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Cover Photo:
Coarse and stemmy turf, the result of poor fertility practices.

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Managing Fertility in High-Sand-Content Greens

by STANLEY J. ZONTEK
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ONE OF THE MOST significant changes in golf course management during the past 30 years has been the switch from the use of topsoil for putting green construction to the use of materials consisting predominately of sand.

This year marks the 30th anniversary of the publication of the USGA Green Section *Specifications for a Method of Putting Green Construction.* At the time of their introduction, these specifications were considered a radical departure from green construction methods that had endured for decades. The specs advocated lighter, sandier soils with lower bulk densities, higher infiltration rates, greater soil aeration and lower moisture retention than the traditionally blended soil-based greens of that day.

Prior to these specifications, greens were typically constructed with mixtures of sand, topsoil, and peat at 1-1-1 or 2-1-1 ratios. Very little consideration was given to the type of sand, soil, or organic matter used. Further, greens were often intentionally underlaid with a thick layer of clay to hold water. At that time, irrigation systems were in their infancy, with hose and sprinklers being the norm. Compaction from heavy play was of little concern because courses simply did not receive the amount of traffic they do today.

These old 1-1-1 mixes were based on general guidelines handed down over the years that utilized blends of manures, composts, sharp sands, etc., all part of the art of putting green construction of that era. Sometimes they worked; sometimes they did not.

The USGA Green Section specifications were an attempt to put numbers on the physical characteristics of a good

Striping due to phosphorus deficiency!

(Left) Sandy mixture meeting USGA specifications. (Below) Old-style topsoil-based green. Different soils require different fertility programs.

quality putting green topmix. A properly sized sand, with the appropriate distribution of small and large pores, is the key to a putting green topmix that handles traffic and drains excess amounts of water, yet in combination with a small amount of soil and organic matter retains enough moisture to grow good turf under the widest range of environmental conditions.

Today, many greens built by architects and builders consist only of washed sand and organic matter. Should these sand/organic mixes be prepared with soil to provide some silt and clay? The anwer is yes; putting green mixes should contain some silt and clay to improve nutrient availability, increase water-holding capacity, and help minimize the potential for severe damage from diseases like take-all patch.

Sometimes the silt and clay are added by way of a separate soil source. Sometimes they come from the use of a dirty sand or from the organic matter source. A maximum of 5% silt and 3% clay is considered the standard for USGA spec greens.

High-sand-content greens have become the standard throughout most of the world because of their ability to drain well and resist compaction. However, many golf course superintendents have difficulty growing good turf on these greens for several years after establishment. Usually, the problem is a lack of understanding of the fertility requirements of high-sand mixes.

Maintaining Adequate Fertility Levels

How much fertilizer is enough for new sand-based greens? This is not an easy question to answer. Compared to topsoil greens, much greater amounts of fertilizer are needed to develop and maintain good growth on high-sand-content greens for the first couple of years. Much depends on how quickly the profile drains. A green which has a percolation rate of 12 inches per hour has the potential to leach more nutrients than a green that drains at 1 inch per hour. This is common sense.

Another important factor is the Cation Exchange Capacity (CEC) of the mix. This number is often overlooked when studying a chemical soil test and when determining how much or what kind of fertilizer to use on a green. The CEC is the measure of that soil's ability to hold nutrients. A soil with a CEC of 10 has twice the nutrient retention ability of a soil with a CEC of 5. Obviously, a soil with a low CEC will often require more fertilizer, more applications of fertilizers applied at lighter rates, and greater use of slow-release fertilizer than a soil with a higher CEC value.

A fertility program that works well for one golf course may not work the same for another course that has a different soil with a different Cation

Exchange Capacity. That's why it is so hard to be specific with soil fertility requirements when establishing new greens.

As a basis for comparison, straight sands with very little silt and clay often have CECs of 2-3 or less. This is very low. Sands blended with a high-quality fibrous organic matter with traces of silt and clay often have CECs of 5-6. This is a common range for CECs in new construction. In contrast, native topsoils have CECs in the range of 12-18, if not higher. Thus, recognizing that soils vary in their abilities to hold nutrients provides the basis for a better understanding of chemical soil test results and formulating a fertility program for high-sand-content greens.

Nitrogen

Nitrogen use rates on new sand greens should be high, beginning with the seedbed. To speed the establishment of new greens, USGA specifications suggest 2 lbs. of nitrogen per 1,000 sq. ft. be added to the seedbed before planting — 1 lb. of nitrogen as a quick-release fertilizer containing phosphorus and potassium as well as nitrogen, along with 1 lb. of nitrogen as a slow-release organic product.

After planting and during the initial growing-in phase, applications of 1 lb. of actual nitrogen per 1,000 sq. ft. per week for at least six weeks is a common and usually reasonable recommendation. As the grass matures, rates and frequencies should be reduced. Nonetheless, the first year totals for nitrogen in new greens could well seem ridiculously high compared to maintenance fertility levels for mature greens.

After the green has matured, maintenance fertility levels in sandy soils are typically about ½ lb. of actual nitrogen per 1,000 sq. ft. per growing month. This can vary due to several factors like CECs, infiltration rates, the amount of irrigation/rainfall, traffic, etc. To some, this may still seem like too much nitrogen, especially when ultra-light fertility programs in vogue a few years ago are recalled. While it is true that older topsoil-based greens can still be fertilized at low rates, this is not the case for new sandy soils. More nitrogen is needed, especially during the initial phase of new putting green establishment. In fact, the lack of adequate fertility is one of the most common problems in the maintenance of new sand-based greens.

All too often the grass establishes as it should and then, after the initial growth slows, the grass becomes thin, shallow rooted, and stalky. These are signs that the green has run out of fertility.

Phosphorus

For years, we have been told that phosphorus is not needed on putting greens. Soil tests often show excessive levels of phosphorus, and besides, we were warned that high levels of

Poor mixing of a sand/peat green only complicates fertility management.

phosphorus stimulate *Poa annua*. This may be true with golf greens constructed of topsoil, but the story changes when dealing with soils composed predominately of inert sand. The fact is, grass needs phosphorus. Topsoils can be rich in phosphorus, but sands are not. Further, while phosphorus is not mobile in heavier-textured topsoils with their naturally higher CECs and slower drainage rates, phosphorus can move in sands with their much lower CECs and rapid drainage.

Do not forget phosphorus. As a general guideline, 2-3 lbs. of actual phosphorus per 1,000 sq. ft. per year as a maintenance fertility level is reasonable. Also, high phosphorus "starter" fertilizers are recommended during establishment. These fertilizers should be raked into the seedbed. Thereafter, periodic soil tests should let you know for certain the extent to which phosphorus needs to be applied to sand-based greens.

By the way, the link between phosphorus and *Poa annua* stimulation is exaggerated and is secondary to the need to grow a strong, healthy stand of turfgrass. The best weed control, including *Poa annua*, is to develop a dense stand of grass. Proper fertility should provide the density which helps contain the *Poa annua*. Sandy soils need adequate phosphorus fertilization.

Potassium

Recent research, in conjunction with field observations, is showing just how important it is to maintain adequate levels of potassium in sandy soils. Potassium is nearly as prone to leaching and luxury consumption as nitrogen. In sandy soils with low CEC values and high percolation rates, potassium needs to be applied at nearly the same rates as nitrogen. Since most sandy soils are naturally low in potassium, a ratio of 1.5 lbs. of potassium to every 1 lb. of nitrogen applied during the growing season is not unreasonable. Field experience and periodic soil tests (at least once per year) should help determine adequate potassium levels and application rates.

One final point. Because grass exhibits luxury consumption of both nitrogen and potassium, periodic applications at light rates are preferable to infrequent applications at heavier rates.

