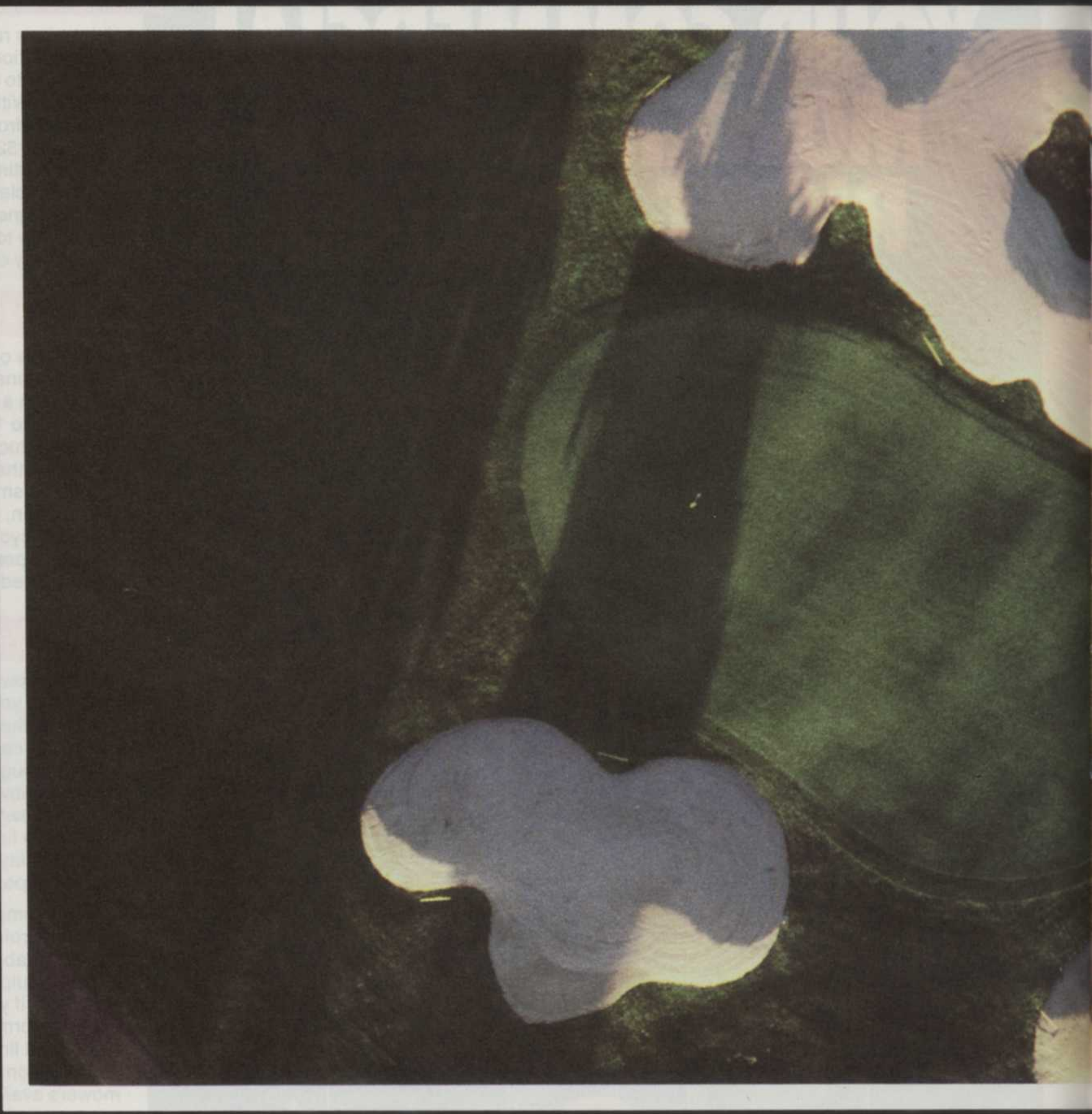
TO PYTHIUM THIS LOOKS LIKE THE



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WATER MANAGEMENT ON COMPACTED SOILS

Dr. Robert N. Carrow, University of Georgia

Foot and vehicular traffic on recreational turfgrass sites often result in soil compaction—the pressing together of soil particles resulting in a more dense soil and less favorable growth medium.

