ergy to make carbohydrates from water, nutrient salts and carbon dioxide. Carbon dioxide is obtained from the atmosphere when it diffuses into the interior of the leaf through pores in the leaf surface.

Pores in the leaf, stomates, are formed by pairs of elongated cells which lie side-by-side attached at each end. An increase in internal water pressure (turgor) within these guard cells swells them, causing the stomates to open. The loss of turgor in the guard cells results in closing the stomates.

Stomates not only allow carbon dioxide to enter, but also permit water to evaporate from the plant into the atmosphere. This water loss is called transpiration. The fate of most of the water taken up by the plant is to be lost to the atmosphere through transpiration, leaving the dissolved nutrient salts behind.

Transpiration's primary function is to dissipate heat from leaves exposed to sunlight. In this process, accumulated heat converts water to vapor, which then diffuses out of the leaf through the stomates. Heat and water vapor are lost. As temperatures rise, so does the rate of transpirational water loss. If transpiration exceeds the rate of water uptake by the roots, the plant experiences water stress. This can result in wilting and, if prolonged, permanent disruption of physiological processes.

Transpiration also pulls water through the plant by maintaining a low concentration of water at the stomates, thus beginning a sort of chain reaction to move water to the leaves from the roots.

Light provides the energy for photosynthesis, and stimulates the opening of the stomates. Stomates are typically open during the day and closed at night, permitting carbon dioxide to enter the plant when the light energy required for photosynthesis is available. It also minimizes water loss from the plant at night.

Moisture stress

Grass plants experience water stress almost daily, usually during mid-afternoon when temperatures peak. As water-stressed plants lose turgor, the stomates close. This prevents further water loss while continued root uptake replenishes the plant and turgor is restored. Increase in turgor reopens the stomates and transpiration resumes. Daytime temperatures are generally lower by the time turgor again builds up and root uptake of water can keep pace with transpiration.

Climatic factors can also influence transpiration rate. Wind quickly moves water vapor away from the leaf surface. This increases the difference in the water vapor concentration between the inside and the outside of the leaf, increasing the transpiration rate. When there is not wind, a layer of still air envelopes the leaf surface, allowing the water vapor concentration outside the leaf to rise, decreasing

> *Grass plants experience water stress almost daily, usually during mid-afternoon when temperatures peak.*

transpiration. This, again, is due to the principle of water moving from high concentration outside to low concentration. Since the water concentration outside the leaf increases, closer to that of the inside of the leaf, water movement out slows down, which slows water movement throughout the plant.

Humidity influences transpiration in a similar fashion. As atmospheric humidity increases, the water vapor gradient across the leaf surface decreases (concentration decreases) and the transpiration rate increases. Low humidity combined with high winds cause a tremendous rise in transpiration rates and quickly lead to water stress.

When stomates close as a result of water stress, the plant is subjected to additional stresses. Heat is no longer dissipated by transpiration. This can injure or possibly kill the plant by disrupting metabolic activities if drought conditions are prolonged. Turf is especially sensitive to mechanical injury during these periods.

Photosynthesis is also inhibited when stomates close. This is because carbon dioxide, an essential ingredient in the photosynthetic reaction, is excluded from the leaf. Without a supply of carbon dioxide, the plant cannot manufacture carbohydrates for building new plant structure. In other words, when the stomates close, growth slows down. Extended water stress can, therefore, adversely affect shoot density and the ability of the plant to recover from injury or disease activity.

Types of turfgrasses

Turfgrasses are typically categorized as being either cool-season or warm-

Cans set out in a grid pattern on a golf green help evaluate the distribution uniformity of the irrigation system.

season species. Cool-season species, as the term implies, are adapted to temperate, northern climates. Bluegrass, bentgrass, ryegrass and fescues are included in this group.

Warm-season species, including Bermudagrass, zoysiagrass, St. Augustine and seashore *paspalum* are adapted to hot, tropical and sub-tropical climates. The differences between warm- and cool-season grasses are much more fundamental than geographic distribution.

