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What's the Lowdown on Turfgrass Leaves?

By Richard J. Hull

To state the obvious, turfgrasses are grown for their leaves. To be sure, new leaf growth is mowed regularly and discarded or left to rot, but still the valued part of a turfgrass plant is its dense, green leaves.

Leaves provide the surface where golfing putts are sunk. Turfgrasses are evaluated for many characteristics but leaf color, texture and density are of primary importance. In this series of *TurfGrass Trends* articles, we have discussed the turfgrass crown (Hull, 2000) and roots (Hull, 2000a & b), so today we will get to the bottom line and consider the biology of turfgrass leaves.

Grass leaf structure

Grass leaves are commonly regarded as consisting of two parts: the blade and the sheath (Figure 1).

The green blade has a roughly horizontal orientation when mature but is more vertical when younger and growing. The blade joins the vertical sheath at an angle in a region known as the collar. The light green sheath encloses the sheaths of younger leaves and may itself be enclosed by sheaths of older leaves. All grass leaves originate from ridge-like horizontally oriented subapical meristems that form just below the apex of the crown. Then an intercalary meristem produces new cells at the base of the emerging leaf. As these cells expand and elongate, the leaf tip is pushed upward inside the sheath of the previously formed leaf.

As the leaf grows, a second intercalary meristem forms below the first just above the crown. This second intercalary meristem generates new cells that will contribute to the elongating sheath. The initial intercalary meristem rises upward along the length of developing leaf and continues to lay down new cells that contribute to further elongation of the blade.

As the leaf grows, the collar region differentiates from the initial intercalary meristem at the junction between blade and sheath. At the collar, structures form that are characteristic of the species. A ligule may grow upward from the sheath at the point where the blade angles toward a horizontal plane. Madison (1971) describes the ligule as "an eruption of the epidermis that is two cells thick."

Ligules are membranous and prominent in bentgrasses, perennial ryegrass and rough bluegrass but are reduced to a fringe of small hairs in bermudagrass, Japanese lawngrass and carpetgrass or are completely absent in barnyardgrass.

In some grasses, an overgrowth of the blade edges at the collar form auricles that clasp claw-like around the upper portion of the sheath. Auricles are not present in most grasses but are prominent in perennial and annual ryegrasses. The collar region can also exhibit hairs at the margins of the sheath or the base of the blade. All these collar features tend to be conservative and are useful in grass identification when flowers and seed are not present.

Essential roles of invisible epidermis

The grass leaf is ideally suited for its primary functions: photosynthesis and the export of sugars (mostly sucrose) to all parts of the plant where growth or storage are occurring.

Leaves consist of three basic tissue types: upper and lower epidermis, mesophyll and vascular bundles (Figure 2). The epidermis is one cell-layer thick and covers both upper and lower leaf surfaces. Its outer cell walls are covered with a waxy cuticle that reduces enormously the evaporative water loss from the leaf. However, since gas exchange between the atmosphere and leaf interior is essential for photosynthesis, the cuticular shield is broken at regular intervals by the presence of guard cell pairs that, when fully turgid, open pores in the epidermis through which gasses can pass. The turgidity of guard cells is regulated such that the stomates are open during daylight hours and closed in darkness.

During drought stress, abscisic acid (ABA) levels increase in the leaves and promote stomatal closure. This was demonstrated in Kentucky bluegrass cultivars by Bingru Huang and her students at Rutgers University. They found that

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greater stomatal sensitivity to ABA concentrations was characteristic of cultivars having greater drought tolerance (DaCosta et al., 2002).

Epidermal cells of turfgrasses leaves appear devoid of pigments but they are able to absorb significant amounts of ultraviolet (UV) radiation that would be harmful to the underlying mesophyll cells where photosynthesis occurs.

The maintenance of photosynthesis requires the repair and synthesis of proteins involved in energy transfer and those processes are sensitive to UV especially UV-B (wavelength = 280-320 nanometers). Yuen et al. (2002) at the University of Nebraska observed that the levels of UV-B radiation declines rapidly as sunlight passes through leaves of turfgrass canopies. Thus the epidermis, while all but invisible, is essential for the proper function of turfgrass leaves.