Soil Reaction — pH

Maintaining soil pH in a reasonable range is recognized as being important by all turfgrass managers and scientists, regardless of the type of soil. This can be a special challenge in sandy soils, with their inherently low CECs and low soil buffering capacity, especially when the greens are young. Big swings in soil pH and nutrient levels are common in new greens. Fortunately, these peaks and valleys tend to soften as a green ages. For example, the addition of a small amount of elemental sulphur can radically change the pH of a new sand soil. Strive for a middle-of-the-road approach to pH management. Maintaining pH in a range between 6.0 to 7.5 is reasonable and is no great cause for concern, especially during the first few years following a green's construction.

Also, when soil tests are done, include the test for buffer pH. Standard pH tests tell you the pH of the soil solution, whereas the buffer pH is more representative of the true pH of that soil. A rainfall can affect the pH of the soil solution, but it will not change the buffer pH.

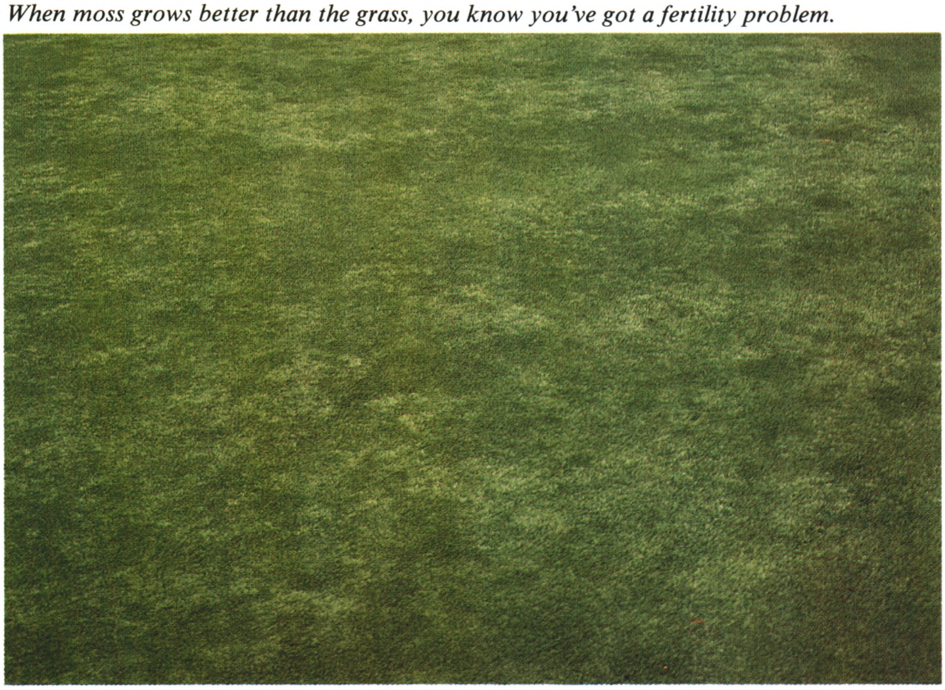
Low pH levels should be slowly raised by light applications of lime, never exceeding 25 lbs. per 1,000 sq. ft. per application. Lighter rates applied more often is preferred to burying the greens in lime.

Similarly, pH values above 8.0 should be managed carefully and slowly with sulphur or, better yet, fertilizers which naturally create acid as they break down. The Calcium Carbonate Equivalent on every bag of fertilizer is one way of measuring how much acidity is created by that particular fertilizer product. If the bag states 640 lbs. Calcium Carbonate Equivalent, then it takes that amount of lime to neutralize the amount of acid that is formed by the fertilizer. On high-pH greens, you can use this value to good advantage in lowering pH without running the risk of burning the turf, which sometimes can occur with granular applications of elemental sulphur.

In my opinion, the use of elemental sulphur to lower soil pH levels can be overdone, especially if the sand used in the original construction of the green is calcareous. Lowering the pH level in this type of soil can be an exercise in futility. Yes, you can change the pH of the soil solution, but it is nearly impossible to overcome a high buffer pH soil such as those constructed with calcareous sands. The best advice to superintendents who must deal with calcareous sand greens is to learn to live with it. Keep a close watch on nutrient levels in these greens, especially iron, and make adjustments accordingly.

This is an important point to consider when choosing a sand for new construction or topdressing. Hard rock or

When moss grows better than the grass, you know you've got a fertility problem.



silica-based sands, which are nearly neutral, are preferred over high-pH calcareous sands. Sometimes there is no choice. However, if there is a choice, the long-term management of nutrients and soil pH is far easier in neutral or slightly acid soils than in high-pH soils.

Micronutrients

Much has been said about the value of micronutrient applications on high-sand-content soils. Actually, the only micronutrient deficiency in sand-based greens that we have identified in the field is for iron. This problem is worse in high-pH sand greens, where iron availability is poor. Beyond this, evidence suggests that heavy use of micronutrients probably is not needed. Prudence would suggest, however, that in sandy soils with low CECs, micronutrient applications be made periodically to satisfy micronutrient requirements. Again, the exception is iron, which should be applied lightly and on a frequent schedule.

In Summary

In the past decade or so there has been a trend in our industry toward low levels of fertility on golf greens. On older topsoil-based greens, about 2-3 lbs. actual nitrogen per 1,000 sq. ft. per year has been successful in many instances. It should be appreciated that these low fertility levels are best utilized for topsoil-based greens and not sand greens. Extremely low fertilizer rates are not appropriate for the growing-in phase of new golf greens or for their follow-up maintenance. This is why so many turf managers are hesitant to apply enough fertility to new greens; they simply are not accustomed to applying that much fertilizer!

Look at your new greens. Do they have good roots, good density, reasonable color, and a developing thatch layer for good resiliency? If so, then you probably are on the right track.

By contrast, is the grass shallow-rooted, thin, coarse bladed, prone to spike marks, and speckled with invading *Poa annua*? Does the grass lack density, color, and an appreciable thatch layer? If this is the case, then your fertility program may be too low.

Consider all of these points. If you do have any questions, call your local USGA Green Section agronomists for advice. Once you become accustomed to the higher rates of fertility required by them, sand greens become far easier to manage than the old greens they replaced.

Environmental Fate of Common Turf Pesticides — Factors Leading to Leaching

by DR. KARL H. DEUBERT
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PESTICIDE users make a precarious decision every time they apply a chemical: Will residues of the chemical contaminate the groundwater or not? To complicate the situation, there is little information available to make such a decision and to guarantee its accuracy. Manufacturers are reluctant to elaborate on this. Scientists use predictive models to make educated guesses about potential residue movement. Though models are based on defined environmental factors rarely found in the same combination in the field, they remain the best available tool to assess the potential of a chemical for contamination of groundwater.

Most models are based on results of studies done in relatively small geographic areas. Consequently, they are most useful in areas for which they were developed. In other areas, different factors and combinations affect the accuracy of the results. Most important, the interpretation of results requires experience.

Despite considerable amounts of available information, the simple question, "Will compound X, when I use it, contaminate groundwater?" is difficult to answer. To illustrate the point, a sophisticated model was chosen to suggest which of the compounds that had been used in the past on several golf courses on Cape Cod might have contaminated groundwater. The computer selected dicamba and suggested that chlordane would remain in the topsoil. Ironically, chlordane was found in water samples (GC/MS analysis), and dicamba was not. This is an extreme example and is not intended to discredit the use of models.

However, the user needs an answer, and there are situations where quick answers are needed to assess the potential for groundwater contamination. In these cases, good knowledge of local soil and weather conditions (environmental factors) in combination with some basic information about the chemicals involved (compound-related factors) provides the basis for a quick and reasonably good assessment of a field situation.