Warm-season grasses use significantly less water than cool-season species. This difference in water use derives from changes in the photosynthetic process that occurred in grasses evolving under hot, dry conditions. These changes, which include modifications to biochemical reactions and internal leaf anatomy, greatly enhance the photosynthetic efficiency of warm-season species and help reduce transpiration. Increased photosynthetic efficiency means that plants can maintain high levels of carbohydrate production and continue to grow even when stomates are partially closed. This partial closure of the stomates slows the plant's transpirational water loss.

Cool-season grasses, with a less efficient photosynthetic process, cannot maintain enough carbohydrate production to maintain growth unless their stomates are nearly wide open. Thus, when water is limited, transpiration rates of cool-season grasses are generally higher than those of warm-season grasses.

Root depth density

Important characteristics influencing the ability of plants to avoid water stress are the depth and density of rooting. Grasses with deep root systems have the ability to draw water from a much greater volume of soil. Plus, there is less chance that water will percolate down beyond the reach of the root system. This is a distinct possibility with shallow-rooted species such as Kentucky bluegrass and perennial ryegrass. With these species, soil water beyond a depth of two feet is essentially unavailable. This water would still be within reach of Bermudagrass or tall fescue.

Low humidity combined with high winds cause a tremendous rise in transpiration rates and quickly lead to water stress.

Greater soil penetration by a large number of roots significantly increases the volume of water upon which a plant can draw. Bermudagrass and seashore *paspalum* both send roots down more than five feet, though Bermudagrass has better drought resistance due to a somewhat deeper and better distributed root system.

The fescues commonly exhibit leaf rolling when subjected to water stress. By enclosing the upper leaf surface, where most of the stomates are located, a high level of humidity is maintained within the rolled leaf and transpiration is reduced.

Water used by plants is thought of as the amount lost to transpiration. When considering irrigation of turf, evaporation becomes important as a part of the water use, or rather, the water loss. A practical means of calculating turf water use is to determine the transpiration rate plus the rate of evaporation, referred to as evapotranspiration (ET). ET is the total water lost by turf.

Many states, through water agencies and districts, provide local ET information for agricultural growers and landscape managers. The irrigation industry has been very active in developing ET guidelines for the turf industry.

Irrigation systems

Though substantial water savings can be realized through proper species selection, those same savings can be just as quickly dissipated by a sprinkler irrigation system with poor distribution uniformity.

The quickest and most effective way to evaluate the distribution uniformity is to perform a can test. This is done by setting out a number of uniform, open-topped containers (motor oil cans, plastic cups, etc.) in a grid pattern over the area to be tested. Distance between containers is up to the user, but should be close enough to be meaningful (10 or 20 feet are often used). The accuracy of the test increases as the number of containers increases. Spacing between containers should be equal.

The sprinkler system should be turned on for about 15 minutes. If the user does not wish to record data, simply looking into and comparing the containers will indicate whether the system is nearly uniform or not. If recorded data would be useful, e.g. to make a point with administrators, measure the amount of water collected in each container.

Measurements are made into a measuring cup or graduated cylinder, being careful to note the grid location of the measurement. Ideally, all measurements would be equal. In reality, the values will vary somewhat. If major discrepencies are evident in values from container to container or from one part of the test area to another, the uniformity of water distribution needs to be improved. Unless the problem is obvious, like a malfunctioning sprinkler head, the system should be evaluated by an irrigation consultant. The resultant savings in both water and money can be significant.

Efficient water use and conservation opportunities are based on selection of grasses, their culture and the efficiency of the irrigation system. All of this is site-specific so the manager must become involved in the use of this vital natural resource. **LM**

This water-efficient low-pressure irrigation system at Canyon Country Club is also a money-saver.

IRRIGATION REVELATIONS

Low-pressure irrigation combined with computerized controls spelled an annual savings of 50 percent for this California country club.

