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USE OF HIGH BORON SEWAGE EFFLUENT ON GOLF GREENS

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California experienced two years of drought that began during the winter of 1975-76 and ended in the winter of 1977-78. In early 1976 Calistoga, a small community of 3,000 in the northern Napa Valley, started an emergency conservation program that consisted of no lawn watering, car washing, or unnecessary use of water (55 gallons per day total allocation).

The golf course in Calistoga had to find alternative water supplies. The Napa River was dry, and the city could not provide water for irrigation. Sewage effluent was available but had to be piped about 2 miles to a holding pond at the golf course before being run through the sprinkler system. Also, the Calistoga mineral baths and spas use hot mineral spring waters in swimming pools and mud baths. These more or less continually discharge high boron water to the sewage plant. When mixed with the low boron domestic supply, normal effluent has about 4 parts per million (ppm) boron. Therefore, it was suspected that

boron would be a problem if this water were used on golf course greens. The soil greens originally were constructed from on-site Bale loam and sown to Seaside creeping bentgrass.

Guidelines exist for anticipating problems that can develop from use of waters varying in quality and containing concentrations of salts, sodium, chlorides, and boron. Table 1 shows current guidelines, which apply to all irrigation water, whether river or canal water, groundwater, return flows, drainage water or sewage effluents. Other guidelines are available to evaluate heavy metals in irrigation waters.

The sewage effluent in the Calistoga golf course holding pond at the start of the period of use had salinity of EC_w (electrical conductivity of water) = 1.0 mmho/cm; boron = 3.8 ppm; adj. SAR (adjusted Sodium Adsorption Ratio) = 7. The guidelines indicated that the salinity and adj. SAR were in the "increasing problem" range

TABLE 1. GUIDELINES FOR INTERPRETATION OF IRRIGATION WATER QUALITY*

Potential problem	Degree of problem		
	Problem	Increasing problem	Severe problem
SALINITY (affects crop water availability) EC _w (mmhos/cm)	< 0.75	0.75-3.0	3.0
PERMEABILITY (affects infiltration rate into soil) EC _w (mmhos/cm) adj. SAR	> 0.5 <6	0.5-0.2 6-9	0.2 9
SPECIFIC ION TOXICITY (affects sensitive crops) Sodium (adj. SAR) Chloride (meq/l) Boron (mg/l or ppm)	<3 <4 < 0.50	3-9 4-10 0.5-2.0	9 10 2.0-10.0
MISCELLANEOUS EFFECTS (affects susceptible crops) NO ₃ -N (NH ₄ -N) (mg/l) NCO ₃ (meq/l) [overhead sprinkling] pH	<5 < 1.5	5-30 1.5-8.5 Normal Range 6.5-8.4	30 8.5

*For more details, refer to FAO-Irrigation and Drainage Paper 29 (1976), *Water Quality for Agriculture*, or to *Journal of the Irrigation and Drainage Division ASCE*, Vol. 103, No. IR2, Proc. Paper 13010, June 1977, pp. 135-154.

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Date	Water	Soil from greens'	Clippings from greens 3,6,7, and 9'
	ppm	ppm	ppm
Jul. 16,1976	0.1 (municipal supply)	3.1 (0.55)	53.8 (11.09)
Aug. 16, 1976	3.0	3.65 (0.33)	20.5 (4.2)
Sep. 20, 1976	3.5	3.8 (0.36)	85.8 (65.72)
Oct. 25, 1976	3.6	3.23 (0.29)	47.2 (17.35)
Mar. 18, 1977t	5.2	3.66 (0.72)	18.0 (5.72)
Jul. 20, 1977	6.2	7.05 (0.54)	78.2 (38.32)
Dec. 7,1977f	7.8	7.81 (1.09)	22.75 (10.69)
Apr. 5, 1978f	1.7	3.6 (0.93)	10.2 (0.50)

*Represents average of several samples taken. Value in parentheses is standard deviation (+ variability) for average value given. Soil sampled to 6-inch depth.
 fNapa River water used to fill pond during this period. High boron may reflect low flow before April 5, 1978, sampling.

and that boron was a potentially “severe problem” unless management practices were adopted that could avoid or correct it.

Crop selection and increased frequency of irrigation are two such management practices. If more salt- and boron-tolerant crops and grasses were planted, and if irrigations were applied frequently enough to keep the crop well supplied with water, the problems would be less severe or perhaps would not develop.

Fortunately, most grasses are fairly salt- and boron-tolerant. In this case, it seemed probable that the boron and salt tolerance of Seaside bentgrass would allow safe use of the effluent. However, it was decided to monitor water, soil, and grass clippings to keep track of changes that might take place through use of effluent.