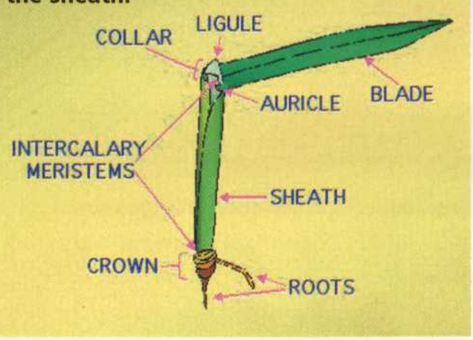
Leaves designed for controlled gas exchange

The green cells that comprise most of a leaf's volume are the mesophyll. Virtually all of the chloroplasts (subcellular organelles in which photosynthesis occurs) are contained in mesophyll cells. The epidermal guard cells also contain chloroplasts, but their photosynthetic output is devoted entirely to the function of stomates.

Mesophyll cells are not packed into the leaf tightly. Instead, numerous intercellular spaces are present that make up a gaseous continuum with the atmosphere. Carbon dioxide (CO_2) must enter mesophyll cells while oxygen (O_2) must exit these cells. As CO_2 is consumed in photosynthesis, its concentration in the leaf intercellular spaces becomes depleted, but is replenished from the atmosphere by diffusion through the stomates.

FIGURE 1

Grass leaves are commonly regarded as consisting of two parts: the blade and the sheath.



As photosynthetic O_2 is evolved, it accumulates in intercellular spaces and diffuses through the stomates into the atmosphere. At the same time, saturated cell walls of the mesophyll maintain the relative humidity (RH) inside the leaf at about 100 percent. Since the atmospheric RH is normally much lower, a substantial water potential difference exists across the stomatal orifice, driving a rapid diffusion of water vapor out of the leaf.

Much of this water loss is inevitable given the structure of leaves and the easy route for water efflux through open stomates. However, water loss does serve some purpose. The flow of water through the plant from roots to leaves through the xylem constitutes the route and means by which nutrient elements are delivered to the leaves. With little or no transpiration occurring, leaves would soon become depleted of nitrogen, phosphorus, potassium, magnesium and sulfur because these elements are constantly being exported from the leaves through the phloem. Plants growing under near-saturated conditions for extended periods will exhibit nutrient-deficiency symptoms.

When water evaporates and passes from the liquid to the vapor form, it consumes heat energy of vaporization. This constitutes a loss of 580 calories/milliliter of water evaporated at room temperature. This has been calculated to represent .26 calories per square of leaf surface per minute or about half of the radiant energy received by a leaf growing in full sun. The energy consumed in transpiration has a marked cooling effect on turfgrass leaves.

When the water potential of leaves decreases because of reduced availability from a drying soil, the stomates close and transpiration slows dramatically. If such conditions persist, damage to the leaves will occur, but the cause is probably not drought as much as it is excess heat caused by the lack of transpirational cooling.

Photosynthate export is critical leaf function

Extending the entire length of a leaf and embedded among the mesophyll cells are several vascular bundles. In a grass leaf, these vascular strands are oriented parallel to each other so that no mesophyll cell is separated by more than a few cells from a vascular bundle.

Numerous small bundles connect the larger parallel veins, further increasing mesophyll contact with conducting tissues. Vascular bundles are enclosed in a sheath of cells that in cool-season grasses contain no chloroplasts but in warm-season grasses have abundant, sometimes large, chloroplasts. Within the vascular bundles are several xylem vessels, phloem sieve tubes with their companion cells, and a number of undifferentiated parenchyma cells associated with the xylem and phloem.

Vascular bundles constitute the transport route by which water and mineral nutrients enter the leaf from the roots while photosynthetic products exit the leaf through the phloem for remote meristematic regions where they are needed.

The tip of a grass leaf is its most mature part, and it's the first to carry on sufficient photosynthesis to load sugars into the phloem and begin exporting energy to less mature parts of the leaf and to the rest of the plant. As the leaf matures, its contribution to the energy needs of the plant increases until it becomes a full source leaf and a major supplier of the plant's energy needs. Such a leaf displays its blade in a horizontal plane at right angles to the sheath enabling it to capture maximum solar radiation.