Soil compaction has a major influence on turfgrass water relationships. In fact, many of the injuries enhanced by compaction are water-related—either from water deficits (wilt, desiccation, winter desiccation) or excess water (scald, intracellular injury).

Before we discuss cultural practices to reduce compaction effects, it is important to understand exactly how soil compaction affects turfgrass water relations. Since the most common form of soil compaction on recreational turf is compaction of the upper 1 to 3 inches, that will be the focus of this article.

Other types of soil compaction also occur and present unique problems where cultural approaches are needed to resolve them. For example, a thick compacted zone of 3 to 12 inches near the surface (as occurs from a heavy clay topsoil where equipment runs over the area during construction) presents different problems than a compacted zone of 1 to 3 inches thick that occurs several inches deep in the soil profile (i.e. a plow pan situation).

Soil responses

As the upper 1 to 3 inches becomes compacted, the total pore space decreases and fewer large pores (macropores) remain. Macropores are important for rapid drainage, gaseous movement into and out of the soil, and root channels. More specifically, the following soil physical properties are altered:

1). **Infiltration decline.** With only a few larger pores at the surface, water does not enter the soil as rapidly. This makes good irrigation scheduling difficult, especially during hot, dry, weather. In periods of high precipitation, water collects in low spots or runs off the site.

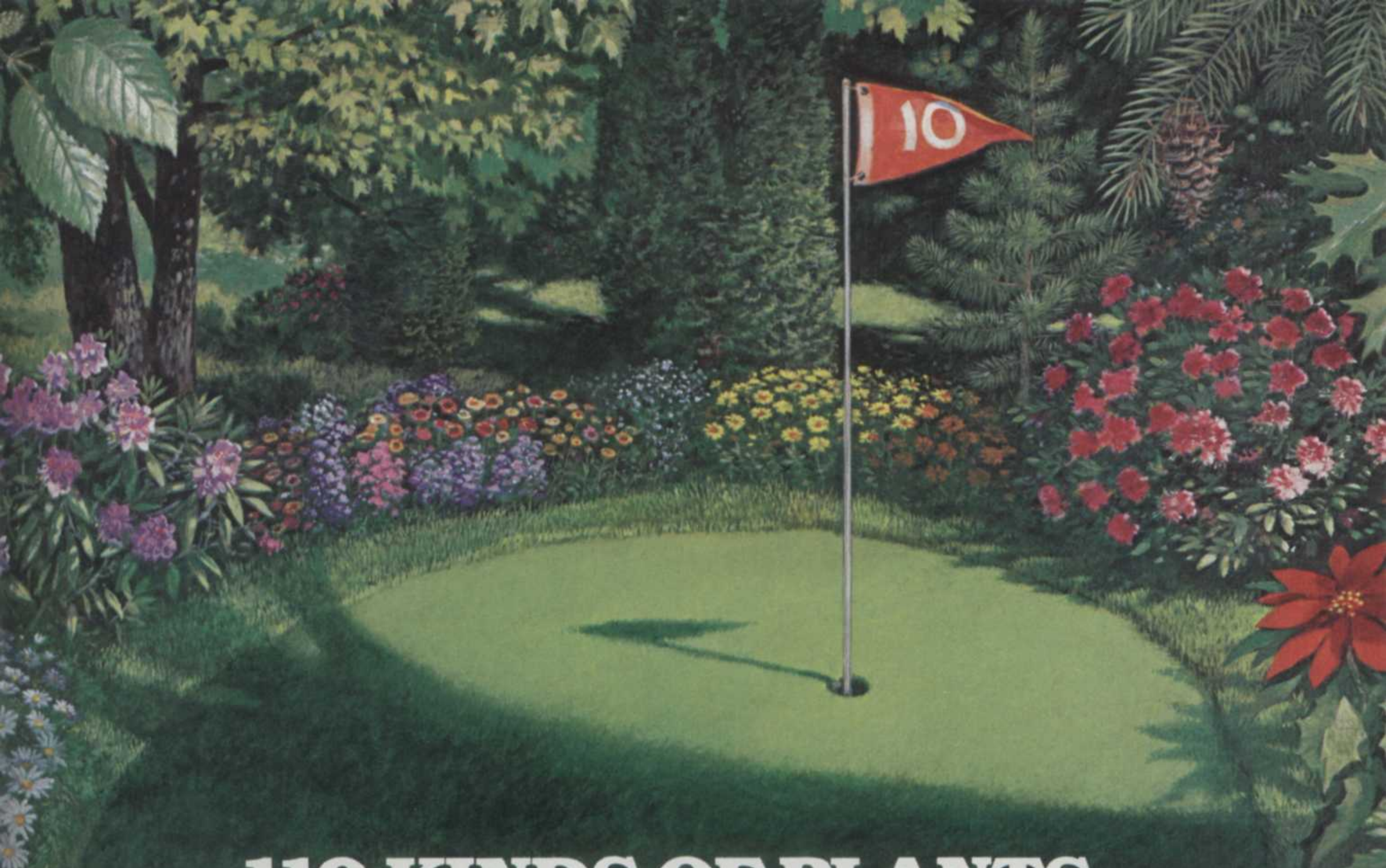
2). **Soil aeration decreases.** Turfgrass roots cannot efficiently absorb water if soil O_2 is low. Since compaction reduces the volume of large pores that would contain O_2, the O_2 level declines for long periods after saturation by rainfall or irrigation events. The net result is poor root growth, root dieback, low root viability, and poor water uptake.

