Figure 1. Experimental golf green at the University of Minnesota Golf Course following topdressing. Sections of different soils are evident from color of topdressing material.

Figure 2. Experimental golf green in August 1986, when bentgrass on all soil mixtures was in excellent condition.

Figure 3. Damaged turf growing in soil mixture No. 5 (right half of photo) compared to the relatively undamaged turf growing in soil mixture No.3 in April 1987.

ADVENTURES IN WATER STRESS

Drought conditions and failure of the irrigation system produce interesting findings on an experimental green in the Midwest.

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The drought of 1988 will likely be remembered for a long time by turfgrass managers and golf course superintendents across the United States. Unirrigated turfgrass through the north central region suffered damage as a result of the drought. Even irrigated turfgrass areas sometimes had difficulty keeping up with the water demand.

Hot, dry conditions during spring, 1987 and summer, 1988 plus irrigation problems gave some interesting results on water stress damage at an experimental green on the University of Minnesota Golf Course.

Here's what happened.

In the early 1980s, golf course superintendents in Minnesota were having difficulties establishing and maintaining a dense creeping bentgrass stand on golf greens constructed with high sand-content soil. The Minnesota Golf Course Superintendents Association investigated but failed to identify the underlying problem. So members decided to construct an experimental green to determine the long-term growth of creeping bengrass on five soil mixtures.

The green was constructed according to U.S.G.A. guidelines, save one. It was divided into five sections, and five different soil mixtures were used in the rootzone layer (Figure 1). The five soil mixtures used on the green are described in Table 1.

The green was constructed in the summer, 1984 and seeded with Penncross creeping bentgrass in September.

Originally, it was thought that nutritional differences or development of excessively compacted soil conditions might lead to differences in establishment and growth of creeping bentgrass. But after four years of bentgrass growth, nutritional differences have remained minimal on each of the soil mixtures.

Soil compaction problems (as measured by root growth and water infiltration rates) appear to be nonexistent on any of the soil mixtures. However, the unusual weather condi-

TABLE 1.
Soil mixtures used in the experimental green.

Soil Mix #	Description
1	3-1-1 by volume sand-soil-peat. sand - fine mortar sand. soil - silt loam (21% sand, 66% silt, and 13% clay). peat - Northern reed-sedge peat. The resulting mixture by weight was 80% sand, 17% silt and 3% clay.
2	5-1-1 by volume sand-soil-peat. sand - uniform, medium silica sand. soil - sandy loam (58% sand, 26% silt, and 16% clay). peat - Northern reed-sedge peat. The resulting mixture by weight was 94% sand, 4% silt and 2% clay.
3	85-15 by volume sand-peat. sand - fine mortar sand. peat - Northern reed-sedge peat. The resulting mixture by weight was 97% sand, 2% silt and 1% clay.
4	85-15 by volume sand-peat. sand - uniform, medium silica sand. peat - Northern reed-sedge peat. The resulting mixture by weight was 98% sand, 2% silt and 0% clay.
5	100% sand with peat tilled into the surface 4 inches. sand - fine mortar sand. peat - sphagnum peat. The resulting mixture in the surface 4 inches, by weight, was 99% sand, 1% silt and 0% clay.

TABLE 2
Water holding capacity of the soil mixtures used on the golf green.

Soil Mixture	Available water holding capacity (-30 mbar to -15 bar)	Inches of water available in 12 inch root zone
	g water/g soil	inches
1	0.20	3.4
2	0.13	2.2
3	0.11	1.8
4	0.10	1.7
5 (surface 4 inches)	0.09	1.3
5 (below 4 inches)	0.07	

tions of the past two years have led to visible differences in response to water stress among the soil mixtures.

Golf greens are often constructed—as this experimental green was—with 12 inches of rootzone soil mixture underlaid by two inches of coarse sand, which in turn is underlaid by four inches of gravel with drain tile installed.

