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to bring it to market," says Mealman, who became PBI/Gordon's president in 1973. "Skip sublicensed Trimec to us in the spring of 1969. That year we sold the first gallon to Southern Hills Country Club in Tulsa, Okla."

When Trimec first came out on the market, it was called Fairway, but the metal can also said "Contains Trimec." The Fairway name didn't stick because golf course superintendents kept calling it Trimec. A few years later, PBI/Gordon's ad agency told the company to change the name to what everyone was calling it — Trimec.

The company's original goal was to target the golf course market only, but it soon branched into other markets, such as lawn and garden, in the mid-1970s. The first ad for Trimec appeared in Golfdom magazine in 1970 (see picture to the left). "We established ourselves in the market with ads in three magazines with a total ad budget of $7,704," Mealman says.

At the time, in the early 1970s, ag products were being used on golf courses. Trimec was part of the chemical company's switch to specialty products.

"Our big break came when the herbicide Silvex was discontinued by the Environmental Protection Agency for the lawn and garden market," Mealman says. "The whole Trimec thing changed our company. The ag market was all commodity products, and we saw needs in the specialty market that weren't being met."

PBI/Gordon controlled a synergy patent for the three active ingredients in the herbicide. The patent, which was filed and accepted in 1966, lasted for 17 years. After the patent expired, several post-patent products came to market.

"But it's still the No. 1 brand despite being off-patent," Obermann says, citing industry surveys.

"We established ourselves in the market, and it was hard to dislodge us," Mealman says. "We had an aggressive ad campaign and conducted a lot of field work."

"We wanted to keep earning the No. 1 position in the marketplace and not take it for granted," adds Obermann.

Obermann says Skaptason was a master at herbicide formulations. He developed many of them on paper and they were tested. He tweaked new formulations when he became a full-time employee of PBI/Gordon in 1970. The company eventually introduced other Trimec products, such as Trimec Southern, Trimec Encore, Trimec Plus and Trimec 992 (for the lawn-care market). The original Trimec broadleaf herbicide was eventually renamed Trimec Classic because Mealman didn't want to lose brand power with it.

A trip down memory lane

Jim Harris, superintendent of the Links at Cottonwood in Tunica, Miss., worked on a golf course with his superintendent father when he graduated from college in 1971. They tried to mix the three active ingredients in Trimec on their own to save money. Their concoctions weren't eradicating weeds effectively, so they gave up mixing and used Trimec.

"I've been using it since," says Harris, who uses it for routine maintenance. "I've tried a couple of three-ways that didn't work as well. I know Trimec works."

Sandy Queen, manager of golf course operations for the city of Overland Park, Kan., began working for the city at the St. Andrews Golf Course in 1974 and became superintendent there in 1977.

"When I first became the superintendent, I was looking at broadleaf control from a cost standpoint," Queen says. "I made applications for broadleaf-weed control without Trimec, and they didn't control the clover. That's when I learned the importance of dicamba. I became a big fan of Trimec. There were no other options for that blend of active ingredients."

Back then, Queen used Trimec as a preventive herbicide, applying it wall to wall in the fall and spring.

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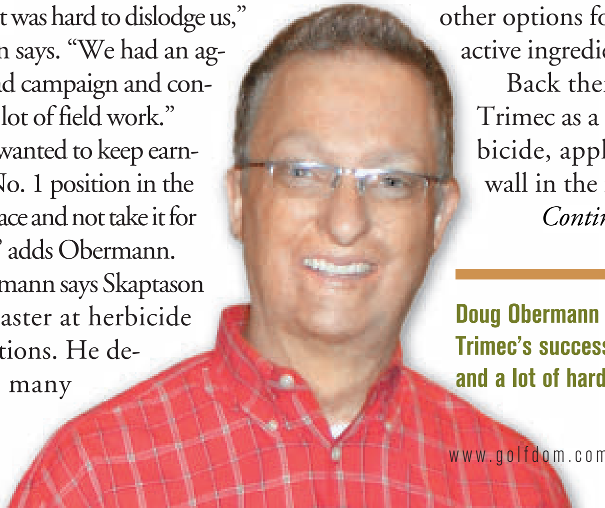
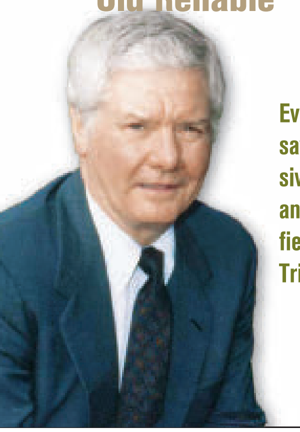


Doug Obermann attributes Trimec's success to a little luck and a lot of hard work.