A quiet revelation has come over the Coachella Valley outside Palm Springs, Calif. Industry experts say the revelation has the potential to drastically change energy and water usage by turf managers, particularly in arid and semi-arid locations.

The Valley has more desert golf courses than anywhere in the world. In October, 1986, the area also became the site of the first irrigation installation to combine low-pressure sprinkling with a computerized control system.

This revelation is that turf managers can use low-pressure sprinkler heads for varied energy savings; that they can also control their precipitation rate, and match actual evapotranspiration rate (ET), unlike ever before.

Center of attention went to Canyon Country Club, a typically-lush desert golf course surrounded on three sides by the Santa Rosa mountains where Richard Ameny is general manager. He, more than any other person, deserves credit for combining the two concepts, low-pressure and computers.

The local power company, Southern California Edison, showed an interest in developing alternative technologies and products that would allow golf courses to use less water and consequently less energy on a continuous basis. That interest led Edison's Tom Olson to low-pressure sprinkler heads, a new technology that had been in development at various irrigation manufacturers for a number of years.

Low-pressure heads operate effectively at much lower P.S.I. than regular sprinkler heads, and the pumps are able to do their job in less time. With pumps operating for a shorter time span, the off-peak demand period was a possibility for golf courses and other turf areas.

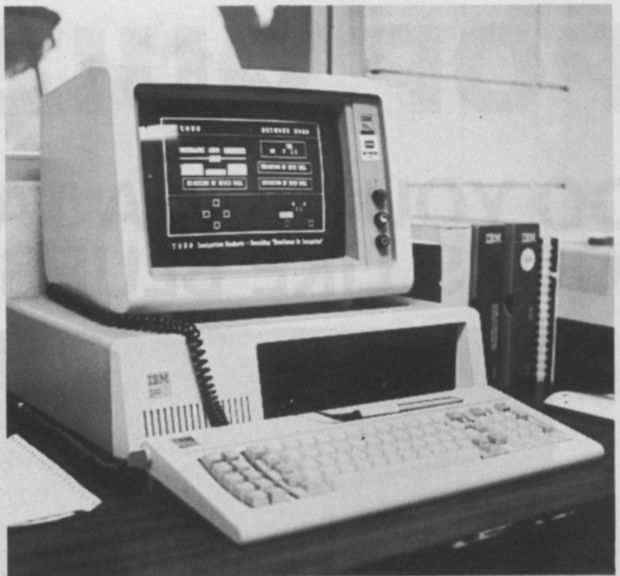
Ameny had come to Palm Springs from Washington State, where he gained years of turf management experience in a humid and wet environment. Ameny had promised the club's board that he would effect major reductions in the maintenance budget, and still maintain the course's lush, well-tended appearance.

First, he changed certain management practices that immediately dropped Canyon's fixed maintenance costs by $25,000. To really affect the course's $850,000 budget, however, he needed to do something dramatic.

That's when Olson suggested low-pressure irrigation.

continued on page 36

REVELATION *from page 34*


A state-of-the-art Toro Network 8000 system like the used at Canyon Country Club.

After his talks with Olson, Ameny contacted the three manufacturers who were then touting low-pressure sprinkler technology, and asked each to install products in a test plot he had laid out on the golf course. The ultimate winner was Toro's 660 Series of low-pressure heads, which "performed faultlessly," said Ameny.

Canyon's membership board was ready for the installation. The proposal for a new, more efficient irrigation system had been made three times in three years, but it took the energy savings of a low-pressure system to convince the board that the cost could be quickly amortized. Olson notes that Ameny deserves a lot of credit for switching to low-pressure heads at a time when other courses had not taken the leap.

"It's a close-knit world among the desert courses, and they're somewhat conservative," says Olson. "These courses are beautiful and prestigious, and not many general managers or superintendents in the area are risk-takers. They want to see what the other courses are doing before they commit to a new way.