The coarse sand and gravel layers increase the amount of water retained in the rootzone soil mixture. This is usually desirable since most soil mixtures used are very high in sand content and have low water-holding capacities.

Water available to the plants in a layered golf green is higher than what would be available in a deep soil profile with no layers. To estimate the amount of water available to plants in this green, water held between tensions of 30 millibars (equivalent to drainage at the surface of 12 inches of mix over a saturated layer) and 15 bars (the point usually considered so dry that plants can no longer extract the water) was measured. Assuming a bulk density of 1.4 g/cm.^{3} in all mixtures, the inches of water available to plants in the soil mixtures are shown in Table 2.

Water infiltration rates were measured on the green in 1986 and 1988. Rates varied dramatically between soil mixtures with soil mixture No. 5 having the highest infiltration rate (30.1 inches/hr. in 1986 and 25.3 inches/hr. in 1988) and soil mixture No. 1 having the lowest infiltration rate (2.8 inches/hr. in 1986 and 1.3 inches/hr. in 1988).

During 1986, the first year turfgrass growth was carefully monitored, bentgrass growth on all five soil mixtures was superb with no differences between plots. Figure 2 shows the golf green as it appeared in August, 1986.

In April, 1987, indications of possible problems occurred when the weather turned warm and dry very early. After a winter of almost no snow cover, March was very warm with an average temperature of 38.7°F, 9.5° above normal. Bentgrass throughout the experimental golf green turned a beautiful dark green in March, providing a stark contrast to the dormant, or dead, annual bluegrass on the fairways and approaches.

March and April were not only warmer than usual but also drier. Rainfall measured in Minneapolis was 0.3 inches in March and 0.2 inches in April, about 1 and 2 inches, respectively, below normal for those months.

In mid-April, before the irrigation system had been turned on for the season, bentgrass growing on soil mixture No. 5 started going into water stress. Despite running hoses from the clubhouse to water the green while the irrigation system was being checked, turf loss occurred on soil mixture No. 5. Figure 3, taken on April 22, shows the damaged turf on soil mixture No. 5 (right half of photo) along with the undamaged turf on soil mixture No. 3 (left half of photo). The lines dividing soil mixture No. 5 and the two bordering plots were distinct and obvious with the damaged plants restricted to soil mixture No. 5. Once

the irrigation system was fully operational, the turf on soil mixture No. 5 gradually recovered until there were no more differences observed between plots for the rest of the season.

In 1988, bentgrass throughout the green looked excellent during April and May. The weather in May was already hot and dry, but irrigation was keeping up with water demand. During the last week in May, one of the sprinkler heads was damaged during some very hot and windy weather. Within a 48-hour period, damage occurred to turf on soil mixture No. 5, again with distinct lines showing greater damage to turf on soil mixture No. 5 than to turf on the bordering plots.

Beginning about the first week in July, the irrigation pump at the golf course began to go bad. Pressure in the irrigation lines gradually decreased for the rest of July, making irrigation of the entire course a tremendous problem. On the experimental green, water distribution problems were evident as portions began getting inadequate amounts of water. Although significant damage occurred to bentgrass growing on soil mixture Nos. 3, 4 and 5, damage was most severe on No. 5, with the edges of that plot distinctly visible. The pump was replaced in early August, 1988, but damage to turf on the green was still evident at the end of the growing season. By mid-May, 1989, bentgrass damaged the previous summer was recovering, but damaged areas were still clearly visible.

Drawing conclusions

The results on this green over the past two summers have reinforced a caution when using high sand, particularly straight sand, for the rootzone of a golf green. Adequate irrigation is absolutely critical; even irrigation problems of short duration can cause significant damage to the green. In the case of this experimental green, when irrigation problems occurred in both 1987 and 1988, sand/soil/peat mixtures or sand/peat mixtures with peat mixed uniformly throughout the rootzone layer maintained bentgrass much better than straight sand with peat tilled into the surface four inches. **LM**

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