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03 ◯ 30 Private
04 ◯ 40 Resort
05 ◯ 50 City/State/Municipal
06 ◯ 55 Other Golf Courses (please specify)________________
07 ◯ 60 Golf Course Architect
08 ◯ 70 Golf Course Developer
09 ◯ 90 Golf Course Builder
10 ◯ 105 University/College
11 ◯ 115 Distributor/Manufacturer/Consultant
12 ◯ 100 Others Allied to the Field (please specify)________________

**2. Which of the following best describes your title? (fill in ONE only)**
13 ◯ 10 Golf Course Superintendent
14 ◯ 15 Assistant Superintendent
15 ◯ 25 Owner/Management Company Executive
16 ◯ 30 General Manager
17 ◯ 35 Director of Golf
18 ◯ 70 Green Chairman
19 ◯ 45 Club President
20 ◯ 75 Builder/Developer
21 ◯ 55 Architect/Engineer
22 ◯ 60 Research Professional
23 ◯ 65 Other Titled Personnel (please specify)________________

**3. What is your facility's annual maintenance budget?**
24 ◯ A More than $2 Million
25 ◯ B $1,000,001-$2 Million
26 ◯ C $750,001-$1 Million
27 ◯ D $500,001-$750,000
28 ◯ E $300,001-$500,000
29 ◯ F $150,001-$300,000
30 ◯ G Less than $150,000

**4. If you work for a golf course, how many holes are on your course?**
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32 ◯ B 18
33 ◯ C 27
34 ◯ D 36+
35 ◯ E Other (please specify) ________________

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| 103 | 115 | 127 | 139 | 151 | 163 | 175 | 187 | 199 | 211 | 223 | 235 | 247 | 259 | 271 | 283 | 295 | 307 |
| 104 | 116 | 128 | 140 | 152 | 164 | 176 | 188 | 200 | 212 | 224 | 236 | 248 | 260 | 272 | 284 | 296 | 308 |
| 105 | 117 | 129 | 141 | 153 | 165 | 177 | 189 | 201 | 213 | 225 | 237 | 249 | 261 | 273 | 285 | 297 | 309 |
| 106 | 118 | 130 | 142 | 154 | 166 | 178 | 190 | 202 | 214 | 226 | 238 | 250 | 262 | 274 | 286 | 298 | 310 |
| 107 | 119 | 131 | 143 | 155 | 167 | 179 | 191 | 203 | 215 | 227 | 239 | 251 | 263 | 275 | 287 | 299 | 311 |
| 108 | 120 | 132 | 144 | 156 | 168 | 180 | 192 | 204 | 216 | 228 | 240 | 252 | 264 | 276 | 288 | 300 | 312 |
| 109 | 121 | 133 | 145 | 157 | 169 | 181 | 193 | 205 | 217 | 229 | 241 | 253 | 265 | 277 | 289 | 301 | 313 |
| 110 | 122 | 134 | 146 | 158 | 170 | 182 | 194 | 206 | 218 | 230 | 242 | 254 | 266 | 278 | 290 | 302 | 314 |
| 111 | 123 | 135 | 147 | 159 | 171 | 183 | 195 | 207 | 219 | 231 | 243 | 255 | 267 | 279 | 291 | 303 | 315 |
| 112 | 124 | 136 | 148 | 160 | 172 | 184 | 196 | 208 | 220 | 232 | 244 | 256 | 268 | 280 | 292 | 304 | 316 |

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| 104 | 116 | 128 | 140 | 152 | 164 | 176 | 188 | 200 | 212 | 224 | 236 | 248 | 260 | 272 | 284 | 296 | 308 |
| 105 | 117 | 129 | 141 | 153 | 165 | 177 | 189 | 201 | 213 | 225 | 237 | 249 | 261 | 273 | 285 | 297 | 309 |
| 106 | 118 | 130 | 142 | 154 | 166 | 178 | 190 | 202 | 214 | 226 | 238 | 250 | 262 | 274 | 286 | 298 | 310 |
| 107 | 119 | 131 | 143 | 155 | 167 | 179 | 191 | 203 | 215 | 227 | 239 | 251 | 263 | 275 | 287 | 299 | 311 |
| 108 | 120 | 132 | 144 | 156 | 168 | 180 | 192 | 204 | 216 | 228 | 240 | 252 | 264 | 276 | 288 | 300 | 312 |
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| 110 | 122 | 134 | 146 | 158 | 170 | 182 | 194 | 206 | 218 | 230 | 242 | 254 | 266 | 278 | 290 | 302 | 314 |
| 111 | 123 | 135 | 147 | 159 | 171 | 183 | 195 | 207 | 219 | 231 | 243 | 255 | 267 | 279 | 291 | 303 | 315 |
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# TURFGRASS TRENDS

Section II • Volume 11, Issue 7 • **July 2002**

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DRAINAGE MAPPING

# Ground-Penetrating Radar Maps Drainage Systems

*By R. Boniak, S.-K. Chong, and T. Boniak, S.J. Indorante, and J.A. Doolittle*

Good golf green drainage is important for healthy turf and a well-maintained playing surface. With time, drainage systems can fail or become plugged because of improper construction and/or management. Unfortunately, many system maps are either unavailable or incorrectly marked, which makes the problems hard to fix.

Locating a drainage system in a green is time-consuming and often frustrating. Many superintendents invest hours in locating theses pipes when drainage problems arise. Correcting the drainage problems can destroy the green and are expensive when the location of the present system is unknown.

Ground-penetrating radar (GPR) is a non-invasive geophysical tool for locating subsurface features.

Ground-penetrating radar (GPR) is a noninvasive geophysical tool for locating subsurface features. It was commercially developed in the mid 1970s, and is primarily used for imaging near-surface features such as buried artifacts (Conyers and Goodman, 1997), drains (Chow and Rees, 1989), irrigation pipes (Vellidis et al., 1990), utility cables (Annan, et al., 1984; Morey, 1974), land mines and human remains.

In addition, GPR has been used to monitor the movement of water through surface layers (Vellidis et al., 1990), detect perched water tables (Collins and Doolittle, 1987), and chart subsurface soil horizons and layers (Asmussen, et al., 1986; Collins and Doolittle, 1987; Mokema, et al., 1990; Raper, et al., 1990). Recently (Chong, et al., 2000), GPR has been successfully used to determine the thickness of the sandy rooting mixture in a golf green, locate the drainage pipes, locate areas of surface compaction and locate areas of concentrated subsurface wetness.

In this study, a SIR System 2000 GPR manufactured by Geophysical Surveys Systems was used to map the drainage systems in a USGA-style green and a California-style green. A previous study (Chong, et al., 2000) indicated that GPR could accurately locate the drainage tiles in a green with minimum time and minimum disturbance.

## Study area and site conditions

The two study sites were located near Carbondale, Ill., located about 90 miles southeast of St. Louis. The first study site was located at the Hickory Ridge GC. The greens at Hickory Ridge are typically sand mixes following the California style of green construction on top of a loamy native soil. The green mix was designed to be 12 inches thick.