"In this case, the timing was good, because Ameny was ready for something new, and maybe his being from outside the area made him more open to other ideas. I have to admit that I didn't see much beyond the energy savings that were going to result from low-pressure sprinkling, but Dick did: they've had savings from labor, fertilizer, chemicals and the amount of water they need."

While Tom Olson brought low-pressure irrigation to Dick Ameny's attention, Ameny himself investigated another new concept, computerized irrigation control. He questioned if there was any reason why the two recently-developed technologies couldn't operate together, for even larger maintenance savings.

Toro's Network 8000 combines a central computer with stand-alone satellites. It was developed to solve the problem of accurately measuring a turf area's actual demand for water through evaporation (ET) loss (see "More eyes for turf managers" on page 20).

Having made his choices in product, Dick Ameny worked closely with all of his contractors and suppliers. "It's unusual for a general manager to get as involved in a new irrigation installation as Ameny did," observes Olson, "but then again, all concerned knew they were breaking fresh ground."

The Canyon "groundbreakers" included consultant Roger Gordon, who designed the new irrigation system; Pacific Equipment and Irrigation Company, the distributor who supplied the products; and McCalla Brothers, who installed a new well. Foremost Construction Company, which installed the system and advised Ameny on the intricacies of the massive installation, was also important to the project's overall direction.

Gordon notes that, having decided to proceed, Canyon and Ameny moved quickly. "We essentially had three months to totally revamp the old quick-coupler system," said Gordon. "Most club members leave in April or May, so the system had to be installed between then and September, in order to be ready for the overseeding period.

"The old Bermuda is dethatched and the course is reseeded with ryegrass so it'll be picture-perfect when the members return from other parts of the country." The installation was "smooth as silk," he says. "There were minor problems, such as bringing all the pipes, communications cables, and electrical wiring under the four or five street crossings, but preparation and working with an experienced contractor are two keys to success.

"Between the lack of water and humidity and the winds, the Palm Springs area in general is hostile to growing grass, and you have to make it happen in spite of itself. Still, the Canyon job was the most effortless way I've ever forced anything.

"The satisfying thing was that the course immediately took less water than before, got a better start on the new grass, and the members were able to get out and play on it sooner. And that system really got the test of its life the first time out of the box. If a course down there can make it through reseeding, it can make it through anything. When it's applicable, I'm convinced that low-pressure is the way to go. The heads don't cost any more than other products, and you could literally take every installation my company has done over the past 20 years, screw out the old heads, screw in new low-pressure heads, and be in business.

"After making appropriate changes to the pump station and lowering the P.S.I., you'll immediately get a lower electric bill."

The Canyon system has been operating since the first week of October, 1986, and projecting current costs through the remainder of the year, Ameny says his water and electric bill will be $40,000 less in 1986-87, for nearly a 50 percent reduction.

In addition to taking advantage of the off-peak demand period, the low-pressure heads allow the golf course to use one new well (rather than two older, less-efficient wells), and reduce the booster station pressure to 80 P.S.I. from 135 P.S.I. The precisely-calculated ET data from the controller afforded further water and energy savings. The first-year maintenance savings includes a workforce reduction of two full-time employees who were necessary with the old, labor-intensive quick coupler system and further savings on fertilizers and chemicals that previously leached out much more quickly.

The total maintenance budget for 1986-87 is expected to drop by $113,000 or 14 percent.

For the turf management industry, the development promises even more. As Toro's Terry Mylne notes, the industry has moved from "gut feel" estimates of ET demand to a precisely calculated equation and a method of dispersing it efficiently.