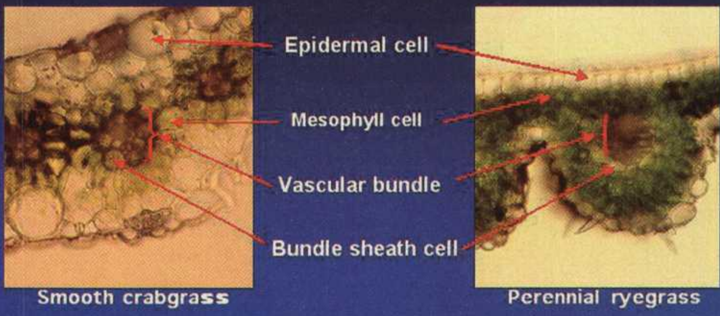
Of course, a turfgrass leaf gets clipped as it grows, losing its most mature and most productive part. However, as growth slows and the remaining blade assumes its horizontal orientation, it will be below the cutter blade and no longer subject to mutilation.

As a leaf becomes overtopped by newer leaves that shade it from the light, its photosynthetic productivity declines. Eventually its photosynthesis barely meets its own energy needs but rather than becoming an energy parasite on the plant, senescence is induced and the leaf mobilizes its remaining resources and transports them to the crown or stem. When this is complete, the leaf dies.

Leaf structure and photosynthetic efficiency

The difference in photosynthetic efficiency between cool-season and warm-season grasses is reflected in its leaf anatomy. The cool-season perennial ryegrass shown in Figure 2 has all of its chloroplasts and photosynthetic activity concentrated in mesophyll cells. Here, CO_2 is fixed by the Calvin Cycle where the first product is the 3-carbon (C-3) compound phosphoglyceric acid. This is soon reduced to glyceraldehyde phosphate, the first true sugar produced in photosynthesis. Two of these C-3 sugars are then combined to form the C-6 sugar glucose that in turn is further combined to form the C-12 sugar sucrose.

FIGURE 2



There are three basic tissue types within turfgrass leaves: upper and lower epidermis, mesophyll and vascular bundles.

Sucrose moves from the mesophyll cells through the symplasm to the bundle sheath cells and in turn is loaded into the sieve tubes and exported from the leaf. In cool-season grasses, oxygen (O_2) competes with CO_2 for its fixation site causing wasteful photorespiration. This can reduce the efficiency of photosynthesis by 50 percent or more, especially under high light and elevated temperatures when CO_2 levels in chloroplasts are particularly low.

Warm-season grasses have evolved a means of avoiding this inefficiency in photosynthesis. They separate the CO_2 fixation and reduction steps in two different cell types, mesophyll and bundle sheath cells, respectively.

In the mesophyll cells, the carbon fixed is not CO_2 but bicarbonate (HCO_3^-) that is 10 times more abundant in the chloroplast sap than is CO_2. The HCO_3^- combines with a 3-C acid phosphoenolpyruvate (PEP) to produce a 4-C acid, oxaloacetate (OAA). This reaction is favored because of the relatively high concentrations of HCO_3^- and because it is not inhibited by O_2. The OAA is next reduced to the 4-C acid malate and shuttled into the bundle sheath cells. There, malate is decarboxylated to CO_2 and the 3-C acid pyruvate.

Within the bundle sheath chloroplasts, CO_2 accumulates where it favors the Calvin Cycle that then can fix and reduce CO_2 much more efficiently. The remaining pyruvate diffuses back

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to the mesophyll cells where it is phosphorylated to PEP and can start the cycle all over again.

This process in warm-season grasses is called C-4 photosynthesis after the number of carbon atoms in its first product.

Conversely, CO_2 fixation in cool-season grasses relies exclusively on the Calvin Cycle and is known as C-3 photosynthesis. The large bundle sheath cells, well-endowed with chloroplasts, are characteristic of plants having C-4 photosynthesis as illustrated by crabgrass in Figure 2. Because C-4 photosynthesis is favored by high temperatures, warm-season grasses do not exhibit the summer decline so evident in cool-season turf.

On the other hand, C-3 photosynthesis is favored by cool temperatures and that makes cool-season grasses better suited for growth early in the spring and during mid to late fall. The advantages of C-4 photosynthesis during high temperatures gives C-4 weeds (crabgrass, fall panicum, yellow nutsedge, prostrate spurge and goosegrass) a competitive edge over cool-season turf during mid summer.

It is evident that turfgrass leaves are not only the source of all energy available to turfgrasses but also are capable of receiving environmental cues and transmitting chemical messages to other parts of the plant where growth patterns may be influenced dramatically. Perhaps those leaves that are mowed with much abandon by the turf manager should be treated with a little more respect.