Factors Affecting Leaching

Two major groups of factors affect the leaching of pesticide residues into the ground. The relatively large number of factors may appear confusing at first, but when used with common sense they can be useful and are not as complicated as they appear.

A. Compound-Related Factors
1. Initial amounts
2. Solubility in water
3. Persistence
4. Adsorption

Taken together, these four factors provide an indication of "Potential Mobility."

B. Environmental Factors
1. Interception by leaves and thatch
2. Photodegradation
3. Precipitation
4. Topography (slope)
5. Soil texture
6. Soil organic matter
7. Root density
8. Soil moisture
9. Groundwater table
10. Size of treated area

Compound-Related Factors

Initial amounts. Larger initial amounts of chemicals (e.g., > 2-3 lb/A active ingredient) generally take more time to break down than smaller amounts (e.g., < 2 lb/A a.i.). Precipitation or sprinkler irrigation may wash more material into the ground after the application of a heavy dose than after a light dose. The smaller the initial amounts, the smaller the potential for groundwater contamination.

Solubility in water. As a rule of thumb, highly water-soluble chemicals leach faster than the less-soluble ones. Chemicals with > 30 ppm solubility may be considered mobile in sandy soil when their persistence is high and adsorption low. Solubility of > 30 ppm alone does not imply that the chemical will contaminate groundwater.

Persistence. Chemicals persist in the ground for varying periods of time. Persistence is reported as half-life, i.e., the time it takes for about 50% of a given amount to break down.

In contrast to older pesticides (e.g., DDT, dieldrin, etc.), most modern chemicals are moderately persistent to non-persistent. Compounds with a half-life of > 3-4 months are considered persistent, while compounds with a half-life of < 1 month are considered non-persistent. High or moderate persistence alone does not imply that the chemical will contaminate groundwater.

Chemicals are usually more persistent in dry, compacted, cold soil than in moist, warm, well-aerated soil. Dry spells after an application may extend the persistence of a chemical in the ground.

Once residues have been leached beyond the root zone, their persistence is greatly prolonged.

Adsorption. Depending on their composition, most modern chemicals are moderately or strongly adsorbed on soil organic matter and clay. Most of the commonly used turf pesticides and herbicides are strongly adsorbed. Adsorbed chemicals do not move with the soil water but remain adsorbed while the water moves towards the groundwater table.

Adsorbed compounds are gradually released back into the soil solution where breakdown takes place. Adsorption is reported as Kd or, more accurately, as Ko c, whereby Ko c < 300-500 is considered low. In case of doubt, company representatives will provide information on the Ko c of compounds they sell.

Combinations of these four factors give rise to the elusive term "potential mobility." We all are painfully aware of the vagueness of the word "potential" and its political value. The term is used correctly only in connection with qualifying factors such as soil condition, precipitation, groundwater table, etc. It states that under certain conditions (e.g., sand soil, low soil organic matter [< 1%], high precipitation, high groundwater table), contamination is possible, but by no means certain. Without a qualifying statement, the term "potential" is misleading.

Notice that chemicals listed as mobile do not necessarily contaminate groundwater. Most of the modern compounds break down before they have a chance to reach the groundwater table.

The potential mobility of a chemical is on the high side when all of the following factors apply: solubility in water > 30 ppm, soil half-life > 3 months, and low adsorption (Ko c < 300-500); it decreases with every factor that does not apply.

Interactions between chemical and environmental factors affect a chemical's mobility, and these interactions determine its probability to reach groundwater.

Environmental Factors

Interception by leaves and thatch. Leaves and thatch of a dense turf area may intercept up to 90% of a pesticide application. Topdressing also intercepts chemical residues. Unless the chemical is watered in, the initial amount reaching the ground is small, which favors breakdown. Subsequent moderate to heavy rainfalls, or the use of sprinklers several days after an application, do wash residues off the leaves; however, the residues reach the ground in small amounts which break down faster than full dosages.

Photodegradation. Sunlight may break down a chemical deposited on leaf surfaces (e.g., triclopyr). This factor generally is of minor importance.

Precipitation. Precipitation up to several days after an application washes residues off the leaves and moves them into the ground. This can be significant for soluble chemicals (> 30 ppm) in sandy soil containing small amounts of organic matter. The farther apart the rainfall events and the less precipitation, the less the potential for leaching.

Topography (slope). The topography of an area may affect the distribution of a chemical through surface runoff, provided the conditions are favorable. Dry formulations as well as residues adsorbed on soil particles are affected. Residues may accumulate in low spots, thus increasing the residue load of an area. This can be significant where the groundwater table is high (1-2 ft.).

Soil texture. Soil texture affects the movement of water as the carrier of the chemical, and indirectly the adsorption of the chemical on soil particles. Sandy soils retain less water and chemicals than clay soils or organic soils. The heavier the soil, the lower the potential for leaching.

Channels resulting from earthworm activity may facilitate the vertical flow of water, which may favor leaching. However, the significance of the amounts of residues leached in this fashion under field conditions is questionable because the channels are filled with organic material that intercepts residues. To increase leaching significantly, the top 10-12 inches would have to be occupied by a large volume of channels, which might render an area unfit for recreational use.

Soil organic matter. Soil organic matter adsorbs larger amounts of pesticide residues than clay. Even 1-1.5% soil organic matter may retain considerable amounts of residues. In addition,

organic matter serves as nutrient substrate for microorganisms active in the breakdown of residues. The more organic matter there is, the more adsorption and breakdown occur, and the likelihood of leaching is greatly reduced.

Root density. The root zone is the most active part of the topsoil for the breakdown of chemical residues due to aeration and activity of microorganisms. Breakdown of residues beyond the root zone is insignificant. The healthier and the denser the root system, the more breakdown takes place and the lower is the potential for leaching.

Residues of herbicides may move inside treated plants into the roots, where they may be released into the soil after the plants have died. These residues do bypass thatch and most of the organic matter in the topsoil, but the amounts are too small to be significant.

Soil moisture. Soil moisture is essential for soil microorganisms active in the breakdown of pesticide residues. Obviously, residues are more persistent in dry than in moist soils.

Groundwater table. All other factors being equal, the closer the groundwater table to the soil surface, the greater the chance of contamination.

Size of treated area. Spot treatment contributes less to potential contamination than treatment of large areas.

Discussion

Water is necessary to leach chemicals; however, chemicals very rarely move at the same rate water does. Most chemicals move more slowly and break down before they are leached past the root zone. To estimate the potential for groundwater contamination, compare potential mobility with the environmental factors mentioned above and use common sense.

In general:

- The lower the potential mobility, the less leaching can be expected.
- All factors favoring microbial activity favor breakdown of chemical residues.

These two basic rules give reasonably good indications for the potential a chemical may have to contaminate groundwater in a particular area.

To help apply these two rules to actual field situations, numerical values were assigned to selected compound-related and environmental factors affecting leaching. The values applied to a particular situation can be totalled to help evalute the leaching potential. In case of doubt, select a value between two values. The closer the sum to eight, the less groundwater contamination is probable. The closer the sum approaches 17, groundwater contamination is more probable. **These figures are suggested as an aid in the first assessment of a situation; they are not to replace predictive models.** For several compound-related factors, consult Table 1.

Solubility	> 30 ppm	2
	< 30 ppm	1
Soil half-life	> 3 months	3
	1-2 months	2
	< 1 month	1
Adsorption	strong (Ko c > 300-500)	1
	weak (Ko c < 300-500)	2
Soil	sand	2
	clay	1
Topography	hilly	2
	level	1
Water Table	high (< 2-3 ft.)	2
	low (> 3-5 ft.)	1
Application	blanket coverage	2
	spot treatment	1
Groundwater Recharge	high (> 10 in./year)	2
	low (< 10 in./year)	1

Sum: 8 = groundwater contamination improbable

17 = groundwater contamination probable

If the sum approaches 15 or 16, a more accurate assessment of the situation is warranted.