Located under the rooting mix are perforated plastic drainage lines, 4 inches in diam-

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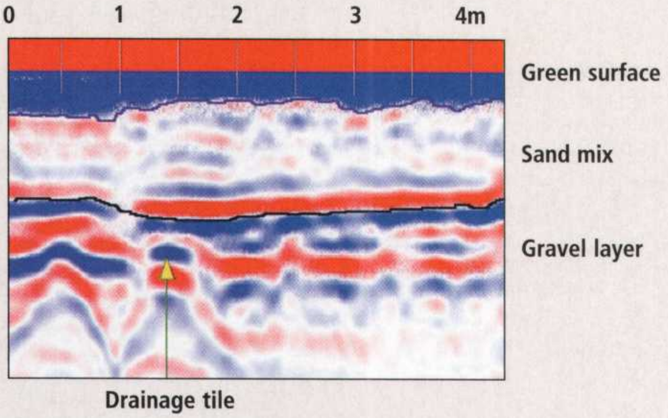
**FIGURE 1**

**Cross-section, No. 3 Green at Stone Creek GC**




***GPR allows small objects, like the drainage tile, produce unique reflections, which help superintendents locate subsurface features more easily.***

eter, lying in trenches cut into the native soil. The greens at Hickory Ridge are Penncross creeping bentgrass, and they were in their ninth season when the study was conducted. The second study site was located at the Stone Creek GC, just south of Carbondale.

The greens at Stone Creek are USGA style. They typically have 12 inches of sand above 4 inches of gravel overlying the native soil. The tile is 4 inches in diameter and lies under the gravel in trenches lying in the native soil. Gravel is placed around the tile.

## Radar equipment and how it works

Our study used the Subsurface Interface Radar (SIR) System-2000, manufactured by Geophysical Survey Systems (GSS).

With GPR, the depth of observation decreases rapidly with increasing antenna frequency and soil conductivity. In one soil, radar may reveal features 10 feet deep, while in another soil material the radar may only reveal features 2 feet deep. In many radar studies, resolution is often sacrificed for increased observation depths as lower-frequency antennas (10 to 300 megahertz) are used.

When profiling and investigating golf greens, the depth of interest is generally 0 to 24 inches. For this study, a 400-megahertz antenna was used because it provides improved resolution of subsurface features at shallow observation depths.

The radar detects the interface between materials with different electromagnetic properties. Density, water content, texture or foreign bodies can influence electromagnetic properties. Each interface revealed on the radar profile is generally displayed as a group of dark bands.

Fig. 1 is a portion of a radar scan from the No. 3 USGA green at Stone Creek. The uppermost interface in Fig. 1 (the top red band) represents reflections from the soil or green surface. The major subsurface reflections in this radar profile are the sand mix, the gravel layer and the interface where the sand mix meets the gravel layer. With GPR even small objects such as rocks, roots or buried cultural features produce unique reflections.

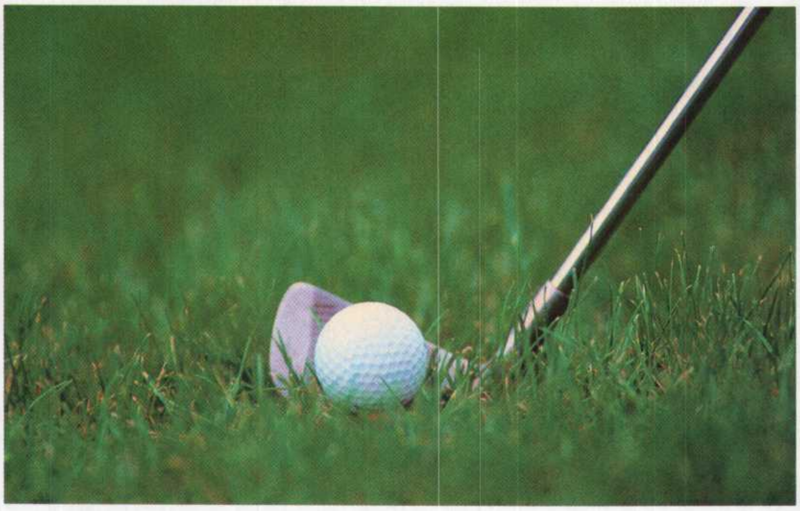
These features are referred to as point reflectors, which can be seen between the 3.3 feet and 6.6 feet marks. This point reflector is the cross-sectional view of a 4-inch-diameter, perforated, plastic drainage pipe. To map the drainage system in golf greens, the radar scans are made perpendicular to the drainage system and the parallel scan lines are spaced 3.3 feet apart.

## Drainage system maps

Prior to scanning, a 3.3-foot x 3.3-foot grid was overlaid on the entire green. To establish this grid pattern, the sprinkler heads were used as reference points. The grid was flagged every 3.3 feet, including the boundary of the green. The GPR system was then calibrated for each green to allow for the best viewing window.

A three-person team worked together to scan the greens. A green of 5,000 square feet took about one hour to flag and scan. In general, flagging takes longer time than scanning. The scanning takes about 15 to 20 minutes. The data was then analyzed. The results were transferred and mapped using a simple spreadsheet to plot the boundary and the drainage system of the green. Fig. 2 (page T4) shows the drainage system of Green No. 2 at Hickory Ridge, while Fig. 3 (page T4) shows the drainage system of Green No. 3 at Stone Creek.

# Contec® Technology



Contec® is The Andersons' homogenous small particle, controlled-release fertilizer technology. Contec products offer competitive advantages in today's marketplace with the increasing interest in lower mowing heights, reduced nitrogen application rates, and a spoon-feeding approach to nutrition.

"Contec gives consistent growth over the long haul and when used in conjunction with a foliar program is a home run for golf course superintendents!" states Andersons Golf Products Territory Manager Ed Price, who covers Idaho, Montana, Wyoming, and eastern Washington for The Andersons. Price's counterpart, Mike Redmond, who covers Minnesota, northern Wisconsin, and North Dakota agrees, saying "Contec's predictable release with an SGN of eighty takes the worry out of putting a granular product on close-cut greens".

## The basics on Contec:

- Homogenous composition to assure even growth and maximum turf response.
- Average SGN of 80 to 90 for greens formulations and 140 to 150 for fairways (SGN = Size Guide Number) to provide rapid dispersion into the canopy, greatly reducing tracking and mower pick-up.
- Average Uniformity Index of over 50 to assure an even distribution of nutrients across the spreader pattern. (A Uniformity Index of 35 is considered acceptable)
- Extensive utilization of "short-chain" methylene ureas (MDU and DMTU)
- Low Salt Index

Short-chain methylene ureas are efficient nitrogen polymers that are available to the plant within a predictable period of time. Other methylene urea fertilizers that rely heavily on "long-chain" nitrogen polymers often exhibit a turf response that is too slow for most applications.