Everett Mealman says an aggressive ad campaign and plenty of field work helped Trimec's cause.

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Eventually though, post-patent products started replacing Trimec.

"Many superintendents, including me, started using other products after the Trimec patent expired," Queen says. "But I've always questioned whether those other products were better than Trimec. The control was darn near 100 percent."

Keith Pegg, now superintendent of the Zama Golf Club in Japan, used Trimec for the first time in 1970 when he was employed by SunRiver properties in Oregon as an assistant superintendent.

"We saved so much work in weed removal," he says. "I had never seen anything like it and was impressed. We used it every year I was at SunRiver."

In 1974, Pegg left for a superintendent position at Fircrest Golf Club in Washington, where he remained for the next 20 years and used Trimec. Today, Pegg uses Trimec products less now because of their lack of availability in Asia.

Bob Belfield, superintendent at Kettle Hills Golf Course in Richfield, Wis., has been in the business for 42 years, 23 of those at Kettle Hills. He was 15 when he started applying herbicides. Belfield used Trimec and Trimec Bentgrass Formula for about six years at the golf course where he worked before Kettle Hills.

"I remember when it first came out — I was thrilled not to have to handle all those products that now came as one," he says. "It worked well."

Mark Claburn, golf course superintendent at Tierra Verde Golf Club in Arlington, Texas, first used Trimec in the early 1990s while on staff at Barton Creek. He was spot-spraying weeds. "Trimec always provided good control, and the knock down was quick," he says.

Despite its age, Trimec isn't done evolving. PBI/Gordon, an employee-owned company founded in 1947, is developing more variations on Trimec to fill a market need. Those new products will debut during the next two years. Incidentally, Trimec's three active ingredients are also used in newer combination products, such as SpeedZone (carfentrazone-ethyl), PowerZone (carfentrazone-ethyl) and SpeedZone Southern (carfentrazone-ethyl), as well as Surge (sulfentrazone) and Q4 (sulfentrazone).

Not many herbicides have lasted as long as Trimec, Queen says. "Many other turf products have come and gone," he adds. "It's a pretty special formulation." ■

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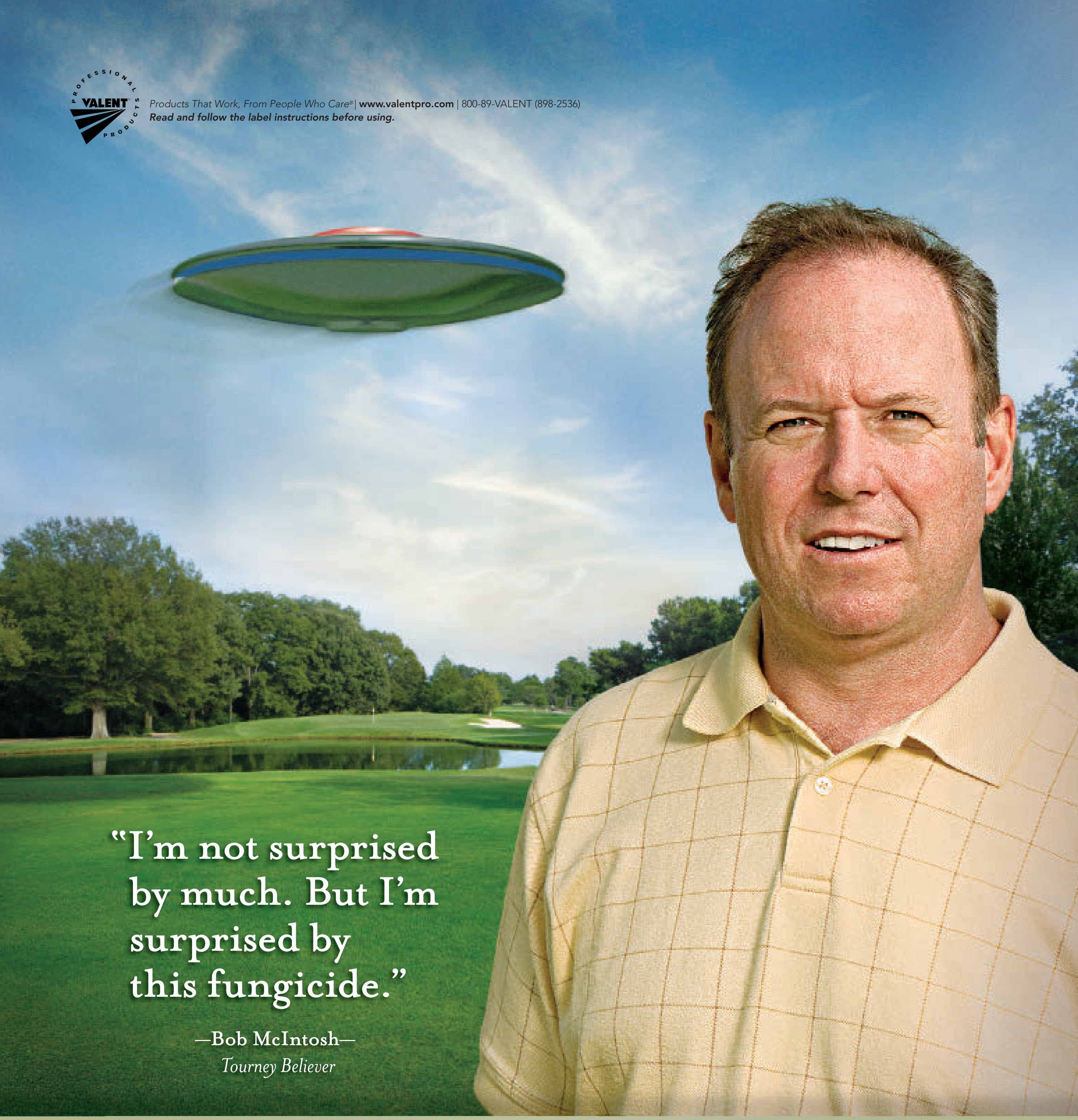