Perhaps just as important for the future of water conservation, the marriage of new irrigation technologies, and their availability to virtually everyone, assures that the turf industry can take a leadership role in overseeing world water resources wisely and judiciously. **LM**

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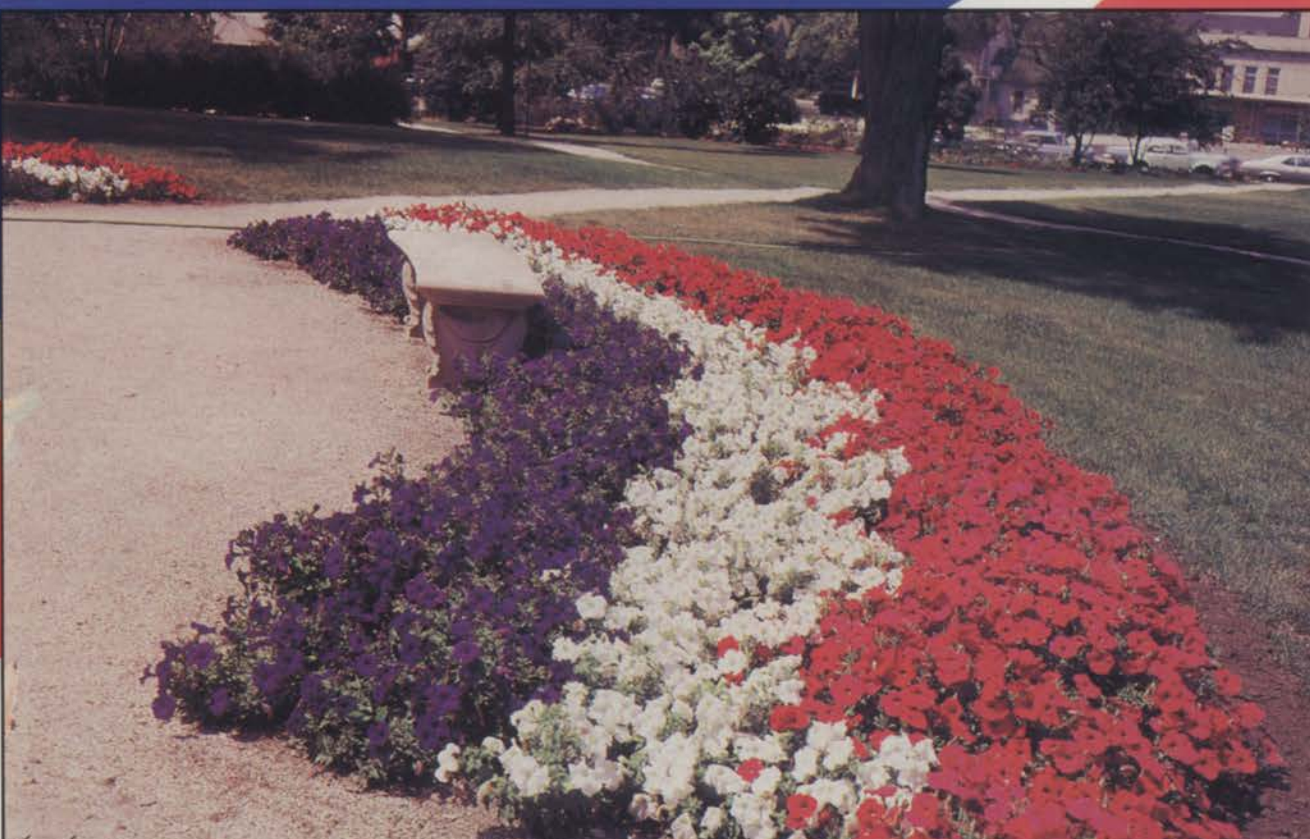
Patriotic Plantings

by Heide Aungst, managing editor



We the People *our founding fathers wrote two centuries ago. On Sept. 17, the Constitution celebrates its bicentennial. To commemorate the occasion, bicentennial chairman Warren Burger has asked communities to plant red, white and blue gardens. Petunias provide just the right hues for a classic patriotic planting, as illustrated by the gardens at the Ball Seed Co. in Chicago, Ill. (above; lower right). The Constitution gardens can get more creative, such as this flag at the University of Minnesota (upper right). Red and white begonias make up the stripes, while dusty miller creates one large star in the corner.*