Contec fertilizers with an average SGN of 80 to 90 are ideally suited for greens with mowing heights of 1/8" or lower. They provide approximately 35 particles per square inch compared to 18 particles per square inch for standard greens fertilizers. This results in more plant tillers receiving a complete nutrient package. The small particle sizing allows for applications at reduced rates, thus in effect allowing superintendents to spoon-feed with a granular material.

The Andersons formulate eight Contec products; all utilizing potassium sulfate, designed to address varying climatic, nutritional, and application situations.

### Greens Formulations

- 9-18-18 w/18% Methylene Urea + 4% Ca and 2% Mg
- 13-2-26 w/100% Methylene Urea
- 17-3-17w.50% Methylene Urea + Fe and Mn
- 18-9-18 w/63% Methylene Urea + Fe and Mn
- 19-2-15 w/100% Methylene Urea & Minors
- 19-3-19 w/100% Methylene Urea.
- 20-0-10 w/75% Methylene Urea & 5% Mn

### Fairway Formulation

- 22-3-11w/98% Methylene urea + Fe And Mn

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**FIGURE 2**

**Drainage System
Hickory Rirdge GC (Green No. 2)**

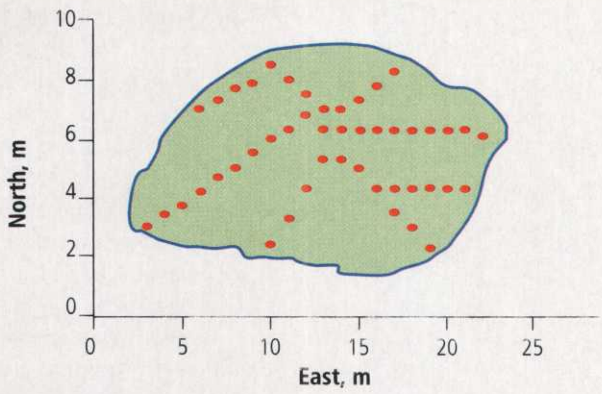
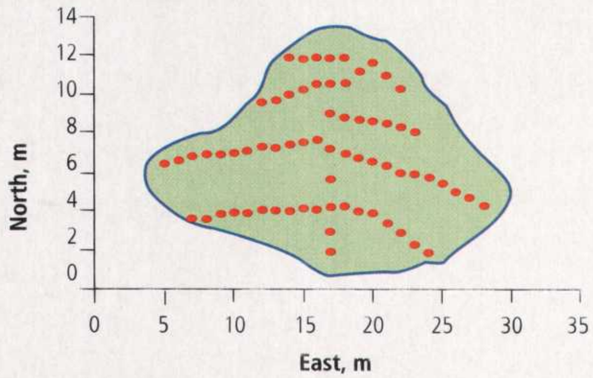



**FIGURE 3**

**Drainage System
Stoney Creek GC (Green No. 3)**




***Superintendents can use GPR to map underground drainage systems without tearing up a green's surface.***

## Summary

Use of GPR for mapping drainage tile in golf greens can be effective. Superintendents can use this technology to accurately and precisely identify drainage tile and other subsurface features (e.g., areas of compaction or wetness) in a golf green.

The application of GPR technology to golf greens is still in the early stages, but it already shows great promise in the trouble shooting and management of golf green drainage systems.

Having the ability to study the subsurface features of a golf green without digging a hole will minimize the cost of finding and fixing subsurface drainage problems.

*Richard Boniak, She-Kong Chong and Thomas Boniak are affiliated with the plant and soil science department at Southern Illinois University in Carbondale, Ill. Richard Boniak is a Ph.D. candidate, Chong is a professor, and Thomas Boniak is an undergraduate student. Sam Indorante and Jim Doolittle work for the United States Department of Agriculture-Natural Resource Conservation Service. Indorante is located in Carbondale and Doolittle is located in New Town Square, Pa. Mention of product or equipment names is for informational purposes only and not an endorsement.*

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# Advances in Seeded Bermudagrasses Could Spark Wider Use

*By Michael D. Richardson*

Bermudagrass has been the backbone of the Southern turfgrass industry for the past century. The various uses of bermudagrass have been almost endless and include golf greens, fairways, tees, roughs, sports fields, home lawns, commercial sites and roadsides.

The wide adaptation of this species reflects a broad range in genetic diversity, from very dwarf, dense putting green selections such as TifEagle or Champion to cultivars that have been selected for their ability to produce massive amounts of foliage.

The genetic advances in the turfgrass quality of seeded bermudagrass will likely increase its use on high-maintenance turf surfaces.

Although these new cultivars should provide a quick, easy and economical way to establish a high-quality bermudagrass turf, several drawbacks do exist, including establishment weed control and the issue of cold hardiness, especially during the establishment year.

Many of the improved cultivars are hybrids. Until recently, most of the improved cultivars or hybrids available to the golf and sports turf industry were infertile and had to be planted using vegetative techniques such as sod or sprig-planting. The bermudagrasses available by seed were generally considered "common" and didn't produce the superior turf surface of the sterile hybrids and selections.

In the 1980s, a handful of turfgrass breeders began a concerted effort to find, cross and develop cultivars of bermudagrass that would produce fertile seed and also produce an acceptable turf. Some of the earliest work was done in New Mexico under the direction of Dr. Arden Baltsenberger and resulted in the release of NuMex Sahara, a seed-propagated bermudagrass with a slight improvement in quality over common.

Further work by breeders at International Seeds in Oregon led to the release of the cultivar Mirage, which had improved performance over NuMex Sahara, but was still inferior to the popular vegetative cultivars.

In the late 1990s, Oklahoma State University and Charles Taliaferro released Riviera, a cultivar with significant improvements in turfgrass quality relative to earlier seeded types. In addition, further work from Baltsenberger's program led to the release of Princess, which also had turfgrass performance that was comparable to industry standards such as Tifway.

## Establishment weed control

The ability to control weeds during the first six to eight weeks after emergence is a key factor to the success of seeded bermudagrasses.

Summer annual grasses such as crabgrass and goosegrass are particularly competitive in a new bermudagrass seeding and broadleaf weeds may also create problems through shading of young bermudagrass seedlings. Therefore, competition during the seedling stage could significantly inhibit the establishment rate and reduce overall stand density.

Dennis Martin of Oklahoma State University has provided good information regarding pre-emergent herbicide tolerance of established and newly emerged seeded bermudagrass cultivars. However, pre-emergent control in new seedings often produces poor or inconsistent results due to the nonselective nature of pre-emergent herbicides.

With regard to postemergent weed control, little is known about herbicides that can be effectively used during the critical period for stand establishment.