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TURFGRASS TRENDS

IRRIGATION

Water-Saving Turf

It's important to select varieties to reduce irrigation inputs

By Leah Brilman

Turfgrasses provide many benefits to the environment including carbon dioxide sequestering, reduction of wind and water erosion, and cooling of the environment. In spite of these documented benefits, there is increasing pressure to reduce the use of grasses — primarily to reduce the water requirements of urban areas. In many settings, turfgrass is watered much more than is required to maintain turf quality, often because of older irrigation systems or failure to understand how to water the grass. However, there are choices that can be made in species and cultivars to reduce water usage.

In areas where they are adapted, warm-season grasses require less water than cool-season grasses. This is due to their different leaf structure and method of carbon capture. Even within these species, however, it has been shown the improved seeded bermudagrasses, such as Yukon and Princess 77, can use 25 percent less water than the hybrid bermudagrasses. If you're in an area that requires green turf during the winter, the overseeded cool-season grasses can add to the water utilization of these species. In general these species also do not do as well in shady sites.

In areas where cool-season species are utilized, selecting a water-saving grass may depend on whether you're looking for drought avoidance, the ability to survive short periods without irrigation or the ability to perform with less water. In many areas of the West, irrigation is required for survival. The dry summers, with low humidity, make for higher water-use rates. The depth of the soil, the type, the slope and level of compaction all influence the availability of water to the turfgrass system.

As golf course superintendents study many trials looking at drought tolerance, they'll find some measure evapotranspiration (ET) rates under non-limiting water conditions, which can be very different than ET rates with limited water. Other trials just limit water availability. Some trials are outside while others are in greenhouses or controlled environments. The other difficulty in evaluating trials is variation in species or cultivars in these trials making cross comparisons difficult.

Kentucky bluegrass has the reputation of being a high water user. If you examine the trial performed at Kansas State by Bremer et al in 2007 and to be repeated in 2009 (http://turf.lib.msu.edu/ressum/2007/8.pdf), the common Kentucky bluegrasses, which are the cheapest seed and are often used in consumer blends, used 22 inches of water over the summer when irrigated at 50 percent wilt, while the Compact-America types and Mid-Atlantic-types of bluegrass had excellent performance at 8 inches of water over the same period. So changes in the cultivars of Kentucky bluegrass could greatly reduce the water requirements in even a hot environment for this species. These are measurements of the water required to keep the turfgrass looking acceptable to the average homeowner using an end point they can understand.

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IN THIS ISSUE

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Sometimes cultivars that wilt first under drought conditions maintain green color longer.