Hull, a professor of plant sciences at the University of Rhode Island in Kingston, R.I., who specializes in plant nutrition, also offered his insights into turf leaves as antennae for environmental signals in the Aug. 27 issue of The Golfdom Insider. It can be found at www.golfdom.com.

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TURFGRASS TRENDS

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Craig Hoffman

The Rock, Drummond Island, Mich., Vice President of the Northern Michigan Turfgrass Managers Association

His colleagues call him "The Senator" because he is so well-connected. But Craig Hoffman has too many other items on his agenda to spend his time in the Michigan Legislature. After all, if he left, who would fill Craig's spot as vice president and education committee member of the Northern Michigan Turfgrass Managers Association (NMTMA), or on the board of the Michigan Turfgrass Environmental Stewardship Program, the Conference Committee of the Michigan Turfgrass Foundation, or on the Environmental Committee of the GCSAA?

No, Hoffman educates Michigan congressmen and state senators about environmental matters and water issues, but he won't join them as a job.

"Craig is one of the hardest-working men in show business besides James Brown," says Dan Bissonette, superintendent at Walloon Lake CC in Petosky, Mich., and immediate past president of the NMTMA. "He's just so involved."

James Husting, CGCS

Woodbridge (Calif.) Golf & CC
Government liaison for California GCSA

If Jim Husting had a Web site it could be called *proactive.com*. From the time he decided to chuck his history degree and return to college to pursue horticulture at California Polytechnic at San Luis Obispo, he has exemplified proactivity.

Since taking the post as head superintendent at Woodbridge Golf and CC in 1987, Husting has been a steady volunteer for his peers. He worked his way through the chairs of the Sierra Nevada GCSA, ascending to the presidency in 1997, and immediately assumed the presidency of the California GCSA, heading the six-chapter state in 1998.

"Jim's been a tremendously positive influence for all our members," says Gary Carls, California GCSA president. "He set up a government-relations network to keep us informed about what's going on in Sacramento and bills we need to keep an eye on."

Carls says Husting led the battle for an exemption from the California legislature for the golf course industry that allowed superintendents to continue using clopyralid, an active ingredient in the popular broadleaf herbicides Confront and Lontrel.

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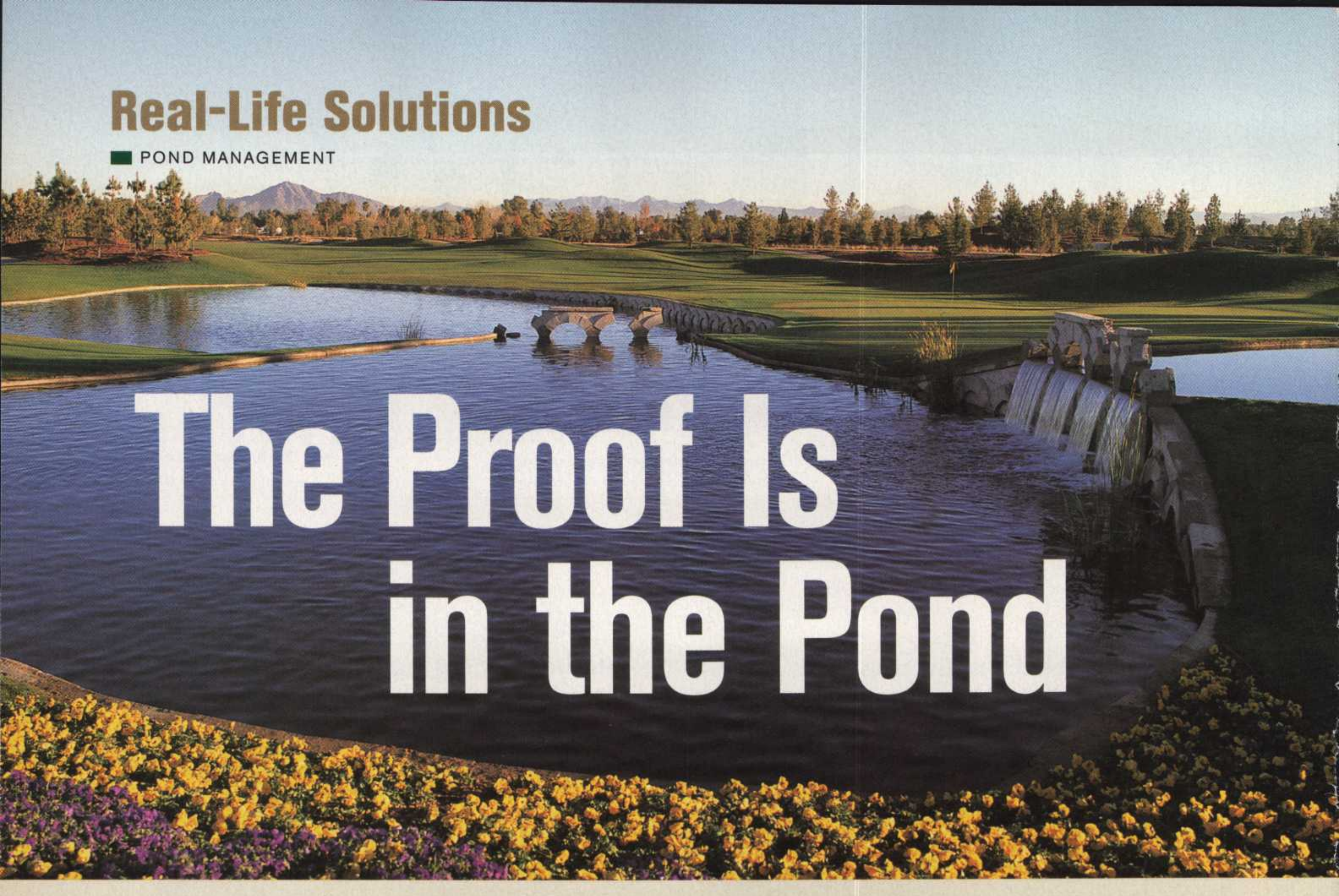