3). **Soil strength increases.** With fewer large pores, the roots must exert more energy to penetrate the small pore spaces. Also, a dense soil exhibits greater total adhesive and cohesive forces holding the soil particles together, especially as the soil dries. The lack of root channels and a hard soil slow the rate of root extension and cause a shallower root system to develop which limits water uptake.

4). **Moisture retention capabilities of the soil are altered.** The greater number of small pores (micropores)

continued on page 40

Constant turfgrass traffic—a result of games such as soccer—often results in soil compaction.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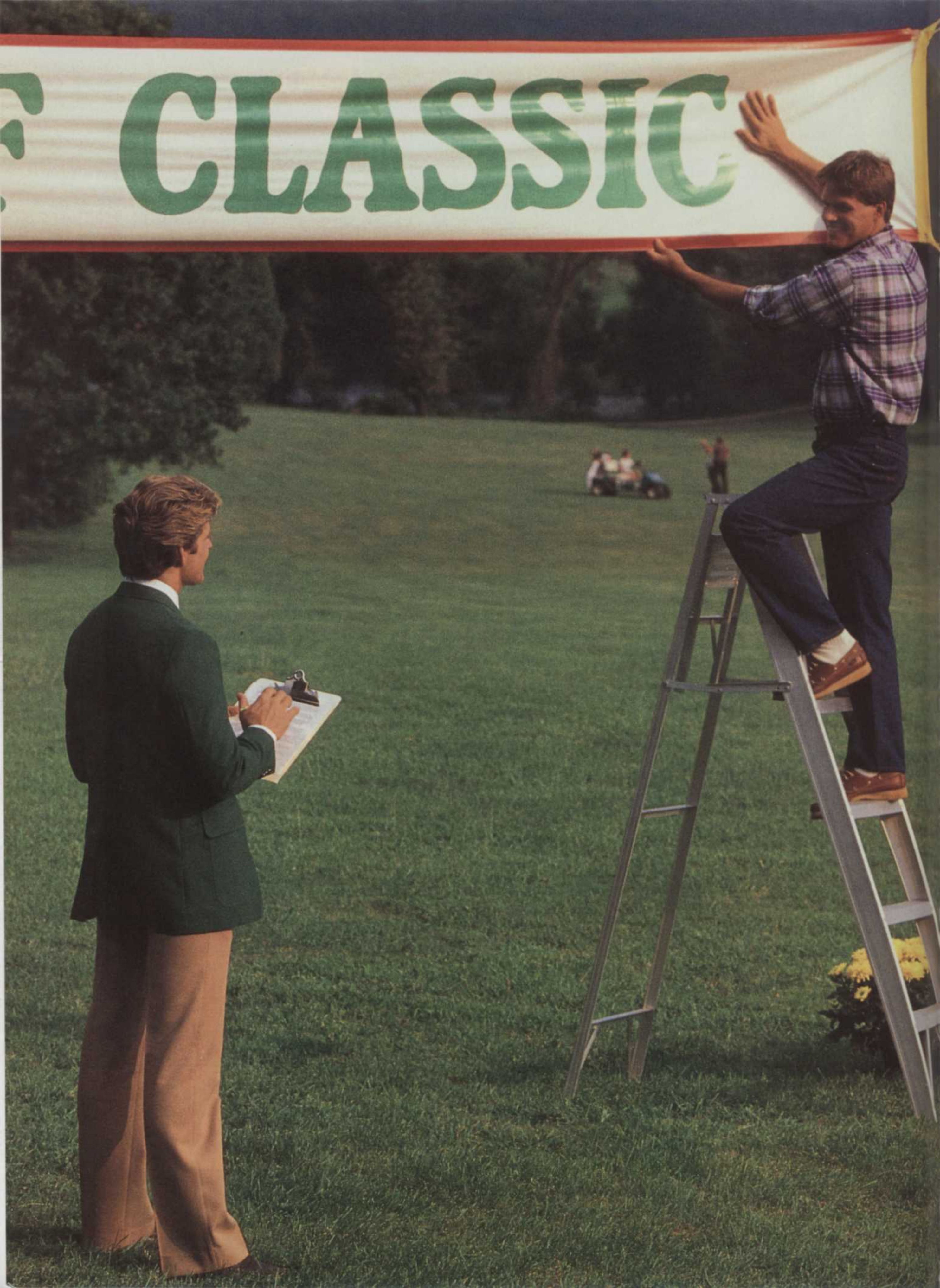
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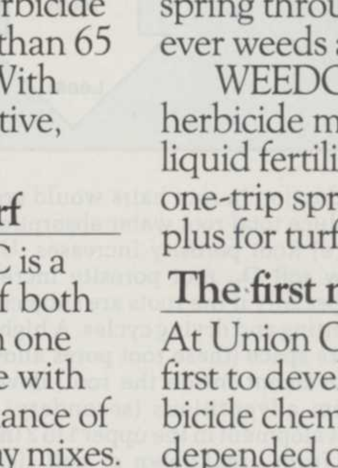

From the turf care group at Union Carbide

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COMPACTION TOLERANCE

Cool-Season Grasses	Compaction tolerance
Perennial ryegrasses	Most
Some tall fescues - Brookston, Houndog, Rebel	
Kentucky bluegrasses - Sydsport, Ram I, Touchdown, and Bensun are somewhat more tolerant.	
K-31 tall fescue and other tall fescues	
Creeping bentgrass	
Red/chewings fescues	Least

Warm-Season Grasses	Compaction tolerance
Bermudagrass	Most
Buffalograss	
Zoysiagrass	
Centipede	
St. Augustine, others	Least

result in more total water retention but the water is often held too tightly by soil particles for plant use. Thus, a compacted soil often has less available water for plants compared to the same soil that is not compacted, especially for loams and clay soils.