Table 2 presents the boron data obtained for the water, soil, and grass clippings during the trial period, starting June 1976. To date the high boron water has caused no apparent problem. Overall visual appearance and playability of the greens have been excellent. Grass clippings have not indicated boron concentrations high enough to cause leaf burn or necrotic tissue (see table 2). The low boron concentration in clippings probably resulted from rapid plant growth and frequent removal of clippings.

Close evaluation of SAR patterns with effluent water use is important, because a high SAR normally results in a marked reduction in the ease with which applied water enters soil. Table 3 presents the SAR data for water and soil for the trial period.

Soil SAR rose steadily from the period of initial effluent use to the December 1977 reading. Following heavy 1977-78 winter rains, soil SAR was reduced considerably.

If water infiltration becomes a severe problem, an amendment such as gypsum can be applied to correct it.

Calistoga expects to continue to use sewage effluent on the golf course. It is hoped this continued monitoring will provide meaningful information on longer term effects of effluent use. Short-term problems appear to be minor.

Acknowledgment

The authors wish to acknowledge the excellent cooperation and indulgence of Howard E. Fisher, Jr., Golf Pro and Course Superintendent, Mount St. Helena Golf Course, Calistoga, California.

Date	Water SAR adj.	Soil SAR*
Jul. 16, 1976	6 (municipal supply)	2.03 (0.46)
Oct. 25, 1976	17	2.69 (0.13)
Mar. 13, 1977f	6	3.06 (0.36)
Jul. 20, 1977	—	4.88 (0.85)
Dec. 7,1977f	12.5	6.05 (1.33)
Apr. 5, 1978t	4.7	5.0 (1.28)

*Represents average of several samples taken. Value in parentheses is standard deviation (+ variability) from average given.
 fNapa River used to fill pond during this period. High water SAR may reflect low flow of river.

DROUGHT TOLERANCE AND WATER RELATIONSHIPS OF TURFGRASSES

Jack D. Butler and Charles M. Feldhake *

Throughout the United States, regardless of yearly precipitation, water availability and conservation has become a common topic of discussion among turf professionals. And it is interesting to note that, in a recently published "priority list" of major issues facing society, first among the top 10 items was "national water supply and demand."

The necessity of carefully planning water use throughout the United States is evident if one considers the lack of dependability in the supply of water and man's limited ability to store and transport this valuable resource. An estimated 42 percent of the total municipal and industrial water supply in Denver, Colorado, is used for lawn irrigation (Woodward, 1972). The direct cost of water for irrigating a golf course in an arid or semiarid region may be as much as \$70,000 to \$90,000 per year.

The cost of energy and equipment required to move water also must be considered in planning and situating large turf installations. In the more arid regions, such as Colorado, when priorities for water use have been established, water for turf irrigation has normally been very low on the list. Thus, it is clear that water must be conserved, especially in drier areas, through the use of efficient irrigation equipment and programs, effluent and other low-quality water, and drought-tolerant plants.

Drought tolerance of turfgrasses

In the past, grasses used for quality turf have not varied much, if at all, between areas that receive adequate or near adequate precipitation, and areas where serious moisture deficits occur.

In cooler and rather dry parts of the western United States, grasses such as buffalograss, blue grama, crested and western wheatgrass, and sometimes even Kentucky bluegrass and bermudagrass may persist without supplemental water.

In areas where drought occurs because rainfall is erratic, although usually adequate, the value of these grasses—except, of course, Kentucky bluegrass or bermudagrass—would be questionable. Buffalograss, a warm-season grass that produces a wear-resistant turf, is nonaggressive and poorly adapted to shady sites. Although this grass has been found as a native as far east as Illinois, competition by cool-season turfgrasses and weeds is quite likely to restrict its use. Trials now under way on the East and West coasts with this and other grasses used for droughty sites in semiarid regions should provide some conclusive information on their adaptability. The characteristics and adaptations of blue grama are similar to those of buffalograss. Crested and western wheat are cool-season grasses that might prove useful for mixture plantings to control erosion on very dry sites in the Midwest and Northeast, but turf quality of these grasses is not good.

In much of the western United States, the ability of a turfgrass to remain alive through several months of drought is often considered more important than the ability to remain green for a few weeks into a drought before dying. Grasses such as tall fescue, with its deep root system, that are drought tolerant in more humid areas, usually do not persist under extended droughts in semiarid climates.