The Proof Is in the Pond

Golfers often see a healthy pond as a reflection of your operation. Here's how to manage ponds using different solutions

BY PETER BLAIS

MIKE KLEMME

Ponds are an essential part of many golf course operations as a source of irrigation water, an aesthetic feature and a hazard to be negotiated by players.

Michael VanErdewyk, founder of Bioverse, a pond-treatment firm that has used its Healthy Ponds program to treat 200,000 ponds nationwide, writes on the company's Web site, "A thorough understanding of the ecosystem of the pond and the interactions that take place when you treat the water will assist you in successfully managing the pond."

To manage water bodies properly, superintendents need to take into account numerous factors including a pond's age, design, size, shape, location, biology (zones) and water-quality parameters (sunlight, water temperature, nutrients, pH and oxygen levels).

"In summary, balance is critical in the pond," VanErdewyk writes. "A healthy pond contains balanced amounts of oxygen, nutrients and water clarity."

Unhealthy ponds quickly fill and refill with algae, leading to a variety of water-quality, irrigation, aesthetic and odor problems. Superintendents generally manage their ponds and combat algae using one or a combination of chemical, aeration and bacterial methods.

Chemicals

It's well-documented that copper sulfates and copper chelates are effective in controlling algae, according to Andy Moore, director of business development with Aquatrols in Cherry Hills, N.J. Several companies manufacture copper-based products.

Last year Aquatrols introduced Radiance, a copper-based pre-emergent pond-management tool. Traditional copper-based products tend to stay in the immediate area where they are applied, according to company literature. "To achieve uniform distribution throughout the pond, the application has to be made at all points around and in the pond, adding

Challenge

Ponds on golf courses just can't be left alone. They need to be maintained. Superintendents need to take into account several factors to maintain a pond successfully.

Solution

A healthy pond contains balanced amounts of oxygen, nutrients and water clarity. Ponds should be managed using one or a combination of chemical, aeration and bacterial methods.

labor and time to the process. Copper used in these products usually settles to the bottom of the pond quickly, where it's relatively ineffective. Additional problems can develop if large amounts of copper settle to the bottom of ponds."

Radiance can be applied in one spot but quickly disperses throughout the entire body of water, according to Aquatrols. The formulation also allows the product to stay dispersed much longer. Radiance can prevent algae blooms for about a month.

Moore says that without a large inflow or outflow of water into the pond, applications are generally made every two weeks. Putting in low levels on a continuous basis prevents large algae outbreaks and places less copper into the ecosystem in the long run.