5). **Soil temperatures can be altered.** In the spring, compacted soils are usually colder due to their higher total water content. This delays root initiation and slows root growth. During the summer, compacted soils are often warmer due to less turf cover. Drier, compacted soils transmit heat more rapidly than an uncompacted soil. Higher soil temperatures can result in root death, especially on cool-season species.

Plant responses

The less favorable soil physical conditions of a compacted soil soon result in adverse effects on the plant. Plant responses that directly influence water use are:

1). **Root growth.** Compaction influences root characteristics in several ways:

a) Reduced depth and extent of the root system. Deep rooting is important during dry periods. Without deep roots, the grower is forced to irrigate lightly and more frequently.

b) Root viability and longevity may decline. Low soil O_2 can reduce the permeability of the root cells to water movement and result in cell death if the O_2 stress is prolonged.

c) Root tips can increase in diameter due to the hard soil and further reduce penetration into the soil.

d) Root hairs may be fewer in number. Evidence for this is limited, but a reduction in root hairs would greatly reduce total root water absorption.

e) Root porosity increases. Under low soil O_2, root porosity increases, especially if the roots are subjected to wetting and drying cycles. A high root pore space (these root pores allow O_2 movement inside the root) develops from adventitious (secondary) root development in the upper 1 to 2 inches or from breakdown of cell tissues. Oxygen moves from the atmosphere into the root and alleviates the O_2 stress; thereby, increasing the ability of the plant to extract water under low soil O_2 levels.

The net effect of these root responses is to limit the volume of soil for water uptake and to reduce the ability of the root to take up moisture during wet soil conditions.

Thus, whether the soil moisture status is wet or dry, compaction reduces water uptake. The beneficial response of greater root porosity aids in increased water uptake but only to a limited extent under very low soil O_2 (i.e. saturated) conditions.

2). **Shoot morphological responses.** A number of shoot morphological (structural) changes occur under compaction that influence water use of the plant. These include:

a) Decreased shoot density. Turfgrasses produce fewer tillers, rhizomes, and stolons under adverse growing conditions. This results in less total leaf area for transpirational water loss. However, with greater solar radiation reaching the soil surface, evaporational losses from the soil surface may increase. This could be a substantial loss of water if the grower is irrigating frequently.

b) Rate of leaf extension is reduced. The leaves grow at a slower rate and this reduces the amount of leaf area that could result in water loss.

c) Stomatal numbers may decrease. Since transpiration occurs through the stomata, a reduction in stomatal numbers would reduce water loss (i.e. stomatal resistance increases).

d) The actual structure (leaf numbers and leaf orientation) is altered with a more open canopy. This would imply that canopy resistance to water loss into the environment would be less. Thus, water should be lost more rapidly, especially by evaporation.

The total effect of these morphological responses is to reduce water use (i.e. water needs) of the turf plant grown under compaction.

However, if a grower is applying water on a low volume, frequent application basis (in response to low soil infiltration and a limited root system), the reverse can be true: evaporational losses become so high that total water use increases over what an uncompacted grass would use. The increased water use results from greater evaporational losses rather than transpiration needs.

3). **Shoot physiological responses.** Compaction may result in certain physiological responses that would affect water use, such as:

a) Leaf water potential is lower for grasses grown under compacted conditions. The reason for this response is not clear but this should reduce transpirational water use.

b) Stomatal diffusion resistances are higher, probably due to the lower leaf water potential and fewer stomata. This would decrease transpiration at any particular soil moisture level.

c) Canopy temperatures are 1 to 3° C. higher under compaction. The higher temperatures would result from increased stomatal and closure reduced efficiency in soil water uptake by the roots. With higher temperatures, evaporation and transpiration increases.

d) Drought hardiness may decline due to a more succulent turf (if frequently irrigated) and lower total non-structural carbohydrates. Drought hardiness does not directly influence water use, but is important for plant survival during drought stress periods.