Work at the University of Arkansas has focused on investigations of postemergent herbicide tolerance of newly seeded bermudagrass, initiated in June 2000, using Princess. At seven, 14 and 28 days after seedling emergence, individual plots were treated with one of seven postemergent

## THE EMERGENCE OF SEEDED VARIETIES

**A sample of the results from the past three National Turfgrass Evaluation Program bermudagrass trials.**

| Cultivar | 1986 Trial Final Report | 1992 Trial Final Report | 1996 Trial 2000 Report |
|---|---|---|---|
| | Turfgrass Quality | | |
| Tifway | 6.6 | 6.0 | 6.5 |
| Midlawn | 6.0 | 6.0 | 6.2 |
| Tifgreen | 6.5 | 6.1 | 6.1 |
| TifSport | * | * | 6.5 |
| NuMex Sahara (seeded) | 4.9 | 4.6 | 4.9 |
| Mirage (seeded) | * | 5.4 | 5.0 |
| Yukon (seeded) | * | 5.4 | * |
| Riviera (seeded) | * | * | 6.6 |
| Princess (seeded) | * | * | 6.4 |
| Guymon (seeded) | 4.4 | 5.0 | * |
| Arizona Common (seeded) | 4.4 | 4.2 | 4.6 |

* not entered into that particular trial

turf herbicides at recommended rates, including monosodium methanearsenat; dicamba; metsulfuron; 2,4-D; chlopyralid; diclofop and quinclorac, as well as an untreated control. This study was repeated during the 2001 season, with seeding occurring on May 24.

**Genetic advances in the turfgrass quality of seeded bermudagrass will likely increase its use on high-maintenance turf surfaces.**

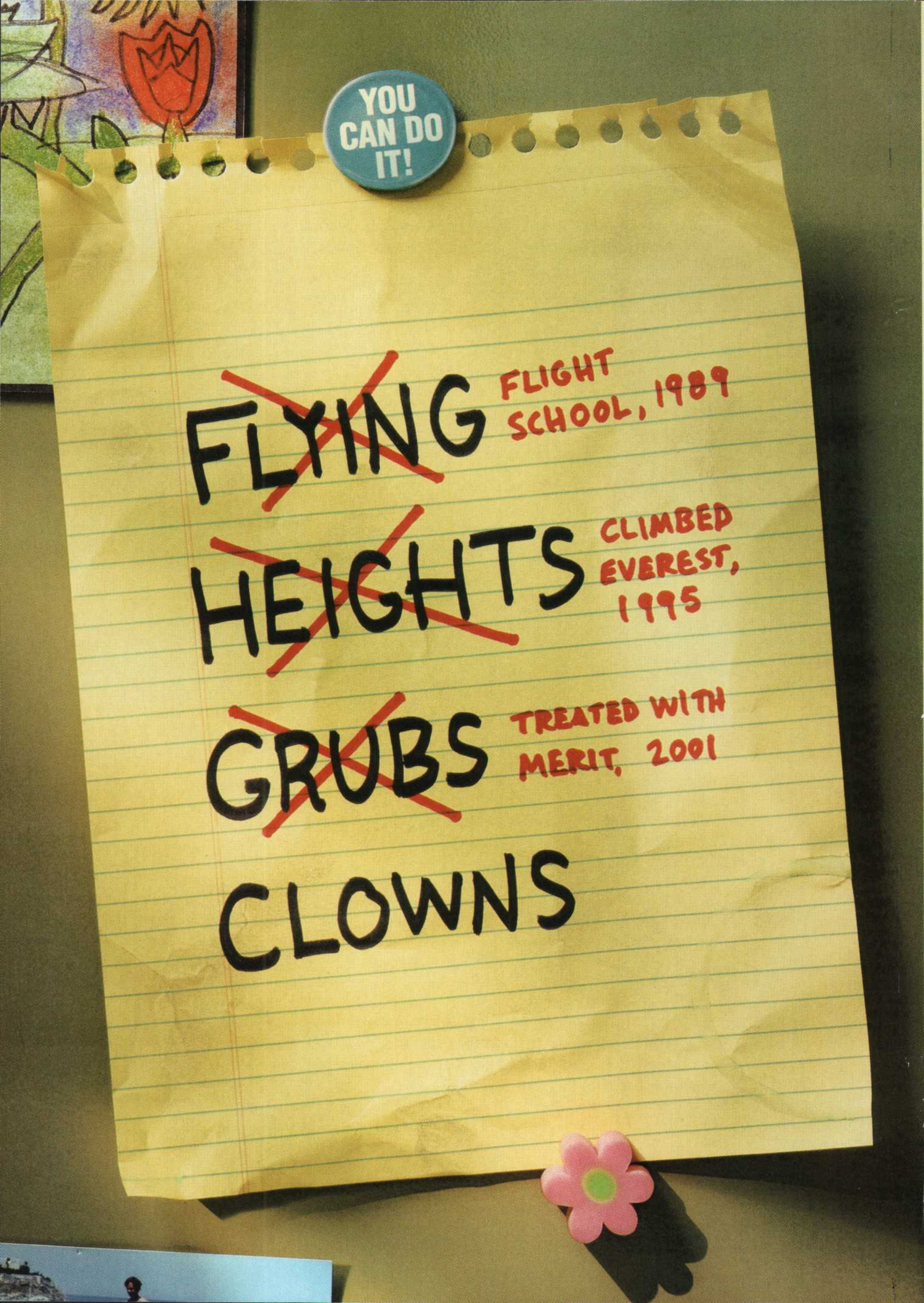
Over both years of the trial, significant injury was observed with most herbicides at the one, two and four weeks after establishment timings. The injury was similar regardless of the application timing, so combined the data from the three timings for this report.

Metsulfuron and diclofop generally produced the highest levels of herbicide injury on Princess bermudagrass, although significant injury was also observed with dicamba and 2,4-D.

These findings were similar from both years of the study. Although the injury observed at each timing was considered harmful, the turf quickly recovered from the injury.

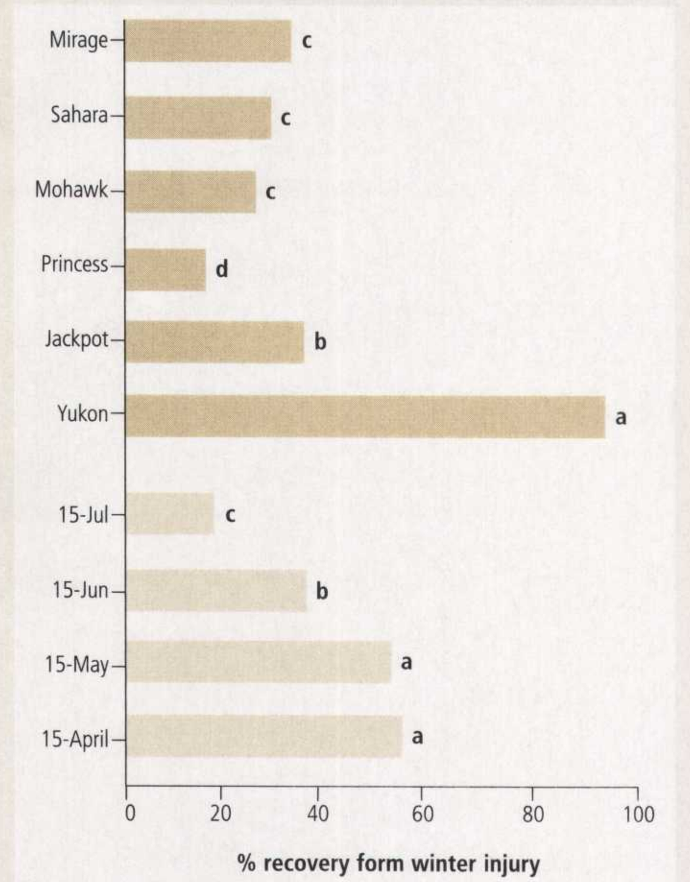
Plots sprayed with metsulfuron and diclofop were only slightly distinguishable from other treatments at 30 days after treatment. During the 2001 growing season, herbicide injury was overall not as severe as 2000, and recovery occurred much quicker. These differences likely reflect a significant difference in temperature and solar radiation between the two seasons.