For cool, humid regions grasses are needed that will perform well by remaining green through drought stresses of a few weeks, whether winter or summer. Of course, grasses are grown in these regions that now perform satisfactorily under droughty conditions. Bermudagrasses and zoysias can have good drought tolerance, but their lack of cold tolerance and their browning out in cold weather, as well as their weedy nature, are problems. Tall fescue and smooth brome remain green through extended drought periods in the Midwest, but they often are considered weedy because of coarse texture. The strong rhizomes of smooth brome and the bunchy nature of tall fescue that often develops a rough turf can also

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be objectionable. Because these grasses are available and generally have acceptable pest resistance it seems that developments such as improved cold hardiness of bermuda and zoysia, finer textured smooth brome and tall fescue, and a moderately fast-sod-forming tall fescue would help meet the needs for drought-tolerant turfgrasses for the cool humid region.

Kentucky bluegrass is usually considered intolerant to drought. However, it persists in certain areas of the United States that receive 12 to 15 inches of yearly precipitation. Often Kentucky bluegrass goes dormant during prolonged dry periods, but individual plants remain green well into an extended drought. In 1974 some 200 Kentucky bluegrass selections were made from nonirrigated sites in Colorado. Some of these have been tested for seed production in Colorado, in the Midwest (where a few performed rather well under droughty conditions), and in the Pacific Northwest. Suitability of a cultivar for the Rocky Mountain region, where droughts are frequent and extreme and the plants can be hardened for drought, will probably be quite different than for the cool, humid regions, where diseases are frequently serious and precipitation may not allow hardening for the infrequent droughts.

Colorado State University research on drought tolerance of Kentucky bluegrass indicates that, through conditioning, this grass can provide an acceptable turf through 2 to 3 weeks or more of drought without watering. Dernoeden (1976) did extensive work in 1975 to determine the drought tolerance of many Kentucky bluegrass cultivars. In general, with the exception of Merion, "common" types exhibited the best drought tolerance. Unfortunately, these common types do not possess normally desirable turf characteristics, such as good color, density, and disease resistance. Except for areas where water is especially scarce for quality turf, savings on water from the use of common types could be offset by increased costs for pest control.

Water relationships

Decisions on how much water to apply to turf are becoming more difficult as pressure increases for efficient water utilization. The physiological nature of turf and the effect of environmental factors on evapotranspiration (ET) should be

understood if quality turf is to be maintained without the traditional excessive applications of water.

Good fertility management and effective pest control need to be implemented before development of an efficient irrigation schedule is attempted. Turf is capable of adapting to different irrigation programs and may grow satisfactorily with infrequent and well-timed irrigation, or it may come to depend on frequent excessive irrigation.

Knowledge of the soil texture is essential in developing an efficient irrigation program. Sandy soils have a low water-holding capacity, a high infiltration rate, and good aeration. Turf grown on sandy soil readily develops an extensive root system. To use water efficiently, determine as accurately as possible the depth of the root system, allow the roots to deplete most of the water in this zone, and irrigate only enough to fill this zone. Excess water will flow to the water table, increasing nutrient removal through leaching. In drier areas, however, it may be necessary to over-water occasionally to reduce salt buildup.

Soils high in clay have a high water-holding capacity, low infiltration rate, and poor aeration. If clay soils are kept too wet, turf does not develop a deep, extensive root system. Adequate aeration to stimulate good root growth can take place only if these soils are maintained under a schedule that allows reasonable drying between waterings. In the absence of a drying cycle, the roots will develop in the top few inches of soil, and this layer is quickly depleted of water in hot weather. The shallow root system results in little drought tolerance and a dependence on frequent irrigation.

Maintaining turf at the highest reasonable mowing height increases exposure to convective energy. This increases ET slightly. However, the increase in ET is more than offset by the ability of the longer cut turf to photosynthesize more and, as a result, to develop a deeper, more extensive root system. A deeper root system decreases the probability of losing water to the water table and decreases the frequency of the need for irrigation. Dernoeden (1976) found that Kentucky bluegrass cut at 1 1/2 inches was more drought tolerant than that cut at 3/4 inch.

A good rule of thumb is: don't irrigate until the

grass shows stress, then add only enough water to bring the root zone to field capacity.

Some location effects need to be considered in evaluating turf water needs. Shading from the sun and shielding from the wind by trees or hills can decrease ET. Turf near large parking lots or on the south side of buildings may have increased ET because of a heat buildup. Smog may decrease solar radiation enough to decrease ET. Areas subject to high foot traffic may need more water to encourage more vigorous growth and maintain an attractive appearance.