Groundwater contamination with pesticide residues tends to occur more often where chemicals are used year after year in relatively large quantities, and where root systems are not coherent (primarily agricultural uses).

Misinterpretation of information about pesticides gives rise to preconceived ideas only time will correct. On the other hand, interpretation of information is difficult because there are many different shades of gray. Those who venture into that twilight zone take the risk of being made responsible for failures. The pesticide user, especially the one who depends on pesticides to remain competitive, is caught in the middle. Therefore, this article was written to help pesticide users decide whether the use of a particular compound might result in groundwater contamination or not. If groundwater contamination is probable, the use of a model is recommended for documentation. Unfortunately, neither estimates nor models protect from liability if contamination does occur: The label is the law.

If the data compiled in Table 1 and the estimates in the column "Potential Mobility" do not concur with similar data published elsewhere, ask your chemical company representative.

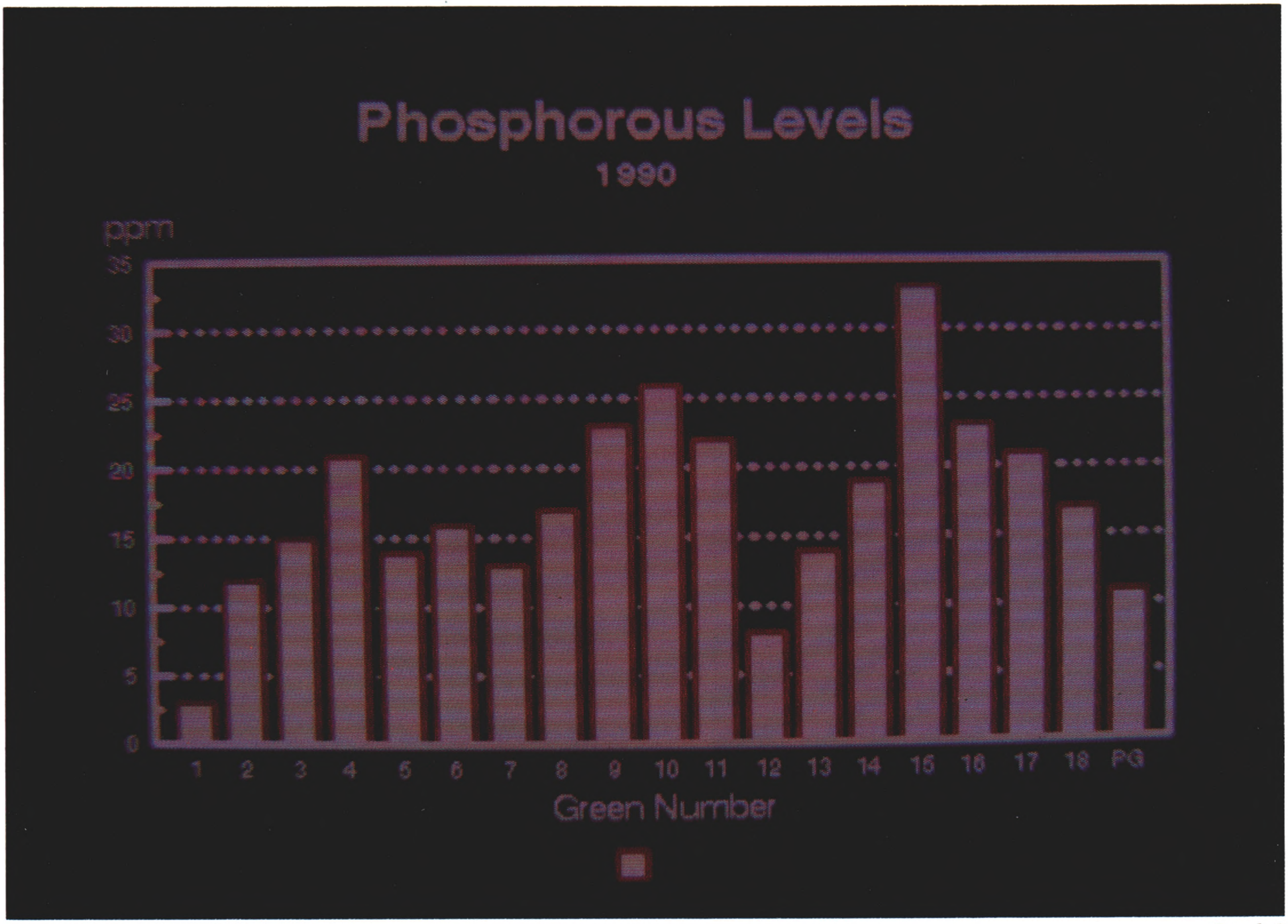
The author thanks Dr. Richard Cooper, University of Massachusetts, Department of Plant and Soil Sciences, and Mr. Ed Nash, Superintendent, Bass River Golf Course, South Yarmouth, Mass., for their helpful comments.

TABLE 1

Water solubility, soil persistence, adsorption on soil particles, and potential mobility in soil of compounds used in turf management.

Name	**Solubility in Water**	**Soil Half-Life**	**Adsorption Ko c**	**Potential Mobility**
INSECTICIDES				
Bendiocarb	40 ppm	days to weeks	570	slight
Turcam				
Carbaryl	30 ppm	7-9 days	570	slight
Sevin				
Chlorpyrifos	2 ppm	2-20 weeks	8,500	slight
Dursban				
Diazinon	40 ppm	2-12 weeks	570	slight
Isofenphos	24 ppm		760	slight
Oftanol				
Trichlorfon	15.4%		6	mobile
Dylox				
Proxol				
HERBICIDES				
Benefin	< 1 ppm	ca. 40 days	4,500	slight
Balan				
Bensulide	25 ppm	2-6 months	740	slight
Betamec				
Betasan				
Chlorthal-dimethyl	0.5 ppm	1-2 months	6,400	slight
Dacthal				
2,4-D acid	900 ppm	1-4 weeks	100	slight
2,4-D water sol. amine	3,000 g/L			mobile
2,4-D ester	barely			slight
Dicamba	4.5 ppm	2-6 weeks	43	mobile
Banvel				
Glyphosate	12 g/L	1 month		immob.
Roundup				
Mecoprop, salts	470-790 g/L	2-3 weeks	2	mobile
MCPP				
Oxadiazon	0.7 ppm	1-6 months	5,300	slight
Ronstar				
Pendimethalin	0.3 ppm	3-4 months	5,300	slight
Prowl				
Siduron	18 ppm		890	slight
Tupersan				
Triclopyr				
Garlon 4	430 ppm	4-6 weeks	160	moder.
Garlon 3A	2,000 g/L			moder.
FUNGICIDES				
Anilazine	8 ppm	12 days	3,000	slight
Dyrene				
Benomyl	2 ppm	3-12 months	2,100	slight
Belate				
Tersan 1991				
Chloroneb	8 ppm		1,300	slight
Chlorothalonil	0.6 ppm	1-2 months	500-3,000	slight
Bravo				
Daconil				
Cycloheximide	2.1%		18	mobile
Acti-dione				
Fenarimol	14 ppm		1,030	slight
Rubigan				
Iprodione	13 ppm	15-45 days	1,065	slight
Chipco 26019				
Rovral				
Maneb	barely		strong	slight
PCNB	0.4 ppm		7,225	slight
Avicol				
Terraclor				
Thiophanate	insol.		strong	slight
Cleary's 3336				
Topsin				
Thiram	30 ppm		670	slight
Triadimefon	260 ppm	1-2 months	205	slight

Mention of trade names does not imply approval of these products to the exclusion of other products with similar or the same effects.