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Often, we read studies where it's decided to irrigate at a set percentage of evapotranspiration. These may be set to 100 percent, 80 percent, 60 percent and 40 percent of evapotranspiration. Ebdon et al (1998) examined the evapotranspiration, water loss of different bluegrass cultivars in high (arid) and low (humid) evapotranspiration environments. Some cultivars had uniform high or low water use in all environments while others varied depending on the environment. Again, in this trial, Mid-Atlantic cultivars had low water use and the common types, such as Kenblue, had very high water use. In general, these types of trials looking at water use are under well-watered conditions.

Richardson et al (2008) did dry-down cycles for extreme drought on Kentucky bluegrass. Again, America-types such as Mallard, SR 2284, and Compact-type such as Diva and Midnight stayed green the longest. Although variation can occur, examination of the NTEP (National Type Evaluation Program) drought trials or drought cycles in other trials can help find lower water-use Kentucky bluegrasses.

Tall fescues are excellent drought avoiders because of their deep root system, as long as you have adequate, non-compacted soil with good water-holding capacity. They are actually higher water users than most Kentucky bluegrasses, but they can stay green all year long without supplemental irrigation in areas with summer rainfall or good soils.

Advances in tall fescues make them finer textured and denser than old cultivars, but most of them maintain good drought tolerance.

A study by Karcher et al (2008) comparing tall fescues with Texas hybrid bluegrass and Kentucky bluegrasses shows that variation in drought resistance does occur in tall fescue, with some new cultivars equivalent to the old, low-density cultivar KY-31.

One feature you can find from NTEP data and other trials is sometimes the cultivars that wilt first under drought conditions actually maintain green color longer. The wilting process may potentially close down the stomates and prevent further water loss. These cultivars may actually use more water initially. Mowing height influences both drought resistance and water usage.

PHOTO COURTESY: SEED RESEARCH OF OREGON

The final set of species to consider for reduced-water use are the fine fescues, which have low water requirements and do well under reduced maintenance. New cultivars have high quality not just in shade but also in full sun. They can be used for golf course fairways and roughs, as well as parks and home lawns.

The photo above shows performance of fine fescues compared to bluegrasses and tall fescues in a low-maintenance unirrigated trial at Rutgers University in New Jersey. Typically, the hard fescue and sheep fescues have done best under these circumstances, but newer chewings slender and strong creeping red fescues show improved performance. The hard fescues transpire less than other species to contribute to drought tolerance and reduced-water usage.

Aronson et al (1987) documented that chewings and hard fescues could maintain their leaf-water potential at lower soil water content than Kentucky bluegrass or perennial ryegrass.

Leah A. Brilman, Ph.D., director of research and technical services for Seed Research of Oregon, can be reached at www.sroseed.com

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Improving Foliar Fertilization of Turf

Basic research on plant cuticles suggests ways to do it better

By Richard J. Hull
and Haibo Liu

What are the merits of foliar fertilization in turf-management programs? Foliar fertilization, not to be confused with liquid applications or fertigation, has been proposed as an efficient and environmentally safe method of supplying nutrient elements to turf, especially intensively managed turf (Middleton, 2001; Liu et al, 2008; Totten et al., 2008). Foliar fertilization specifically targets turfgrass leaves as the site for nutrient application and absorption, while other liquid methods deliver substantial nutrient to the thatch and soil ultimately available for root absorption.

While there are ample opportunities for nutrient loss from all liquid and granular delivery methods, there seems to be a growing sense that foliar fertilization losses can be minimized if appropriate application methods and materials are used (Middleton, 2001). This may be true, but it depends entirely upon how effectively foliar-applied materials can cross the cuticle of leaf epidermal cells and become assimilated within the living protoplasts of those cells.

Foliar-applied materials are sometimes thought to be at least partially absorbed into leaves through the open stomate pores (stomata) but there is really little direct evidence to support that notion. True, the underside of leaves, where most stomata normally are present, absorbs more foliar-applied nutrients than the astomatous (lacking stomata) upper surface, but absorption rates are greatest in darkness when stomata are closed. Also, the guard cells bordering stomatal pores and the outer portion of the substomatal chambers are both covered by a waxy cuticle making wetting and penetration of aqueous solutions highly unlikely. Adding surfactants (wetting agents) to a spray solution increases stomatal penetration but only involving a small percentage of stomata. Due to the limitation of space, this review will focus only on the primary barrier to nutrient uptake by leaves: the surface cuticle.