In summary, adequate water of acceptable quality has become a major concern for those who keep quality turfgrass. The use of available grasses and the development of "new" ones for

use under droughty conditions can help conserve water. Proper maintenance, such as fertilization and mowing, can save water. Irrigation practices can generally be greatly improved upon by closely monitoring the soil and turf and meeting the ET needs.

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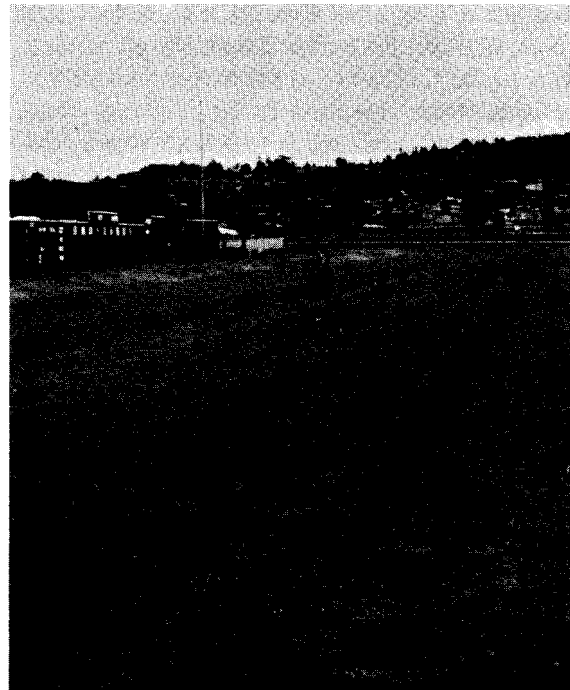
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THOROUGHBREDS NOW RACING ON BAY MEADOWS TURF COURSE

*Forrest D. Cress, David L. Hanson, and William B. Davis **

Bioengineering, a design approach that has led to many technological advances in modern medical science, is beginning to make a name for itself in a related but virtually untapped field-botany. A recent, large-scale example of its successful application to a botanical project is the newly constructed turf course at Bay Meadows Race Course, San Mateo, California. Especially designed to meet that facility's environmental conditions and the heavy demands of summer and winter horse racing, the infield turf course reflects considerable engineering as well as agronomic expertise.

The growth medium for the course's perennial ryegrass/Kentucky bluegrass turf is a 12-inch-deep, uniform fine sand amended with fir bark and enriched with fertilizer that allows the track to drain freely during winter rains yet retain sufficient moisture and fertilizer needed year-round for healthy grass. It also helps to prevent soil compaction. The track is banked at 3 percent on the straights and 4 percent on the curves. The subgrade below the growing medium also is sloped, which allows all drainage to flow to an



Home stretch at Bay Meadows Race Course.

infield ditch and eliminates any need for drain-pipes on the track itself.

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Bay Meadows added the turf course to attract some of the more prestigious thoroughbreds that race only on turf. (All of Europe's thoroughbred meets are on turfgrass courses.) Once the turf has matured, plans are to run one race daily on the course during meets. The new turf track is fast and firm. Thoroughbreds are setting good times on it.

A sand-based racetrack is a natural outgrowth of the use of sands for turf areas subject to heavy traffic, such as golf course putting greens, lawn bowling greens, and athletic fields. The basic research behind this concept has been done by University of California horticulturists.

A look at the turf track's cross-section reveals the following: Originally seeded at 50 percent, by weight, of Manhattan perennial ryegrass and BenSun A-34 Kentucky bluegrass, the turf is now about 80 percent rye and 20 percent bluegrass. If managed properly, the turf mix should be about 70 percent bluegrass and 30 percent perennial ryegrass two years from now.

Beneath the turf is a layer of special sand amended to a depth of 6 inches with fir bark and a complete fertilizer mix. The bark gives resiliency to the turf, a bonus for horses raced on it, and aids water retention in the turf root zone. Once a mature grass sod is well established, resiliency will be maintained by proper management of organic matter produced by the grass. The growing medium slopes from 14 inches in depth at the track's inside rail to a depth of 10 inches at its outside rail. Below the sand is a soil subbase that has been smoothed and compacted to a high degree. This allows runoff to occur at a high rate on the subbase.

The most critical factors during the construction phase of the project were to maintain the uniformity of the sand being applied and to keep the course's cross-section within specifications. The particle size of the sand was checked daily. About 80 percent of its sand grains fall within the medium to medium-fine range. By regulating the sand's particle size, the level of moisture in the sand layer can be controlled. What is needed is a particle size that will drain but retain enough moisture to keep grass healthy.