Graph 1

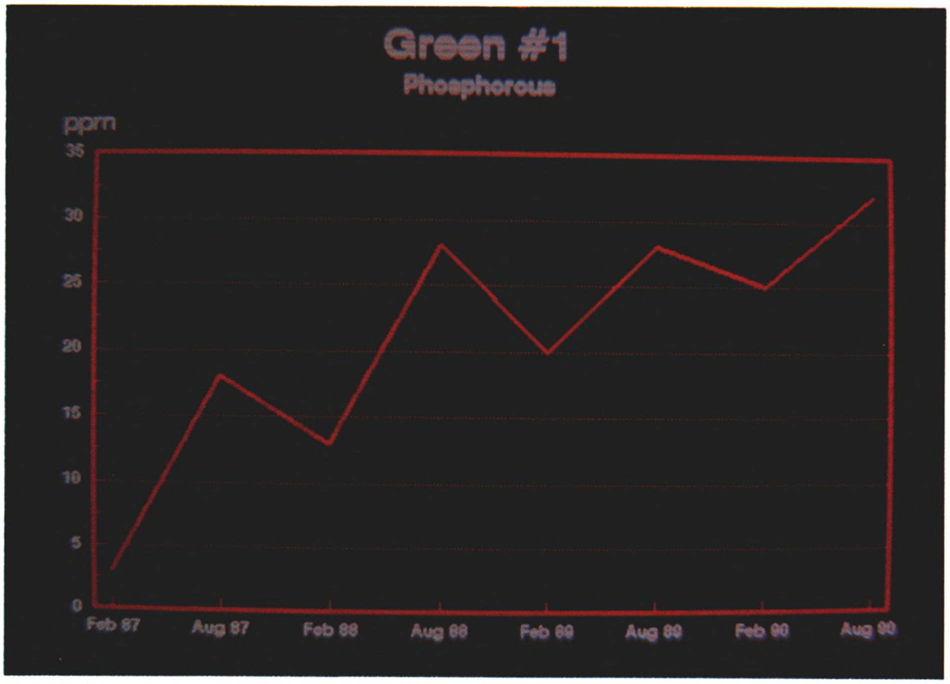
GRAPHIC GOLF COURSE MANAGEMENT

by JAMES F. MOORE
Director, Mid-Continent Region, USGA Green Section

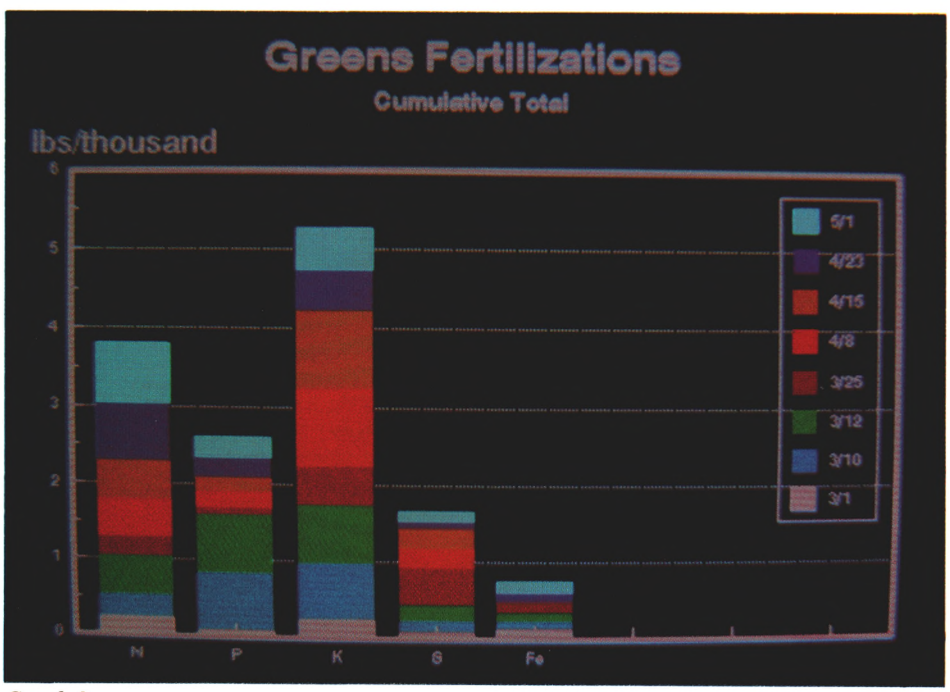
HOW OFTEN have you heard a superintendent say, "Growing grass is the easy part most of the time." Many of today's superintendents spend more of their time dealing with the business end of managing the course than they do the agronomic side of things. Or at least they do until something goes wrong on the course. It is often a simple matter of priorities. The superintendent juggles his time back and forth trying to stop the bleeding. This problem is not unique to the golf course superintendent. In fact, managers in many industries find themselves in exactly the same situation.

The crux of the dilemma is that a manager often receives information faster than he can process it or use it to his advantage. He receives input from many directions at once; his crew, the equipment, the turfgrass, the climate, the members, etc. It becomes nearly impossible to keep track of so many variables at once.

To better cope with information overload, managers in other industries have learned to use a simple technique — graphs. Graphs or charts allow you to keep tabs on many things at once and



Graph 2



Graph 3

quickly spot trends. Identifying such trends can help you avoid trouble before it happens, identify programs that are working, and better stay in touch with your operation. Let's examine how five simple graphs can help in a few specific areas of golf course management.

Soil Test Results *(Graphs 1 and 2)*

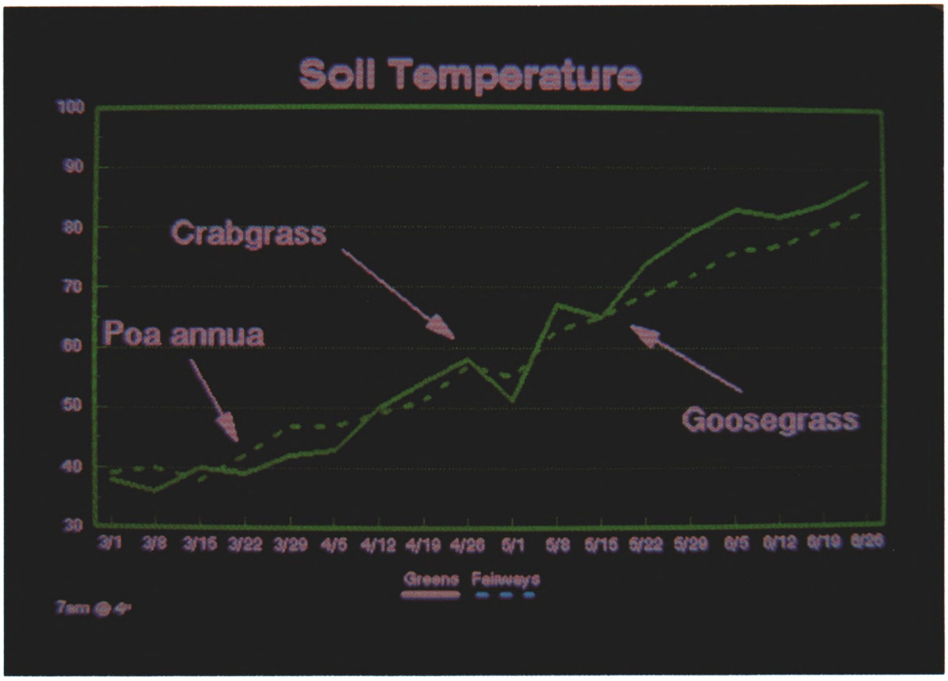
While most superintendents recognize the value of soil tests, they also know that the tests can be a source of frustration. Occasionally, a superintendent decides to "test" the laboratories by sending the same sample to two different labs. Often the tests come back with different results. Since laboratories often use different testing and extraction techniques, this is not a fair test. (If you really want to test a lab, submit six samples, two of which are actually composed of exactly the same material but labeled differently.) Also confusing are the labs' comments such as "high," "excessive," "deficient," etc. From a practical standpoint, you should be more concerned with the changes from test to test rather than the exact numbers on any one test. The changes represent trends in soil fertility that are brought about by your programs. These trends are best identified by graphs.