It should be clear that many factors (soil physical properties, root and shoot morphological, and physiological factors) may affect water use of grasses on compacted soils. While the grass plant uses less water under com-

continued on page 40

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pacted versus uncompacted conditions, the grower often finds it necessary to irrigate with low quantities of water on a frequent basis. This type of irrigation regime greatly increases evaporational losses and, therefore, total water use.

Cultural practices

If the soil and plant effects of compaction are alleviated or reduced, then water management problems are improved. Several approaches are possible. The grower should use a combination of cultural practices because no single approach, except total soil modification, will resolve the problem.

1). Use of species/cultivars adapted to your climate, pest stresses, use, and cultural level is important. Compaction makes the turf more susceptible to other stresses and reduces recuperation once injury occurs. By limiting other stresses, soil compaction problems are less frequent.

After the above selection criteria are used, the grower can determine if a particular species or cultivar is more tolerant to compaction than another and use the tolerant grass. Limited information is available on specific compaction tolerance of species and cultivars but the list contained herein summarizes current information.

2). Traffic control to minimize compaction is another approach. This may take several forms such as:

- using alternate practice fields;
- moving around the total area of a football field during practice;
- limiting traffic on excessively wet fields;
- limiting band practice on the main field;
- using larger greens and tees;
- more frequent movement of tee markers and flags on greens
- cart paths; and
- careful design to prevent excessive traffic areas.

3). Cultivation to provide openings for water infiltration, gas exchange, and root channels is a major means of reducing compaction effects. Generally, a program should be developed using one or more cultivation techniques and possible topdressing with sand. Core aeration is especially effective but other methods can be useful—slicing, grooving, spiking, forking, shattercoring, deep core aeration, and sub-aerification.

4). Other management programs should be adjusted to allow for the best growth. For example, high levels of nitrogen (N) on compacted turf can restrict rooting even more than compaction or high N alone. Good surface and subsurface drainage should be developed. A good pest program to control diseases (brown patch, pythium) and weeds (knotweed, goosegrass, Poa annua) that are problems on compacted sites should be formulated.

Irrigation scheduling is worth particular attention, and every effort should be made to irrigate as deeply and infrequently as possible. Practices to improve soil infiltration and to develop deeper rooting will allow for such an irrigation approach.

The grower should remember that the use of a low volume, frequent irrigation schedule is the primary reason for excessive water use under compacted soil conditions.

5). Chemical soil modification may provide some help in specific situations. Gypsum can assist in promoting a better structure on heavy, salt affected soils. However, remember that even naturally well-structured soils succumb to compaction if the traffic is severe enough. Sometimes chemicals have been used to stabilize a soil structure. Examples include polyvinyl alcohols, polyacrylamides, and various algae-based polymers. These products stabilize the existing structure but structural units can still break down under compaction. Wetting agents have been used to improve drainage of compacted soils but research evidence for their use is limited and conflicting.

6). Physical soil modification can effectively reduce the potential for compaction. Partial modification by the addition of sand or organic matter to a heavy, clay soil can be useful if the proper proportions and materials are used. Organic matter contents up to 15% are normally used but a total sand content of 85% or more may be more effective. Complete modification is an alternative to partial modification if intensive traffic is expected. The USGA Green Section specifications, the Purr-Wick, and the PAT systems are all effective for golf greens and athletic fields.

7). The paver system is the last approach. Many of these systems have a concrete or plastic matrix to withstand traffic with some openings for grass to grow. For cart paths and parking areas, this can be a good approach. The ultimate "paver" is artificial turf.

Certainly a compacted soil presents a severe challenge to good water management. But if the above cultural approaches are utilized, compaction will be reduced and as a result, water management will improve.

Research has demonstrated that a 25% to 50% savings in water use can be achieved with proper management. **WT&T**