meterological factors, can influence resistance to flow.

Resistance to flow is generally greater in the soil than in the plant, and greatest in the transition from leaves to the atmosphere, where water changes from liquid to vapor.

In the soil-plant-atmosphere continuum concept the resistance to flow may, by analogy, be compared to electrical current passing through a stress of variable resistors. The resistance is variable because hydraulic conductivity varies with fluxation of soil wetness and because roots change their density. In the plant, resistance is also variable. Stomatal apertures vary with changing leaf water potential. The atmospheric boundry layer may also vary its resistance as humidity, temperature and wind velocity change.

SOIL MOISTURE

When soil moisture decreases soil water suction increases, thus the plant water suction must increase to obtain water from the soil. As water uptake increases and soil-water decreases, plants will wilt at higher soil moisture levels. If plant-water suction is less than soil-water suction, the root will not take up water and desiccation will commence. This principle may apply to dry or frozen soil, as both will have very high soil-water suction.

As the soil dries near the root zone a soil-water suction gradient develops and water will move from the wetter to the drier area. Plant wilting depends whether the plant can increase root-water suction or root density, and if the soil-water moves toward the root fast enough to compensate for the plant water loss to the atmosphere.

In the field it has been shown that because of different root activity and rooting density, the soil-water uptake from the different depths is non-uniform. Suction gradients, therefore, can induce water transfer from one layer to another.

Decreasing water in a sandy soil has little influence on plant response until a critical point, then wilting takes place. In sandy soils water is held at low suction and only when water content is as low as 6-7% is a larger root suction needed to further extract soil-water. In clay soils suction increases gradually with decreasing water content. At any particular suction, clay soils retain more moisture than sandy soils. The hydraulic conductivity of clay soils tends to be larger than sandy soils.

Changes in transpiration rate will not affect the wilting point of plants grown in sandy soils but may in clay soils. In clay soils wilting occurs at higher soil moistures than in sandy soils as water uptake increases. Thus, both suction and wetness at wilting are affected by water uptake. A clay soil can maintain a higher rate of transpiration longer than a sandy soil since both its water content and hydraulic conductivity are generally higher.

PLANT RESPONSE TO WATER STRESS

Not all plants need the same amount of water. Plants classified as hydrophytes are those that need large amounts of water (i. e. rice); mesophytes grow where amounts of water are intermediate (i. e. Ky. bluegrass) and xerophytes grow in dry regions (i. e. buffalograss). This discussion will be limited to the mesophytes.

Through evolution many of the grasses we use for turf are able to survive droughts. Most grasses have features such as closing or reducing stomata apertures, rolling of leaves or increasing cuticle thickness to resist transpiration losses when water stress is initiated.

The grasses that are utilized for turf in states like Michigan and Virginia will tolerate or resist short periods of drought. Some of these must go dormant (only buds, crown or rhizomes survive) to persist. At the same time other grasses will remain green and grow because they have root systems that are able to obtain enough moisture to satisfy their transpiration needs. The fescues, bermudagrasses and zoysiagrass are some of the most drought hardy turfgrasses, while the bluegrasses are moderate and the creeping bentgrasses are poor.

Within turf species we find certain cultivars better able to withstand drought than others. In our studies with Kentucky bluegrasses, the more drought resistant varieties are those with deep root systems.

PHYSIOLOGY OF WATER DEFICITS

When plants are subjected to drought, protoplasmic viscosity generally increases and metabolites breakdown. The hydrolysis of starch and protein increases during desiccation. In drought (and frost), the water level decreases within the tissue and osmotic and matric potential becomes more negative. It appears that in drying the water is absorbed in the hydrating matrix, especially protein, thus reducing enzymatic activity. It has been proposed that enzymes cease activity (especially during freezing) when the water layer around protein molecules desiccates and permits sulfhydryl groups to contact each other and form disulfide linkages.

Plant response to water deficits may be altered with water management. It has been shown that under water stress roots may increase to a larger extent than tops. This may be explained on the basis that free energy of water in the roots exceed that in the tops. Therefore, more water is available for cell elongation in the roots than the tops. This condition prevails regardless of water stress. However, during water stress a large portion of the carbohydrates are transported to the roots where they can enhance root growth. From this it appears that a limited water-stress at critical times may actually increase resistance to drought stress.

Generally, low nitrogen and high phosphorous fertilization may increase drought resistance. In Virginia we have found late fall nitrogen fertilization stimulates root development but also increases winter desiccation of creeping bentgrass. This increase of desiccation, however, may be off-set with iron fertilization. Therefore, in this area we are better able to withstand summer droughts when fertilization is properly managed to develop deep root systems.

Water stress reduces the aperture of the stomata, which influences photosynthesis and respiration. Some species will differ as to the influence of water stress on these processes. There is some evidence that respiration increases with decreasing water potential to a point, then respiration decreases with further decrease of water potential.

METEROLOGICAL FACTORS

It has been mentioned previously that transpiration rate is dependent upon the water potential (water vapor) gradient between the stomatal cavity and the atmosphere as well as the resistance of water flow.