Two types of graphs should be kept for soil tests. The first, a bar graph, identifies specific greens (or other areas) that stand out from the others when it comes to a nutrient surplus or deficiency. It's a good idea to keep one such graph for each specific aspect of soil fertility with which you are concerned. For example, graphs should be kept for phosphorus, potassium, and soil reaction (pH). Additional graphs are justified if your greens have a history of problems with magnesium, sodium, iron, or any other nutrient.

The second type utilizes a line graph and is helpful to track nutrition trends in a specific green over time. One good program is to test greens in the spring, prior to developing your fertility program for the year. Testing again mid-season gives you an idea of how well your program is working. A line graph kept over several years quickly summarizes your efforts. Obviously, it is critical to use the same laboratory throughout all of the testing.

Fertilization History *(Graph 3)*

Another type of graph can prove extremely valuable in tracking how much you have fed your greens. This type of graph is called a cumulative bar graph. Each time the greens are fertilized, the bar for each nutrient is extended. This graph provides a quick reference concerning the amount of fertilizer applied so far this year, the increments in which it was applied, and the date of each application. It is well worth your time to keep such a graph for greens, tees, fairways, and other specific areas of the course.



Graph 4

Soil Temperature *(Graph 4)*

Soil temperature is another piece of information that many superintendents find quite valuable. A graph of the rise and fall of soil temperature is particularly useful when notations are included concerning the occurrence and activity of various pests. As data accumulates over several seasons, you will find yourself better able to predict events such as the germination of *Poa annua* or goosegrass, and when an application of an insecticide for grubs would be most effective. Soil temperature can also lend insight as to ideal planting dates of your course. One superintendent recorded both soil temperature and Stimpmeter readings from the same green throughout the year. He found that on his course the growth rate of the turf affected green speed more than cutting height. Since growth rate closely followed soil temperature, he was able to anticipate changes in green speed and adjust other cultural programs accordingly.

Like soil testing, the key is to be consistent in how the temperatures are taken. A good method is to read the temperature at a depth of 4 inches at approximately the same time each morning. You might also check greens and fairways since the soil types are usually radically different. Graphically tracking soil temperature can be done best using a line graph.

Inventory *(Graph 5)*

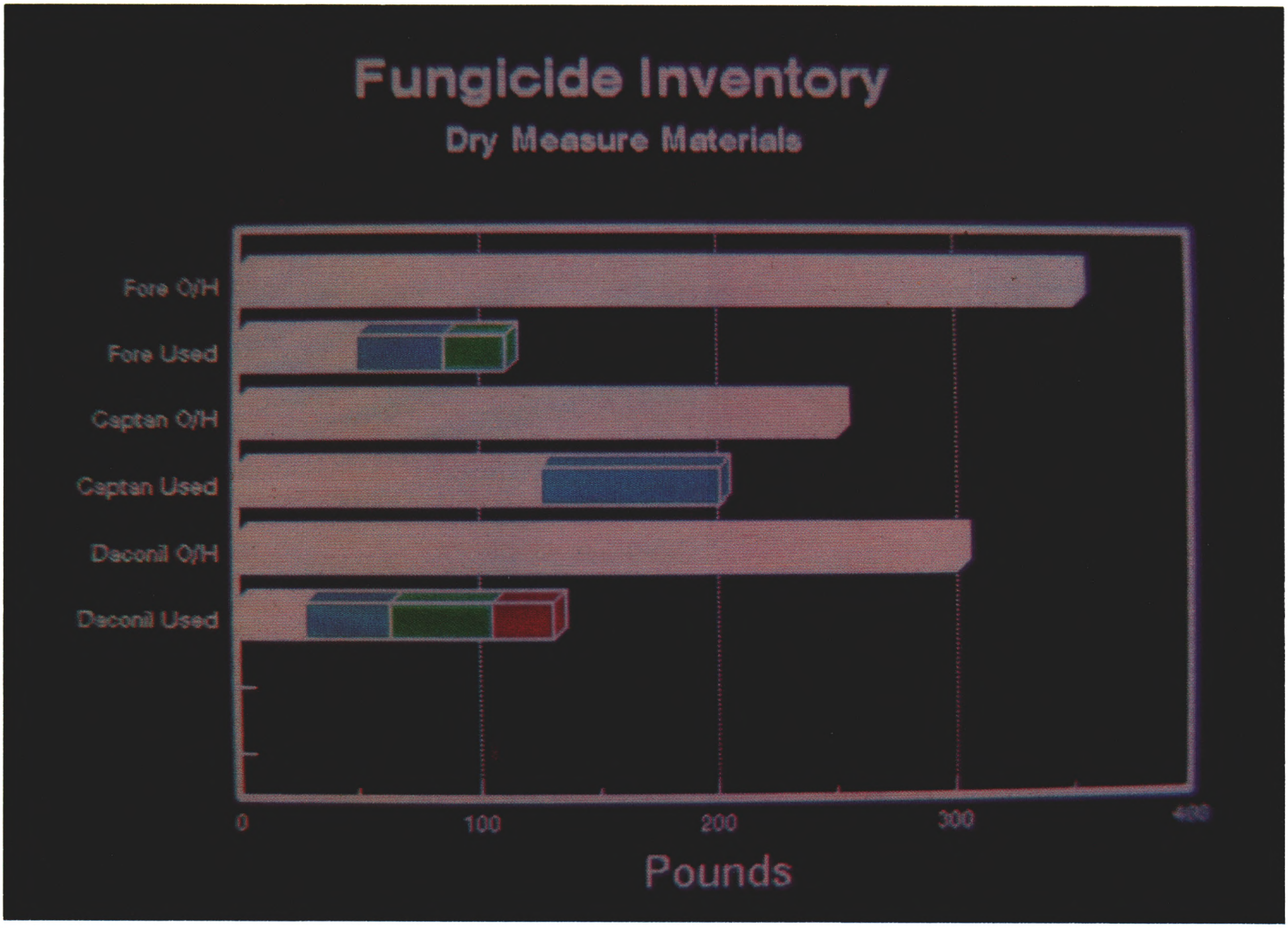
A common complaint among superintendents is that it is difficult to track their inventory. A cumulative bar graph can provide an easy, quick means of checking what is on hand and if there is enough for a typical application. Each time a purchase of a product is made, the respective bar is extended by that amount. Likewise, whenever some of the product is used, the bar depicting use is extended. Notice that the "used" bar also displays the increments of use. By comparing these increments against the length of the "on-hand" bar, the superintendent can quickly estimate how many more uses he can expect before making another purchase. (For example, a quick look at the Captan bars shows there is not enough on hand for another application.) Since both dry and liquid measure materials are probably used, keep separate graphs for each. You also might use separate graphs for fertilizers and various types of pesticides. This particular graph is a budget tool, too, since at the season's end you know exactly how much of each material you have purchased and used.