A wax-coated cuticle covers the outer cell walls of upper- and lower-leaf epidermal cells. The primary function of this cuticle is to minimize the evaporative loss of water from the leaf. Leaves are designed for gaseous exchange (carbon dioxide, oxygen and water vapor) between a leaf's interior and the atmosphere to be controlled by the opening and closing of stomata, not by movement across the cuticle. The cuticle's multilayered composition suits it well to function as a hydraulic barrier (Riederer and Muller, 2006).

The outer-most layer consists of epicuticular wax composed of straight-chain alkanes, long-chain (25-35 carbon atoms) fatty acids and alcohols and esters formed by them. Just beneath the surface wax is a lamellate-structured cuticle proper composed of wax and cutin (polymerized hydroxy fatty acids). Still deeper is a thicker cuticular layer composed of wax, cutin, suberin and long cellulose (glucose polymers) microfibrils that are carbohydrate and have a high affinity for water. Finally, the cell wall proper is reached composed almost entirely of highly hydrated carbohydrate polymers (cellulose and hemicelluloses) and glycoproteins. This carbohydrate cell wall is bonded to the cuticular layer by a pectin (polymers of galacturonic acid and sugars) layer. Through calcium linkages and borate esters, pectin binds cell wall carbohydrates with cellulose in the cuticular layer. The protoplasts of epidermal cells abut the cell walls at their plasma membranes, the final barrier that must be crossed before anything applied to a leaf surface can be useful to the plant.

Given the structure and composition of epidermal cell walls exposed to the atmosphere, it's obvious that virtually any leaf-applied substance will have a difficult time crossing the multilayered outer wall to enter the living protoplasts. However, experience indicates that such passage is possible and occurs readily. Lipid-soluble (lipophilic)

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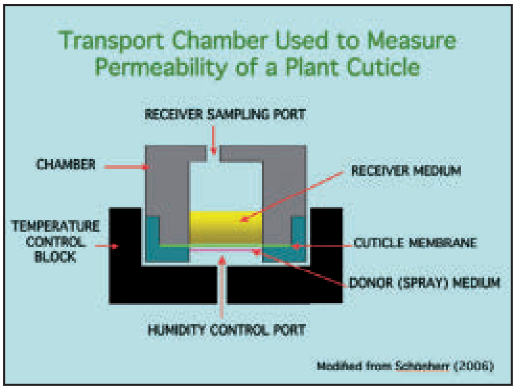
pesticides and growth regulators have been shown to enter leaves in sufficient amounts to influence plant growth. Plants also utilize water-soluble (hydrophilic) nutrients and agricultural chemicals when they're sprayed on their leaves. Years of experimentation have lead to the conclusion that the cuticle of epidermal cell walls provides both a lipophilic pathway as well as aqueous pores by which diverse substances can enter plant leaves.

The structure of a leaf cuticle described above provides no path or mechanism by which a water-soluble nutrient can cross from a leaf surface into living cells. A polar molecule (charged ion or organic dipole) is totally insoluble in the waxes comprising the epicuticular wax surface or the cuticle proper and would have no way to cross such a formidable barrier. Since hydrophilic substances clearly do cross these barriers, it's important to understand how this happens. In a recent review article, Schönherr (2006) summarized the present thinking on mechanisms of foliar absorption based on his extensive research initiated in the late 1960s.

Much of Schönherr's research used isolated cuticles, referred to as cuticular membranes (CM), through which the passage of various substances and the impact of altering environmental conditions on the process were measured. Removing the cuticle from a leaf is tricky. However, by incubating an epidermal peel or leaf piece in a solution of pectinase enzyme, the pectin layer between cellulose cell wall and cuticular layer can be dissolved and the cuticle removed easily. The enzyme causes no physical or chemical damage to the CM and transport across it in either direction is thought to occur by natural means and can be observed by positioning donor and receiver media (filter paper or gelatin sheets) on either surface of a CM. In this way, much critical information on the permeability of cuticles from many plant species to both lipophilic and hydrophilic substances has been obtained. Combining such observations with knowledge of the chemistry and physics of CMs has provided a convergence of ideas that should be very helpful in understanding how foliar fertilization works in the field.



Modified from Schonherr (2006)

The device used by Schonherr (2006) to measure foliar transport of chemicals applied to the surface of a cuticular membrane.