During 2000, June was cloudy, wet and cool, while June 2001 had less frequent rain and 4° C to 8° C higher average temperatures compared to 2000. The results of these two studies indicate that several, common postemergent herbicide programs that are effectively used on mature



YOU CAN DO IT!
FLYING
FLIGHT SCHOOL, 1989
HEIGHTS
CLIMBED EVEREST, 1995
GRUBS
TREATED WITH MERIT, 2001
CLOWNS

FIGURE 2




***Winter recovery of seeded bermudagrasses, as affected by cultivar (top) and planting date (bottom). Different letters indicate a significant difference between treatments according to their lowest statstical difference (LSD).***

bermudagrass can also be used to establish bermudagrass from seed.

Future studies are in place that will investigate the use of herbicide combinations in combination with repeated applications of chemicals on seedling bermudagrass during establishment.

## Winter injury

A second limitation to seeded bermudagrasses, especially in the upper transition zone, is a potential for winter kill following the establishment year.

Winter survival of bermudagrass has been an important issue in this region for many years, with major emphasis on cultivar variability (Anderson et el., 1993), fertility management (Reeves et al., 1970), and the underlying physiology associated with cold tolerance (Dunn and Nelson, 1974).

Unfortunately, most of the research in the literature has focused on established bermudagrass turf with particular emphasis on vegetatively propagated hybrids.

Crown and rhizome development are

**Problems associated with weed control and first-year winter survival can be solved with proper management.**

critical for winter survival in bermudagrass ,and a short growing season can restrict the development of bermudagrass seedlings prior to the onset of chilling temperatures. Philley and Krans (1998) reported that several new seeded bermudagrass cultivars suffered significant winter damage in Mississippi during the establishment year following a June seeding.

A study in Arkansas (Hensler et al., 1999) evaluated the effects of five seeding dates (April 15, May 15, June 15, July 15, Aug. 15) on morphology and cold tolerance of several seeded cultivars. In the following December's establishment of new plots, rhizome development was virtually absent in all seeded cultivars.

Collectively, these studies suggest that a minimum period of favorable weather will be required to successfully establish a seeded bermudagrass turf that can survive the first winter.

Research at the University of Arkansas has focused on the effects of cultivar selection and seeding dates on the morphology and freeze tolerance of newly seeded bermudagrass.

The overall approach for this study was to plant a replicated test containing six seeded bermudagrasses cultivars (Princess, Yukon, Mohawk, Jackpot, Mirage and NuMex Sahara) on a monthly basis through the growing season.

The experiment was planted near April 15, May 15, June 15 and July 15 in 2000 and on the same dates in 2001. Each plot was seeded at one-half pound of seed per 1,000 square feet.

These plots were evaluated during the dormant season for morphological development, and winter recovery was evaluated during the spring green-up period. The 2001 study is still underway and will not be discussed in this report.

The 2000-2001 winter was one of the most severe on record for Fayetteville, Ark., and bermudagrass winterkill was observed throughout the region. Morphology analysis of these plots included evaluations of stolon density, stolon mass and weight per stolon.

In addition, rhizome quantification was attempted in these plots, but none were observed for any cultivar across all seeding dates, similar to earlier reports (Hensler et al., 1999).

**The most important data obtained from this study was the recovery of the plots from the significant winterkill that occurred during the harsh 2000-2001 winter.**

Weight per stolon was affected by both cultivar and planting date. To summarize, Yukon had the highest weight per stolon of any seeded cultivar across all planting dates, while an April seeding led to significantly higher weight per stolon than any of the other planting dates.

Stolon number was more affected by planting date than by cultivar, but Yukon, Mohawk and Jackpot were able to maintain more uniform stolon densities across all planting dates than did Mirage, Sahara and Princess.

The most important data obtained from this study was the recovery of the plots from the significant winterkill during the harsh 2000-2001 winter.

During the months of December and January, temperatures at the Fayetteville location routinely dropped into the low single digits, and the plots experienced a snow/ice cover for more than 40 days during that period.

The cultivar Yukon had much higher recovery from winter injury compared to any other seeded bermudagrasses, followed by Jackpot (Fig. 2). Princess bermudagrass had the lowest overall recovery from winter injury, with less than 20 percent recovery by early May.

Planting date also had a significant effect on winter survival and recovery, with April and May seeding dates producing much higher recovery from winter injury than June or July seedings (Fig. 2).

This study demonstrates that early seeding dates are critical in the upper zones of bermudagrass use. In addition, these data also demonstrate that great advances in cold tolerance have been made in recent years and the cultivar Yukon will have great potential in regions where other bermudagrasses have not been adapted.

*Dr. Michael Richardson is a turfgrass physiologist in the department of horticulture at the University of Arkansas in Fayetteville, Ark. He received a Bachelor of Science degree from Louisiana Tech University, a Masters degree from Louisiana State University and Ph.D. from the University of Georgia. Prior to joining the faculty at the University of Arkansas in 1998, he was a member of the faculty at Rutgers University and was also the director of research at Turf Merchants, an Oregon-based turfgrass seed company.*

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# Copper Management Demands Attention

*By Richard J. Hull*

Of the six metallic micronutrient elements, copper (Cu) is one of the least abundant in plant tissues. Only molybdenum and nickel are required in lesser amounts.

The sufficiency range for Cu in turfgrasses reported by Jones (1980) is five to 20 parts per million (ppm) of leaf tissue dry weight. This compares with 35 to 100 ppm for iron (Fe) and 20 to 55 ppm for zinc (Zn). A summary of Cu concentrations reported in turfgrasses is presented in Table 1. While values differ among the three laboratories, probably due to different analytical methods used, it appears that field-grown turfgrasses contain about 20 to 30 ppm Cu.