Obviously, there are many other types of graphs that would prove useful. You might decide to graphically follow climatological information such as rainfall, humidity, and daily temperature extremes. This information can be compared to previous years or what is considered "average" for your area. Managers of all types often use graphs to better monitor expenses. Graphs for your major budget accounts comparing the amount budgeted against the amount spent can help you adjust spending habits.

In spite of the usefulness of graphs, it is important to keep in mind your original intent. Remember, the idea was to help you keep track of information in a manner that is easy and makes the information readily available. Do not begin keeping so many graphs that you find yourself spending more time updating them than using the information they depict. Also, do not attempt to keep too much information on any one graph. Three simple graphs are far more useful than one complex graph.

While the graphs depicted in this article were made using a computer, it absolutely is not necessary to have a PC to keep good graphs. Graphs should be posted on a wall in your office and updated routinely. In this manner they will jog your memory and help you keep in touch with many aspects of your operation with relatively little effort. Most superintendents already keep much of the information discussed in this article. Graphs simply get this information out of the file cabinet and present it in a manner that is easily understandable and therefore far more useful.

Graph 5



A USGA-SPONSORED RESEARCH PROJECT

Heat Shock Protein Synthesis in Turfgrass

by JOHN DiMASCIO and KARL DANNEBERGER
Department of Agronomy, The Ohio State University

HIGH TEMPERATURE stress is a physiological disruption of turfgrass growth. Whether it is acute (direct temperature kill), which rarely occurs in the northern United States, or chronic (long-term exposure to higher than optimum temperatures), the metabolic disruption results in a weakening of the plant. Turfgrasses have various mechanisms of protecting themselves during high temperature stress. Our research involves studying the role of heat shock proteins in thermal tolerance and how the identification of these proteins may aid turfgrass breeding programs.

Eukaryotic organisms, including plants, respond to superoptimal temperatures by synthesis of a unique group of proteins called heat shock proteins. Several studies involving mammals, insects, bacteria, and yeast have shown a positive correlation between heat shock protein synthesis and the development of thermal protection. Patterns of protein synthesis change when environmental temperatures are increased from about 82° to 104° F. During a temperature stress period, the synthesis of normal cellular proteins may be reduced or even stopped completely while an increase in the number of heat shock proteins occurs. Organisms responding to high temperature synthesize an assortment of these heat shock proteins, which can roughly be divided into two classifications. These are the high molecular weight (ranging in size from 60 to 110 kiloDaltons*) and the low molecular weight (ranging in size from 15 to 30 kiloDaltons). Although the exact function of these proteins is not fully understood, their presence has been associated with acquired thermal tolerance. Some research suggests that these heat shock proteins may act as transient matrices to stabilize various cell organelles and compartments during elevated temperatures, and then disassociating when temperatures return to normal.

By definition, heat shock proteins are a new set of proteins that are rapidly and abundantly produced in response to elevated temperatures. These temperature levels are variable, depending upon the organism, but are best described as a temperature shift that is 14° to 20° F above optimal growing temperatures.

To understand the role heat shock proteins (and proteins in general) can play in heat tolerance and breeding, a brief description of proteins is needed. Proteins are linear sequences of amino acids that as a group are very diverse. Proteins make up cell structure and control cell function as 1) enzymes that act as reaction catalysts, 2) structural products such as cell walls and membranes, 3) hormones, and 4) storage and transport molecules.

Linear protein sequences orient themselves into coils, sheets, folds, or globular shapes. It is these shapes that give proteins their biological roles. High temperatures can cause protein denaturation, which is the process whereby proteins lose their structure and consequently their biological activities.

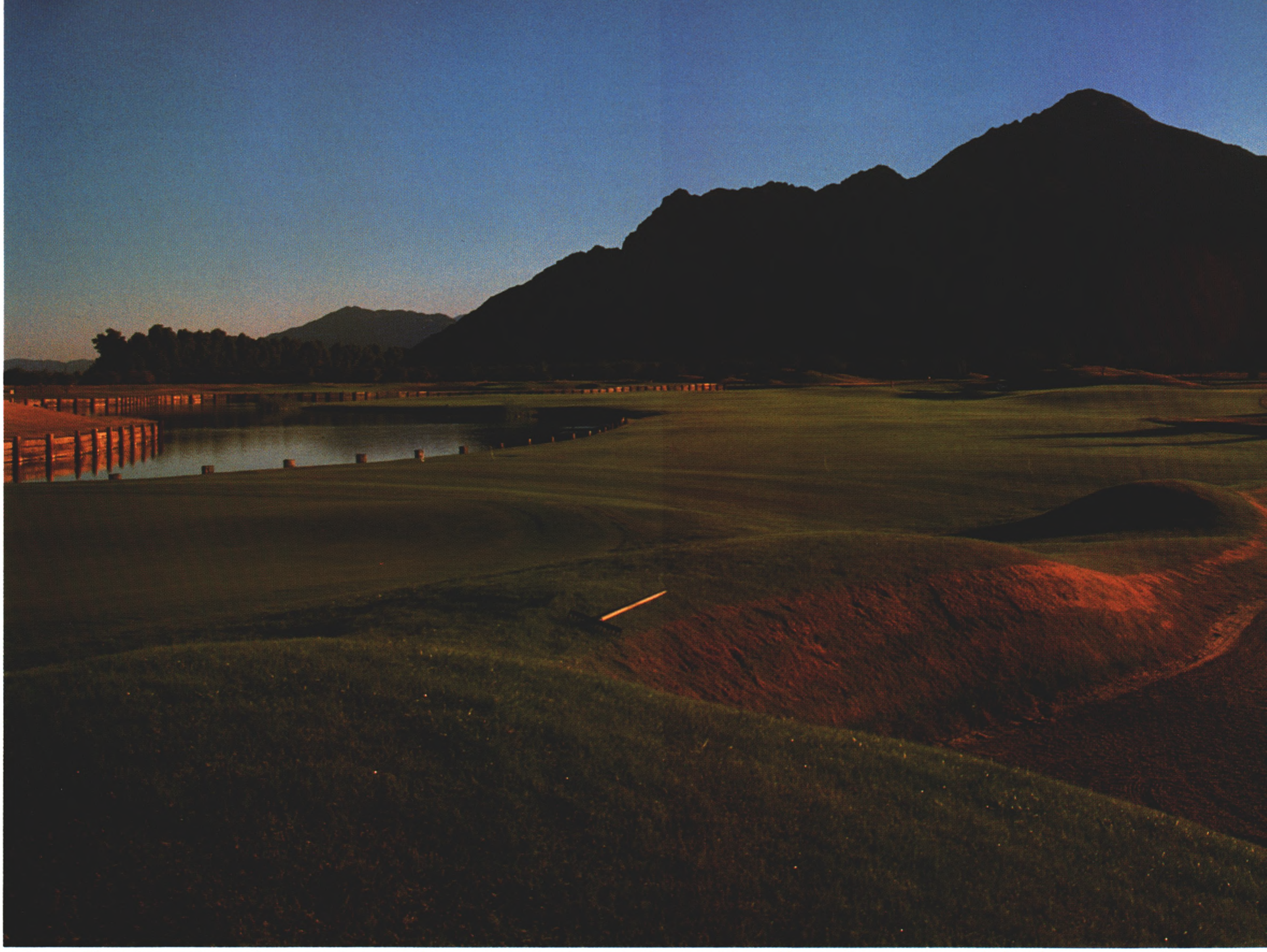
The synthesis of proteins, including heat shock proteins, begins with deoxyribonucleic acid or DNA. DNA contains the genetic instructions for protein synthesis. DNA is composed of four nucleotides (five carbon sugar containing a nitrogenous base and a phosphoryl group) called cytosine, thymine, adenine, and guanine. The matching of nucleotides (cytosine to guanine and thymine to adenine) is called base pairing. Two strands of nucleotides face each other, forming base pairs and creating a double helix.