Applications should start when water temperatures rise above 60 degrees F and algae begins to grow. Treatments should cease when water temperatures cool below that level. Application rates are 1 gallon of Radiance per 1 million gallons of water initially, followed by a half-gallon per 1 million gallons of water every two weeks thereafter. A Northern superintendent may use 12 gallons in a 1 acre pond that is 6 feet deep. At $30 per gallon, that amounts to $350 to $400 per golf season, Moore estimates.

"The preventive approach requires some education because people generally don't think about their ponds until they turn ugly," Moore says. "They are more in tune to doing a preventative fungicide application or preemergent herbicide application on turf. People haven't thought about their ponds in the same way."

Aeration

Doug Cramer, president of aeration equipment manufacturer Air-O-Lator, says water quality is dependent primarily on how much oxygen is in the water.

"Oxygen is important because it feeds the microorganisms so they can degrade the solid matter," he says. "Chemicals are fine to treat a symptom [algae], but they don't treat the cause."

Fountains, aerators and diffused air systems are common ways superintendents artificially introduce oxygen into their ponds.

"Mother Nature tries to get oxygen into the water naturally through sun, wind and babbling brooks," Cramer says. "On a golf course, that balance is upset because the ponds are containment basins with high volumes of organic matter, low oxygen and occasionally some runoff from nitrogen fertilizers.

"Most of our products ride on a flotation platform, and the modular unit sits down inside the float, making it more user-friendly to service," he adds. "People frequently go out in a row boat, lift the unit out of the flotation device and service it. It's designed to be worked on easily."

Superintendent Nels Lindgren has installed one Air-O-Lator unit and plans to add three more at Loch Loyd GC in Kansas City, Mo.

"We have a water feature that has aerated itself over the past 13 years," he says. "Water went over a series of waterfalls, and the ponds stayed aerated. But we got into a water-restriction deal, and the residents came into control of our 100-acre lake. So now we run less water through the water feature, meaning less aeration, which is why we are going with the aeration equipment."

Bacteria

Bacteria, enzymes and other microorganisms are becoming an increasingly popular way to manage ponds. Bioverse's Healthy Ponds program is a good example. It's an all-season system that incorporates testing, balancing and treating, according to VanErdewyk.

"We have a patented dispensing system that meters bacteria and enzymes into the pond to break down the organic waste and nutrients, consume the nutrients, reduce sludge and odors, and improve the water quality and clarity," the Bioverse CEO says. "We offer cold- and warm-water formulas. We also offer a mosquito-control formula, a biolarvicide that kills mosquito larvae in the pond."

The cone-shaped dispenser is 12 inches in diameter at the top and 18 inches in height. Into the dispenser goes a mixture of different strains of bacteria as well as micronutrients, vitamins, minerals and buffers that make the conditions right for microorganisms to thrive, along with a time-released gel that

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"Chemicals are fine to treat a symptom [algae], but they don't treat the cause."

DOUG CRAMER
AIR-O-LATOR

Read another Real-Life Solutions on page 86

A healthy pond contains little algae and appears picturesque on a golf course.

MIKE KLEMME

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holds those vitamins and nutrients in place while creating a large surface on which the bacteria can grow. The dispenser needs to be refilled every 30 days. One dispenser treats one surface acre of water.

The expense varies depending on the climate, VanErdewyk says. On average, the cost is about $1,000 per surface acre during the first year. The cost goes down roughly 30 percent in the second year because the polypropylene dispensing system does not have to be purchased again.

Bacteria and enzymes are permanent, long-term solutions to algae problems, VanErdewyk says.

"You may not get the immediate results [like with copper products] and have your pond clear in a few days," he says. "It may take four to six weeks before you see substantial results."

But the wait is worth it, according to superintendents who have used the product.

"We use it in conjunction with aeration, which adds to its success," reports Drew Annan, who employs the system on his 11 ponds at Forest Highlands GC in Flagstaff, Ariz. "It has reduced our weed growth moderately and our algae growth severely."

Bob Schneiderhan, superintendent at Chalk Mountain GC in Atascadero, Calif., is in his third year with the Bioverse program, and says it is an environmentally responsible solution.

"In our case, the algae was regenerating every five to seven days when I was treating it with copper," he recalls. "If you knocked it down every time it bloomed, that would have been even more costly than the bacteria system.

"Our pond is next to a fresh-water runoff pond that runs into the Salinas aquifer," Schneiderhan adds." When I realized the copper sulfate would require repeated applications, that's when I became concerned enough to find an alternative." ■

Blais is a free-lance writer from North Yarmouth, Maine.