The gradient in pressure of water vapor is determined to a large extent by the thickness of the boundry layer between the leaf and the atmosphere. The thinner the boundry layer the larger the transfer of water vapor (or heat convection). Since the boundry layer becomes thinner as wind increases and the boundry layer is thinnest for small leaves, small leaves in high wind will generally have high water vapor transfer to the atmosphere.

The vapor pressure (potential humidity) is a function of temperature. As temperatures increase there is an increase in vapor pressure deficit (the difference between actual vapor pressure and the potential vapor pressure). If we assume that the leaf is saturated with water vapor and the leaf temperature is higher than the air temperature and the leaf holds much more water vapor than the air, the loss of leaf water will then be rapid. Here we can see that transpiration (and possibly wilting) will occur if the air has lower relative humidity (actual humidity compared to potential humidity) than the leaf or if the leaf has a higher temperature than the surrounding air even if both the leaf and air are vapor saturated.

Another factor that will influence the transpiration rate is the substances dissolved in the cell-wall water. Our current studies indicate that fertilization may influence this phenomenon. Also the tension with which water is held by the cell walls will influence transpiration rate.

In addition, the stomatal aperture is variable and is nature's way of changing transpiration rates to benefit the plant under varying environmental conditions.

RELATION OF SOIL MOISTURE AND TRANSPIRATION

A plant canopy that completely covers the soil will approach maximum transpiration rate if meterological factors are correct and the soil has a high water content. However, as the soil dries, the leaf-water potential results in closure of the stomates and increases resistance to water transfer to the atmosphere.

SOME PREVENTIONS TO MINIMIZE DROUGHT STRESS OF TURF

Since most drought stresses may be directly related to soil-water potential, it seems fitting that prevention to reduce drought begins with the soil. Where possible, steep slopes that are condusive to rapid water run-off and consequently low water infiltration should be eliminated as much as possible. Also, it is important that adequate internal soil drainage be provided. When gravitational water is not permitted to escape, or exceptionally high water tables exist, roots are prevented from growing deep and are readily subjected to drought stress.

When modifying soils for specialized turf areas, such as golf putting greens, the tendency is to use large quantities of sand to prevent compaction. In some cases sand is used exclusively. These soils, of course, will not maintain as long a duration of transpiration as one that contains adequate clay or organic matter. Therefore, to minimize drought stress, the soil volume should constitute 10-15% of clay and 10-15% organic matter.

Drought resistant species should predominate on turf areas that will receive no supplemental irrigation. For example, the fescues will tolerate drought stress better than the Kentucky bluegrasses and either of these species will tolerate drought better than creeping bentgrass.

Shaded areas should be considered as drought susceptible areas, especially under trees. The trees, in addition to reducing the light the grasses intercept which limits photosynthesis and consequently lowers the turf root depth, will also utilize water, thus creating a soil with a high water suction.

Fertilizer schedules should be employed to enhance root depth. Cool season grass roots are mainly formed in April and early May. Excess nitrogen nutrition should be avoided immediately prior to or during this period. Fertilization with nitrogen at this time will stimulate top growth, utilize the reserve carbohydrates and limit root development. Subsequently grasses that develop shallow root systems in the spring will be most drought stress prone in the summer.

Turf grasses, such as creeping bentgrass, that need more moisture than the normal precipitation provides will have to be irrigated. To reduce drought stress, prudent water management must be exercised. Frequent watering, especially when roots are developing, will prevent good gas exchange between the soil and the atmosphere which limits root development. Also this will produce grasses with large cells and large air space between the cells which are relatively less drought hardy.

During periods when transpiration rate is low (spring), a limited restriction of irrigation frequency may induce better drought hardiness. Inducing moderate soil water suction at these periods will limit foliar growth, decrease cell size and enhance root development, all of which increases drought resistance and hardiness.

Restricting watering during periods of high transpiration (summer) may increase soil-water suction to the point that roots will be irreversibly damaged. However, frequent irrigations, light or heavy, should be avoided as much as possible since this practice limits gas exchange in the soil.

This is especially true if the irrigation system must be shut down during the winter. There is good evidence that a heavy irrigation in the late fall will help prevent desiccation during the winter.

As has been pointed out earlier, wilt can occur during periods of high transpiration even though the soil may be saturated. This wilting may be prevented by syringing. Syringing should not be confused with light irrigation. When syringing, only enough water should be applied to wet the grass leaves and provide a cooling effect when the water evaporates.

Thatch build-up that limits water infiltration into the soil thus increases drought stress. Periodic aeration, vertical mowing and soil topdressing will reduce thatch and subsequently improve soil moisture. Also the practice of aeration eliminates the effects of compaction that demeans water infiltration.

Establishing wind breaks in critical areas, applying mulches, such as straw and wood cellulose fiber, on new seedings, and installing protective winter cover will reduce the transpiration rates and limit drought stress.

The simple practice of adjusting the mowing height will reduce drought stress. By raising the mower in the spring, more leaf area is permitted to remain. This increase in photosynthetic producing material will increase the plant carbohydrates and produce a deeper root system. By maintaining a high mowing height in the summer, a better insulation layer is provided to reduce the transpiration rate.

Prevention of insect damage (such as white grubs), elimination of disease, and proper use of pesticides could also reduce the ill effects of drought.