It's probably evident by now that many trace elements perform similar functions in plants. While I shall try not to repeat what we have already considered, it is useful to recognize the similarity in biological functions exhibited by these nutrients. Understanding functional similarities can help the turf manager judge the value of applying these nutrients as part of a turf management program. We shall consider this further before closing our discussion of Cu use by turfgrasses but first let's see exactly how Cu is obtained by and used in turfgrasses.

## Copper in soils

Most soils contain little Cu, with values from over 1,000 sites in the United States ranging from one to 191 ppm (Kubota, 1983). Soils considered high in Cu have about 50 ppm, with most soil being substantially less than that.

Soil Cu exists in two oxidation-reduction forms: oxidized cupric ($Cu^{2+}$) and reduced cuprous ($Cu^{+}$).

The reduced $Cu^{+}$ form exists mainly in soils that are constantly waterlogged where, being highly unstable, it generally forms inorganic or organic compounds that are insoluble. Cuprous is the stable form of Cu in most Cu-minerals. But when they are weathered and solubilized, the $Cu^{+}$ is rapidly oxidized to $Cu^{2+}$ and can even react with itself to produce $Cu^{2+}$ and elemental $Cu^{0}$ (Clarkson & Hanson, 1980).

**TABLE 1**

**Copper content in leaf tissues of several turfgrasses**

| Turfgrass | Copper content* | | |
|---|---|---|---|
| | Waddington & Zimmerman (1972) | Butler & Hodges (1967) | Turner (1980) |
| | | ppm | |
| Annual bluegrass | 26 | - | - |
| Kentucky bluegrass | 25 | 30 | 7.3 |
| Colonial bentgrass | 31 | 19 | - |
| Creeping bentgrass | 35 | - | - |
| Tall fescue | 23 | 34 | |
| Creeping red fescue | 25 | 20 | 8.4 |
| Perennial ryegrass | 24 | 38 | 8.0 |
| Bermudagrass | - | 43 | - |
| Zoysiagrass | - | 18 | |

* As reported in Turner & Hummel (1992)


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The oxidized $Cu^{2+}$ form is more abundant, but it's a strong oxidizing agent and readily reacts to form mineral complexes and metallo-organic groups. Being a divalent cation, $Cu^{2+}$ also binds strongly to mineral (clay) and organic cation exchange sites. The consequence of $Cu^{2+}$s reactive nature is that its concentration in soil water is rarely more than 1 or 2 ppm.

In neutral or alkaline soils, $Cu^{2+}$ forms weakly soluble salts with carbonate ($CuCO_3$) or hydroxide [$Cu(OH)_2$] resulting in even less of the soluble ionic form being available for plant uptake. Consequently, Cu deficiency is most likely to be observed in high pH soils, similar to the situation with iron ($Fe^{3+}$) in well-limed soils (Hull, 1999).

## Copper uptake

The absorption of Cu by plant roots is not well understood. Because $Cu^{2+}$ is present in the soil solution at concentrations of 1 to 2 ppm and within the cytoplasm of root cells at even lower concentrations, uptake should be passive, moving down a concentration gradient. The cytoplasm of root cells also is electrically negative compared to the soil solution, making additional energy available to transport $Cu^{2+}$ into root cells from a positively charged soil environment to the negatively charged cell cytoplasm.

All that is required for $Cu^{2+}$ uptake is the presence of membrane channels through which cations can pass. There is ample evidence that such cation transport channels exist in root epidermal and cortical cells (Marschner, 1995). Most of the data that I've seen for Cu uptake by grass roots shows a linear relationship between $Cu^{2+}$ concentration in the soil solution and Cu accumulation in roots. This is consistent with the passive influx theory outlined above.

Research, comparing the efficiency of Cu uptake by several cultivars of wheat and other annual grasses, shows dramatic differences among cultivars (Marschner, 1995). Some cultivars grow poorly and produce no grain at low Cu levels while others produce normal yields at the same Cu concentrations. This indicates Cu absorption is under genetic control and could cast doubt on the passive uptake theory. However, more recent molecular studies have shown Cu-efficient cultivars to have the genes for the enzymes that synthesize the phytosiderophore mugineic acid that enables most grasses to capture and absorb $Fe^{3+}$ from iron-poor soils (Hull, 1999).

Although this organic chelating agent does not bind $Cu^{2+}$ as readily as it does $Fe^{3+}$, it does react with Cu sufficiently to increase its solubility and enhance its uptake by roots. It appears that $Cu^{2+}$ uptake by turfgrass roots might occur through passive transport along an electrochemical gradient between soil solution and root cells, as well as by chelate capture from the soil and transport across cell membranes.

It has also been demonstrated that nutrient uptake by several plants is enhanced dramatically when the plant roots have a mycorrhizal association with specific soil fungi (Marschner, 1995). This symbiotic relationship between root and fungus has been shown to increase markedly a plant's ability to recover phosphorus (P) from low fertility soils. Among the micronutrients, Zn and Cu have proven to be more available to plants when roots are mycorrhizal. This beneficial association appears to work best when plants are growing in low fertility soils.

High soil fertility, especially high P, inhibits mycorrhizal associations, resulting in little if any benefit to plants. It is, therefore, questionable if mycorrhizae can be helpful in making poorly available nutrients like Cu more available to turfgrasses. Since turf is normally grown at fairly high fertility levels, it would likely be difficult to maintain healthy mycorrhizae that could make Cu or other nutrients more available.

If turf is growing on a soil of alkaline pH and high cation exchange capacity due to the presence of clay or organic matter, the soil's capacity to immobilize $Cu^{2+}$ would be great, making little available to plant roots and causing a Cu deficiency. Adding Cu fertilizer to such a soil would do little good because most would be quickly bound into the soil matrix and largely unavailable for root absorption. Similar availability problems have been observed for manganese (Mn), Fe and Zn. While grasses are less prone to soil fixation problems than are most broad-leaved plants, maintaining adequate micronutrient supply to turfgrasses still can be difficult on nutrient-binding soils.

Under these conditions, Cu is often more effectively applied as a foliar spray several times during the growing season. Any soluble Cu source can be used, but chelated forms applied with a surfactant are normally most effective. Water is the medium by which $Cu^{2+}$ penetrates the leaf surface, so applications made late in the day, when free water will persist for several hours, are more effective. Because Cu is not readily translocated from grass leaves to other plant organs, applications should be repeated every six weeks.

Most foliar applied Cu will be lost in clippings, so this should not be viewed as a long-lasting solution to a soil unavailability problem.

## Copper sources, management

The most common Cu source applied to turf is copper sulfate that contains 25 percent Cu and is highly water soluble. This salt readily dissolves to release $Cu^{2+}$ ion, the most plant-available form of Cu. Copper sulfate is most effective when applied to acid or neutral soils ,but in alkaline soils the $Cu^{2+}$ rapidly precipitates to an unavailable form. Organic soils and those having a high clay content also strongly bind $Cu^{2+}$, making it less available to grass roots. If these soil conditions are prevalent in your area, you are at risk of experiencing a Cu deficiency and applying copper sulfate may provide only temporary or no relief.

