



TURFGRASS TRENDS

Volume 9, Issue 3 • March 2000

AGRONOMY

Stomata : The Plant's Port of Entry

By Dr. Karl Danneberger

Whether it is a golf course green, home lawn or athletic field, we often forget that a turf is composed of millions of individual plants. How each of those plants respond to environmental and cultural management programs dictates the quality of the turf. When we look at the structure and function of individual turfgrass plants, the complexity of life is easily seen.

In this paper, one small plant structure — stomata — will be discussed. Stomates are rather simple structures that allow for gas exchange and transpiration to occur. However, when you think of survival of turfgrass plants through the necessity to create usable energy from solar radiation via photosynthesis, and the dissipation of heat from the plant via transpiration, stomata play a critical regulation role.

Stomata structure

The stomatal area of the leaf blade includes the guard cells and the stomatal pore (Esau, 1977). The stomatal pore or opening is where carbon dioxide (CO₂) enters the plant for photosynthesis and the point of transpiration of water from the leaf. Two cells called the guard cells define the stomatal pore. The guard cells are rather elongated and slightly constricted in the middle. When guard cells are turgid they create the open pore.

The stomatal area generally accounts for 1% of the total leaf surface. For turfgrass species, the stomatal density is approximately 2% to 3% of the leaf surface (Beard, 1973). The number of stomates can vary depending on the turfgrass species. Green et al. (1990) calculated the stomatal density for ten turfgrass species and found greater stomatal density on the adaxial (upper) leaf side than the abaxial (bottom). Densities ranged on the adaxial side from 68 stomata mm⁻¹ for tall fescue to 203 stomata mm⁻¹ for hard fescue. Interestingly, no stomata were found on the abaxial side of hard fescue, sheep fescue, chewings fescue and rough bluegrass.

Although we think of all plants having stomata, some plants do not. There are two major groups of astomatous plants (Woodward, 1998). The first group contains plants that never possessed stomates, like the gametophytes of bryophytes and lichens. The second group contains plants that were stomatous at one time, but developed effective astomatous characteristics. These types of plants are generally aquatic or parasitic in nature.

As previously mentioned, stomates play a role in gas (CO₂) exchange and transpiration. A question that can be asked is: What did stomates initially evolve to do? The earliest land plants were astomatous with a thick cuticle around their arial organ (Edwards et al. 1996).

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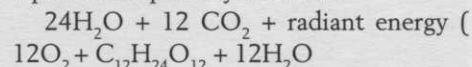
The absence of stomata along with a thick cuticle reduced any water loss from the plant. However, given the extremely low CO₂ diffusion rate into the leaf, a minimal level of photosynthesis occurred resulting in slow growth and development. These early plants probably evolved during periods of high CO₂ concentrations in the atmosphere.

Later, periods of low CO₂ concentration drove evolutionary forces toward high stomatal density in plants such as horsetails, ferns, conifers and angiosperms (Edwards et al. 1996). Stomata most likely evolved initially for gas exchange followed later as a mechanism to regulate water loss (Danneberger, 2000).

Let's look at the effect of stomata on gas exchange and transpiration.

Gas exchange

Photosynthesis is the process where plants convert radiant energy from the sun into usable metabolic energy. The overall equation for photosynthesis is:



Where:

H₂O is equal to water

CO₂ is carbon dioxide as previously mentioned

Radiant energy is light from the sun

O₂ is oxygen and

C₁₂H₂₄O₁₂ is carbohydrate molecules where the usable energy for metabolic processes is stored.

The presence of atmospheric CO₂ is critical for photosynthesis. For CO₂ to enter the photosynthetic process, it must have an entrance point in the leaf. The port of entry for CO₂ is through stomata. The opening and closing of stomates follows a circadian rhythm in many plants.

During daylight when photosynthesis is active, the stomata open to allow for CO₂ diffusion, while at night when photosynthesis is not active, closure occurs. The exceptions are CAM plants (ex. desert plants). The trigger for stomatal opening is the CO₂ concentration in the intercellular spaces and not at the leaf surface or in the stomatal pore (Mott, 1988).

Thus, if CO₂ concentrations are high in the leaf, stomata will close. Conversely, if CO₂ concentrations are low, the stomata will open. Light also plays a role in stomatal opening. Illumination increases pore opening by increasing the uptake of potassium and chlorine, along with increased synthesis of malate, which results in a swelling of the guard cells (Raschke, 1975).

Within the visible light spectrum, blue light elicits the greatest response in governing stomatal opening, although the blue light effect is enhanced in the presence of continual red light (Karlsson, 1986).

Transpiration's role

For turfgrasses, transpiration is the major mechanism for dissipating heat from the leaf blade. Favorable conditions for transpiration are low atmospheric humidity and high leaf temperature. The major mechanism in regulating transpiration is the opening and closing of stomata. The closure of stomata reduces transpiration.

Although I previously mentioned that, from an evolutionary stand point, stomata evolved initially for CO₂ exchange, the evolution of stomatal density most likely allowed for the development for more advanced and taller plants.

If we look at water movement through the plant xylem (the plants' water transport system), the tension of the water increases when transpiration increases and soil moisture decreases. If this water tension increases to a point where the column of water breaks in the plant, air enters the xylem, disrupting water flow.

This process is called xylem cavitation. It is postulated that increased stomatal density enhanced the evolutionary process of plants by preventing xylem cavitation, thus allowing for longer xylem pathways to develop for taller plants (Woodward, 1998).

Only 1% to 3% of the water absorbed by a plant is actually used for metabolic processes. The vast majority of absorbed water is used for transpiration, with 90% of that water escaping through stomata (Beard, 1973). Thus, stom-

atal opening or closure can have a drastic effect on the cooling of a turfgrass plant.

A field study at Rutgers University looked at the effect of summer stress on the performance of two Kentucky bluegrass cultivars (Perdomo et al., 1996). They found that the cultivar that gave the best quality during summer stress (drought and high temperature) had more open stomata during conditions of decreasing leaf water.

The more open stomata on the higher quality cultivar allowed for greater cooling. Structurally, stomata that are under moisture stress are smaller and have less turgor than stomata from well-watered plants.

Related to water loss but not necessary stomata action, mowing can add to summer stress. Increased transpiration has been detected immediately following mowing due to injury to leaf cells and the cut ends (Hull, 2000; Kneebone et al., 1992).

This is significant on frequently mowed turfs (Hull, 2000). During summer stress times, mowing with a sharp blade versus a dull blade (causes more damage to the leaf) would be an important factor in water loss.

How antitranspirants work

In some cases, it would make logical sense if you could limit transpiration — by restricting water loss, you could conserve plant moisture. You could argue, however, that a turfgrass plant undergoing water stress would close stomata on its own.

There are two major types of antitranspirants. The first is stomata inhibitors — synthetic compounds that induce stomata closure by affecting the stomatal mechanism. They include certain plant growth regulators, herbicides and fungicides.

The second type of antitranspirant are film-forming products. Film forming products coat the leaf, acting as a physical barrier to water loss. Unfortunately, these products tend to cause a greater reduction in photosynthesis than transpiration (Martin et al. 1983).

Conclusion

Turfgrass health depends on the ability to capture and store energy through photo-

synthesis and cool itself through transpiration. A major regulating mechanism for these processes are stomata. Although small and relatively insignificant when compared to the entire leaf surface, stomata play a critical role in turfgrass health.

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