Ground was first broken for the project in mid-May of 1977. Grading was completed the follow-

ing month. Some 25,000 tons of Presidio shoals sand, dredged from the bottom of San Francisco Bay, went into the course's growing medium, along with 3,000 cubic yards of fir bark and 3,000 pounds of fertilizer. (Total area of the turf course is about 10 acres.)

The track was seeded on July 16, 1977, and excellent root growth was obtained by September. The grass was allowed to mature the following year. When seeding such a project, it's very important to get the seed growing the first week into the first inch of sand. Initially, the turf track was hydroseeded, and the results were not satisfactory. Use of a cultipacker to force the seed into the growing medium solved the problem. In a sand medium, grass seed can be placed deeper than would be typical for a soil medium.

The new turf course is irrigated by pop-up turf sprinklers set inside and outside it. Forty-two electronic remote-control valves, operated by a fully adjustable electronic timer clock, control watering cycles.

The 75-foot-wide track has a 3-foot elevation drop from its outside rail to its inner one. The highly permeable sand growing medium drains excess water rapidly to the subgrade interface of compacted clay loam. The excess water then flows as a perched water table to the track's infield, since the subgrade below the growing medium parallels the top surface. Like a flow net with water always running through it, a dynamic condition, the course is designed to require no more than three irrigations per week when the turf is mature. As frequency of irrigation is reduced, the amount of water applied will be increased so that the course always will be receiving about the same amount of water.

Drainage of the turf track and infield was designed to allow for maximum water recycling. Both drain to a lake at the north end of Bay Meadows. The lake, in turn, drains into an underground 40,000-gallon storage tank from which water is drawn for conditioning the facility's dirt track.

Another design feature of the track is an inside rail which can be moved to allow worn turf to recuperate. (Most wear is toward the inside rail.) This movable rail enables Bay Meadows to reduce the turf track width from 75 feet to 62.6 feet or to 50 feet, when desired.

Irrigation and fertility will be the two most critical management problems for the course, because they influence weed growth and the rooting depth of turf. The objective, of course, is to keep out the weeds while maintaining maximum turf rooting depth.

Mowing height during race seasons is 3 1/2 inches. It will be dropped to 2 or 1 1/2 inches during

the off-season to increase turfgrass density.

"The people at Bay Meadows have pride in their turf track and I know they'll manage it right," commented Brent Ogden, who was engineer/planner for the project. Impressed by the Bay Meadows project, his firm of Read, Vorhees and Associates, Ltd. of Toronto, Canada, is now constructing a 125-foot-wide turf course at Toronto's Woodbine Racetrack.

UC TURF CORNER

Victor A. Gibeault and Fowest D. Cress *

UC Turf Corner contains summaries of recently reported research results, abstracts of certain conference presentations, and announcements of new turf management publications. The source of each summary is given for the purpose of further reference.

WHAT'S A RHIZOTRON?

Texas A&M University scientists have built themselves a root observation laboratory that's giving them a new and valuable perspective in their turfgrass research. They call it a "rhizotron."

Basically, it's a walk-through tunnel with the soil side on part of its walls lined in glass. In the tunnel, the Texas researchers can remove covers from both walls to observe turfgrass roots growing down the face of the 15-degree angled glass. Because roots grow away from light, the glass is covered light-tight except during observation periods.

The rhizotron offers several advantages. Now the scientists can observe directly and continuously a grass root system growing in the field under almost typical conditions. Without disturbing the turfgrass system, they can see the influence of environmental and cultural conditions on root initiation, growth, rate, distribution, and maturation.

("Development of a Turfgrass Rhizotron at Texas A&M," by J.M. DiPaola, and J.B. Beard, *Proceedings of the Thirty-first Annual Texas Turfgrass Conference*, Texas A&M University and The Texas Turfgrass Association, Dec. 6-8, 1976.)

TEMPERATURE, RELATIVE HUMIDITY EFFECTS ON GLYPHOSATE TOXICITY

Results from a recent study at the Delta Branch of the Mississippi Agricultural and Forestry Experiment Station indicate that temperature and relative humidity influence glyphosate toxicity to bermudagrass.

Increasing relative humidity from 40 to 100 percent increased glyphosate absorption, translocation, and toxicity. Increasing temperature from 72° to 90° F also increased glyphosate activity but not to the extent to which relative humidity affected activity.

The findings show that, by applying glyphosate at a time when temperature and relative humidity favor increased translocation, one can significantly improve its control of bermudagrass.

("Effects of Temperature and Relative Humidity on the Toxicity of Glyphosate to Bermudagrass [*Cynodm dactylon*]," by T.N. Jordan, *Weed Science*, Vol. 25, No. 5, September 1977.)

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