Even sand-based greens may be deficient in Cu and other micronutrients if none were supplied during construction and topdressings were lacking in these elements. Copper is not normally mobile in soil, but in sandy acid soils with low cation exchange capacity, Cu can be lost by leaching. This can occur on greens, especially new greens, where subtle turf problems may be noted that can be difficult to explain.

In a Rutgers University study, take-all patch disease of creeping bentgrass was found to be reduced substantially by monthly applications of Mn and Cu (Hill et al., 1999). The requirement of Cu and Mn for lignin biosynthesis and the resulting increase in disease resistance was the explanation offered for their results.

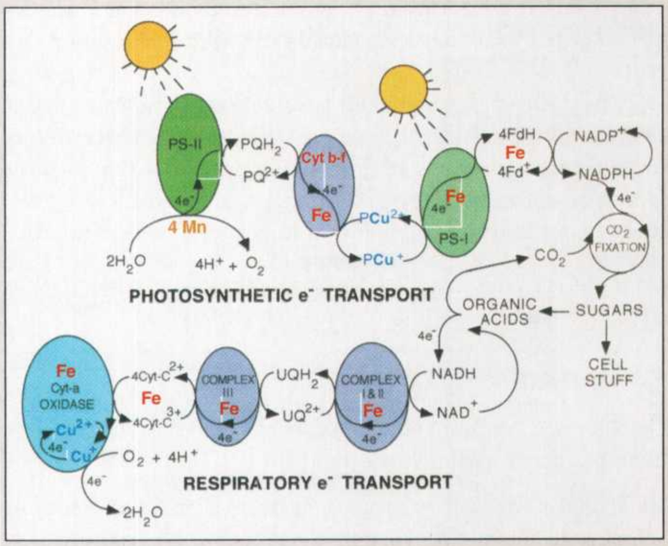
Applications of copper sulfate will correct any Cu deficiency, and its addition might well become part of a turf fertility program. As with Zn and Mn, Cu tissue levels should be monitored every three or four years to insure turf is receiving sufficient Cu and to check on possible toxicity levels. Leaf analysis is not a good indicator of plant Cu toxicity because transport from roots is limited. Cores should be taken and roots removed for Cu analysis. Root samples can be collected during hollow core aeration.

If roots are found to contain much above 25 ppm Cu, stop adding that element and look for other sources that could contribute to high Cu levels. Waste water and sludge-based topdressings are likely sources of excess Cu.

Chelated Cu sources are more expensive than copper sulfate, but their Cu is less likely to be immobilized in soils prone to metal fixation. These materials contain about 13 percent Cu but because little of the Cu is released as $Cu^{2+}$, it's not fixed and rendered unavailable to plants. The chelate remains soluble and can be drawn toward plant root surfaces, where increased acidity will promote somewhat more $Cu^{2+}$ release and absorption into roots.

Chelated Cu can also be applied as a foliar fertilizer where it may be absorbed by

**COPPER AND THE PHOTOSYNTHETIC EFFECT**




***The functions of copper (Cu) in photosynthetic and respiratory electron transport.***

leaves and effectively meet turf needs. While one might question the efficiency of foliar feeding as a general practice for turf fertilization, there is no question about its effectiveness as a means of supplying micronutrients, especially metallic ions and chelated forms.

Copper deficiency is not likely to be a problem for turf managers unless metal immobilizing soils are involved. However, fine turf maintenance is an intensive demanding operation where success depends on covering all the bases. Micronutrient sufficiency is one of those bases that the turf manager might well want to touch.

*Richard Hull is a professor of plant sciences at the University of Rhode Island in Kingston, R.I., who specializes in plant nutrition.*

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## TURFGRASS TRENDS

SECTION STAFF

**Managing Editor**
Curt Harler
440-238-4556; 440-238-4116 (fax)
*curt@curtharler.com*

**Golfdom Staff Contact**
Frank H. Andorka Jr.
440-891-2708; 440-891-2675 (fax)
*fandorka@advanstar.com*

**Online Editor**
Lynne Brakeman
440-826-2869; 440-891-2675 (fax)
*lbrakeman@advanstar.com*

**Senior Science Editor**
Dr. Karl Danneberger
614-292-8491; 614-292-3505 (fax)
*danneberger.1@osu.edu*

**Production Manager**
Jill Hood
218-723-9129; 218/723-9223 (fax)
*jhood@advanstar.com*

**Art Director**
Lisa Lehman
440-891-2785; 440-891-2675 (fax)
*llehman@advanstar.com*

**Publisher**
Patrick Jones
440-891-2786; 440-891-2675 (fax)
*pjones@advanstar.com*

**Group Publisher**
John Payne
440-891-3126; 440-891-2675 (fax)
*jpayne@advanstar.com*

**Corporate & Editorial Office**
7500 Old Oak Blvd.
Cleveland, OH 44130-3369



CONTACT US:

**Editorial**: 440-238-4556
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sure, burn from the organic product or flush growth.

"We didn't observe any increased disease and we did this on July 11," Campion says. "There was no brown patch or pythium, two diseases you expect when you make an application of fertilizer in July in central Ohio."

Wohlner says superintendents will like the product because the wetting agent's longevity matches or exceeds that of the fertilizer, and the two elements work together for up to 12 weeks.

Wohlner says Precision Laboratories plans to introduce other nutrient-based wetting agent carriers in the future.

*Editor's note: Here are other products that can help superintendents combat the stress of summer by managing their turf with less water:*

### L-amino acids

MACRO-SORB and QUELANT L-amino acid biofertilizers from **Nutramax Laboratories** are based on years of research to develop ecologically sound turfgrass solutions. The exogenous application of L-amino acids greatly reduces the energy requirements of plants. The net result is a healthy, strong and efficient plant that's more able to withstand the rigorous stress caused by drought, high temperatures, traffic, diseases, poor soil and other adverse conditions. L-amino acids enhance the uptake of nutrients and other materials. *For more information, contact 800-925-5187 or www.macro-sorb.com.*

### Water-absorbing polymer

**AAdvanced Water Management** offers Hydrozone, a water-absorbing polymer that absorbs 30 to 40 times its weight in water and later releases the water to a plant's root zone. Hydrozone, a white, free-flowing powder with little or no odor, lessens water loss caused by evaporation and percolation, the company says. When integrated into the growing medium properly, it reduces run-off by at least 50 percent. A recent study also reveals that Hydrozone reduces wilt on high-stress days. *For more information, contact 877-994-3494 or www.hydrozone.net.*

### Wetting-agent pellets

**Montco Products** offers Surf-Side Pellets to control localized dry spot. The pellets are 99 percent active nonionic wetting agent. One superintendent reports that Surf-Side Pellets help eliminate hard-to-wet areas on his golf course and improved water movement

*Continued on page 54*

*Continued from page 53*

through the soil. The pellets decreased the need for daily irrigation and nearly eliminated the need for daily syringing. *For more information, contact 800-401-0411.*

### Cure localized dry spot

**United Horticultural Supply** offers Alleviate, which cures localized dry spot. The hydrophobe tenside chemistry in Alleviate targets the coating of waxes, lipids, fulvic acids and other materials that make soil unable to re-wet. Alleviate is a blend of organic solvents designed to attack and break down the hydrophobic materials that bind to the sand particles in the soil profile. This action removes the waxy materials and places them in solution, which means they can be flushed from the soil profile. As Alleviate keeps the materials in true solution, they cannot reattach themselves to the sand particles.