It's generally agreed that hydrated metal cations and less-hydrated but bulky oxy-radical anions require an aqueous pathway to cross a leaf cuticle. They are simply too insoluble in the cuticular wax layers (surface wax and cuticle proper) to dissolve sufficiently for measurable diffusion across these barriers. However, there are no microscopically observable aqueous pores traversing a cuticle through which charge bearing ions or hydrated organic molecules could pass. When ionic fluorescent dyes are applied to a leaf surface, they can be observed crossing the cuticle in aqueous pores having a diameter ranging from 0.9 to 2.36 nm (nanometer = 1 billionth of a meter = 3.9 x 10 to 8 inches). These values were obtained by measuring CM permeability to molecules of known diameter. Dyes exceeding a diameter of 2 nm generally failed to penetrate a leaf cuticle. Since most nutrient ions fall within this size range, they should be able to traverse a leaf cuticle via these aqueous pores.

The nature of these aqueous pores is somewhat conjectural but the current thinking seems to view them as forming around clusters or groupings of permanent dipoles (polar uncharged groups) and ionic units (+ or - charge) of cutin, carbohydrates, sugar acids and polypeptides (protein). All these groups have an affinity for water and within the waxy cuticular layers they would be hydrated and could form an aqueous path along which hydrated ions or polar molecules

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could migrate single file from the leaf surface to the highly hydrated cellulosic walls of epidermal cells. These pores would be unstable, forming and breaking with the kinetic movement of the large cuticular polymers. Their existence depends on a near-saturated external atmosphere or free water on the leaf surface to insure hydration of polar and potentially ionic groups within the cuticle layers. That is consistent with field observations that show greatest nutrient penetration while spray is in the liquid form on leaf surfaces and when humidity is near 100 percent. Organic ions within the cuticle originate mostly from carboxyl groups (organic acids) that ionize in the presence of water to form fixed negative charges along the aqueous pores and on the leaf surfaces. These negative charges attract cationic nutrients and tend to repel anions while small nonionic (no charge) but hydrated molecules move along readily with the flux of water.

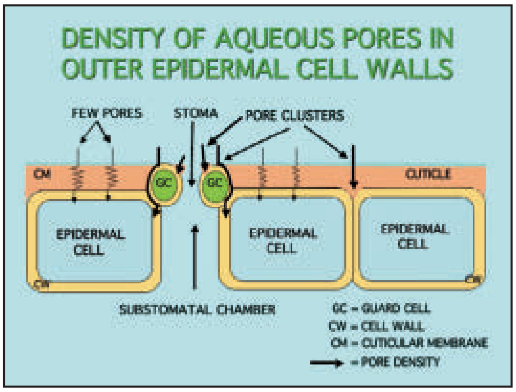

Diagram of a leaf epidermal segment showing the sites of greatest concentration and activity of aqueous cuticular pores.

This is pretty much what has been observed in field experience with foliar fertilization (Totten, 2006; Totten et al., 2008). Cations are absorbed through leaves more rapidly than anions and urea is absorbed most rapidly of all. The absorption rate of foliar-applied nutrients also is dependent on their concentration gradient between the leaf surface and the cellulosic cell walls. However, the cell wall concentration is normally low because nutrient uptake across the plasma membrane of living cell protoplasts is rapid. Only calcium and some micronutrients are likely to accumulate within the cell wall of healthy leaves following a foliar application.

Therefore, high concentration spray solutions penetrate turfgrass leaves more rapidly than more dilute solutions and this can easily cancel out any repulsion of anions by negative charges in the aqueous pores. Bowman and Paul (1992) observed that increasing spray concentrations eliminated differences in uptake rates of ammonia, nitrite and urea.

The distribution of cuticular aqueous pores across a leaf surface is not at all uniform. Studies involving fluorescent dyes, heavy-metal precipitation within pores and radio-labeled nutrient distribution have shown aqueous pores to be much more densely concentrated in cuticular ledges of guard cells facing the open pore of stomata, at the base of surface glandular trichomes (multicellular surface hairs) and in cuticle over anticlinal cell walls. Also, pores in guard cell ledges and those associated with trichomes are substantially greater in diameter and could readily accommodate large metal chelates and other hydrophilic organic solutes of molecular weights up to 800 grams per moles. This would explain the more rapid uptake of nutrients applied to stomata-rich lower leaf surfaces than astomatous upper surfaces even in darkness when stomata are closed.

Dr. Richard Hull is professor emeritus of plant physiology at the University of Rhode Island and adjunct professor of horticulture at Clemson University. Dr. Haibo Liu is associate professor of horticulture at Clemson Universityand stress.

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