UHS also offers Respond 2, a concentrated wetting and penetrating agent. Its penetrating action moves water deeper into the soil profile to increase root depth, the company says. *For more information, contact 800-847-6417 or www.uhsonline.com.*

### Soil surfactant, etc.

**Aquatrols** recently introduced these products:

- Primer Select is a soil surfactant that allows superintendents to select the application rate and frequency to match soil type and spray program preferences.
- PrimerSelect SWDG is a spreadable, water-dispersible granular (SWDG) carrier that is easy to spread and dissolves instantly when watered in, leaving no carrier residue.
- Aqueduct SWDG provides rapid recovery of localized dry spots and wet spots. It's easy to spread and dissolves instantly when watered in, leaving no carrier residue.
- Dispatch is the first in a line of water and energy-saving tools offering faster penetration and wetting times than that of competing products.

*For more information, contact 800-257-7797 or www.aquatrols.com.*

### Foliars

**Milliken Turf Product**'s foliar products are developed to enter the plant and not the root zone. So when the root zone is compromised by drought, water restrictions and root dieback, the plant still has nutrient access. In addition, the company's biostimulants are positioned for their hormonal benefits, reducing the carbohydrate consumption for root/shoot growth in stressful periods. *For more information, contact 800-845-8502 or www.millikenturf.com.* ■

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Yamaha and *Golfdom* are partnering to pay tribute to superintendents around the nation who serve their profession as volunteer leaders of local chapter associations. Please join us in thanking these "local heroes."

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### Michelle Frazier

**Boston Hills CC, Boston Heights, Ohio**
**Northern Ohio GCSA's Turf Newsletter Editor**

One of only 18 female certified superintendents (and 96 total female superintendents in the country), Michelle has proven by her tireless work that she fits perfectly in this male-dominated profession. "My colleagues are absolutely wonderful," she says. "They treat me like a daughter or a sister." A 1995 graduate of Virginia Tech, Michelle took over as editor of the NOGCSA's Turf newsletter in 1999, and it has won two consecutive national most-improved honors from the GCSAA. Michelle is also a member of the NOGCSA board of directors.

"Michelle spends unlimited hours on association-related business," says chapter Vice President Tim Cunningham. "The newsletter is probably the most important thing we do for our members. It allows them to see what we're doing and puts something in their hands that is related to our association. We were really proud of her getting those awards."

### Gary Carls

**Sunningvale GC, City of Sunningvale, Calif.**
**President of California GCSA**

Gary Carls didn't have enough on his plate as a member of the Northern California GCSA's Education Committee and the GCSAA Environmental Stewardship Committee. This year, he added teaching to his résumé, introducing students to recreation and sports turf management as careers through an innovative program at Castlemont High School in Oakland, Calif.

"Volunteering has helped me develop in my career, and I feel that I'm making a contribution and being a valuable part of the organization," Carls said.

Northern California GCSA President Jeffery Shafer said: "Gary's work, dedication and enthusiasm have been almost unparalleled, and he does it for all the right reasons. He is someone whose desire for the membership and the association far outweighs any personal desire."

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## IDENTITY/IMAGE APPAREL



At a golf course, four men approached the sixteenth tee. The straight fairway ran along a road and bike path fenced off on the left. The first golfer teed off and hooked the ball in that direction. The ball went over the fence and bounced off the bike path onto the road, where it hit the tire of a moving bus and was knocked back onto the fairway. As they all stood in amazement, one man asked, "How on earth did you do that?!"

Without hesitation he said, "You have to know the bus timetable."

Golfdom's JOKE of the month

# lemonade


## PUT DOWN YOUR COUNTRY TIME AND TRY OUR RECIPE FOR THIS DELICIOUS SUMMER STANDBY

BY MARK LUCE

While you're burning burgers and bratwurst on July 4, you may want to thank the agricultural wizards of Asia. Some 4,000 years ago, the good farmers started cultivating the yellow fruit that we use to concoct the perfect American liquid — lemonade.

Lemonade holds a nostalgic place in our lives. The mention of it conjures mouth-watering images of family gatherings on hot summer days, with grandma clinking a wooden spoon around a glass pitcher.

In today's culture of convenient consumption, most folks balk at the labor-intensive craft of squeezing fresh lemonade, choosing instead concentrated substitutes laden with artificial colors and wistful-sounding names. However, no powder will ever provide the zest, flavor and sheer pleasure of fresh-squeezed lemonade.

So put down the Country Time and try our recipe for *Golfdom's* Independence Day Lemonade. Here's what you need:

- 4 cups of cold water;
- 3/4 cup of sugar;
- 1 cup of fresh lemon juice (about four large lemons);
- One small lemon, cut into wheels;
- Ice cubes; and
- A pitcher.

In a saucepan, put the water on the stove to boil and begin juicing the lemons. If you are free from paper cuts and sport strong hands, squeeze the quartered lemons until you have enough. If you are practical, use a cheap plastic juicer. If you're lazy, push the button on an electric juicer. If you're a sophisticate, procure a high-end commercial manual juicer from Metrokane or Hamilton Beach and watch 1,000 pounds of pressure squeeze out ounces of lemon nectar.

By now, your water should be boiling. Remove it from the heat and dump in the sugar. Stir vigorously until the sugar dissolves. Now pour in the lemon juice and continue to stir. Before you transfer your lemonade into a pitcher, taste it. If you like it sweeter, add sugar and stir again. If it's too tart, add water. Repeat until perfected.

Put the concoction in the fridge and let it chill. When you're ready to serve it, load the pitcher up with ice cubes and lemon wheels. Then present the mixture to impressed guests, kids or spouses.

If you desire a Martha Stewart moment, double the recipe and fill a couple ice cubes tray with the nonchilled lemonade. Freeze them and toss the flavor cubes in a pitcher when you're ready to present your gourmet lemonade.

It's hard to beat the taste of this treat, but the real benefit of lemonade is that it's the perfect mixer for something harder. Although the research was exhausting and complex, I'm pleased to report your lemonade will taste better with a splash of any of the following: Stolichnaya, Tanqueray, Jose Cuervo or Grand Marnier.

Since it's Independence Day, however, a heavy wristful of Jack Daniels in your glass of lemon goodness may be more properly patriotic.

*Mark Luce sips lemonade on the makeshift back patio of his home in Kansas City, Mo. He can be reached at mluce@earthlink.net*

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