If we look at DNA as the book of life, then the nucleotides form the coded words and sentences. Within these "sentences" (genes) are the information of protein synthesis and structure. Genes are the smallest portion of DNA that contain the hereditary information for proteins. Looking for the "sentences" of specific proteins is no trivial matter. Plant genomes or "books of life" can consist of from 10^7 to 10^{10} nucleotide base pairs.

The induction of heat shock proteins has been shown to be a universal response to thermal stress in a wide range of organisms. One of these heat shock proteins, hsp 70, is synthesized in all systems examined to date. This gene is highly conserved among these organisms, meaning that little change has occurred through evolutionary time. We have found that this gene is contained within the Kentucky bluegrass genome (Figure 1). Just because this or other heat shock genes are contained within a genome, however, does not mean the protein it codes for will be produced.

Our research focuses on the role of heat shock proteins in heritable thermal tolerance and the potential use of these genes as a molecular selection criterion for improved breeding of turfgrass cultivars for heat tolerance. In breeding, current practices involve analysis of phenotypic responses as a guide to genetic characterization of a cultivar.

*NOTE: A kiloDalton is a molecular weight measurement. A Dalton is the unit of mass equivalent to the mass of a hydrogen atom (1.66×10^{-24} gram). Kilo- is the metric prefix meaning 10^3.



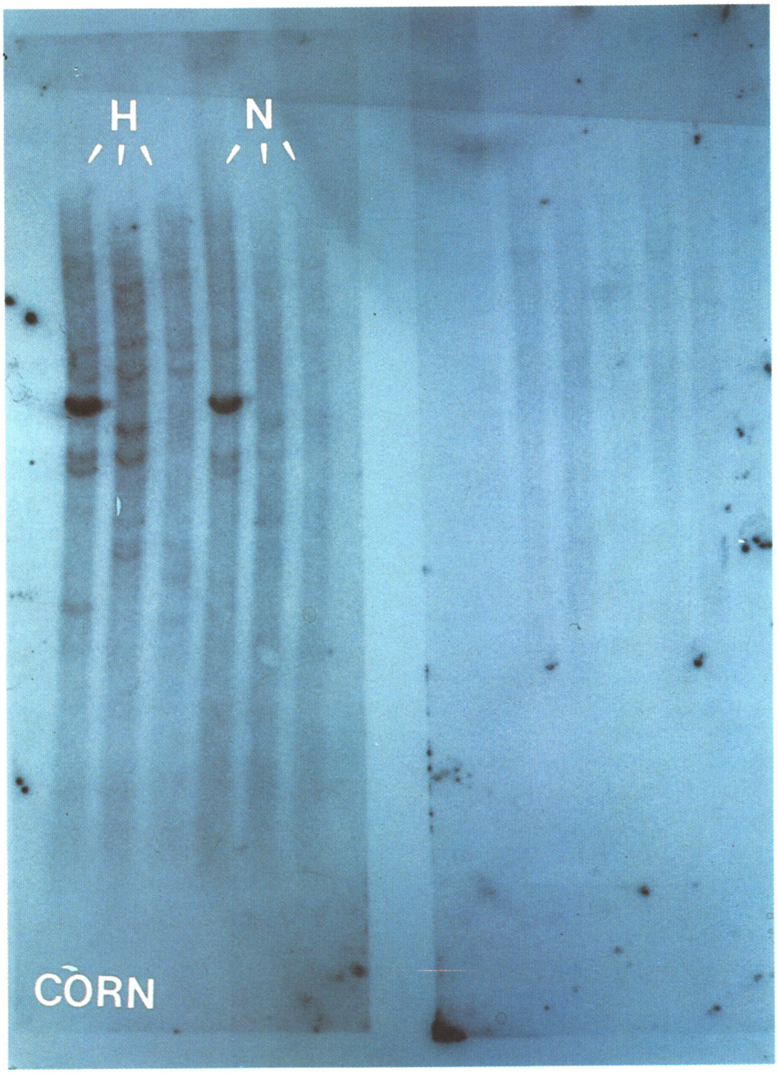
(Above) The inherent heat tolerance of perennial ryegrass is one factor in the transition of bermudagrass overseeded with ryegrass in the spring. (Opposite page, top right) Autoradiograph showing regions of homology in Kentucky bluegrass with the hsp 70 gene probe from maize (corn). The H = "Huntsville" and the N = "Nugget" Kentucky bluegrass cultivars. The homologous regions are the dark banding patterns located at various points of the 6 lanes. (Opposite page, bottom) View of restricted or "cut" genomic DNAs prior to blotting.

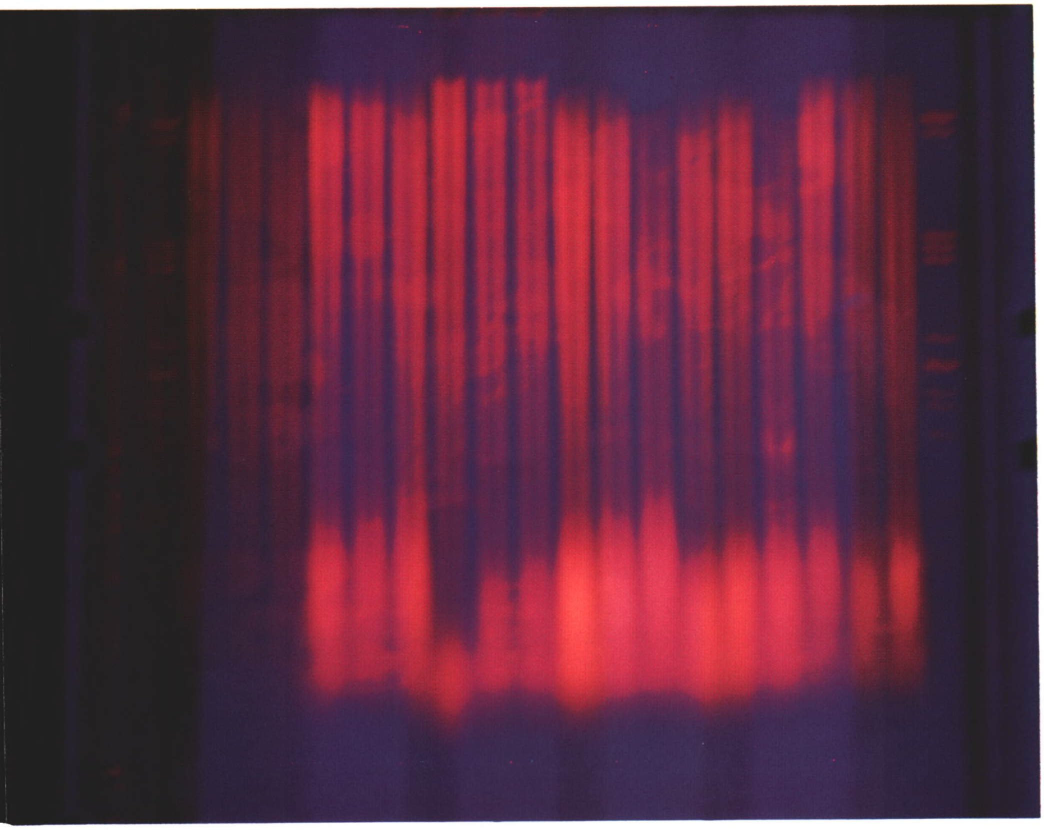
This involves much time, money, and effort to allow possible cultivars to grow and mature to express their phenotypes. These phenotypes are not an accurate picture of the plants' genetic potential, for they are expressions of genes according to environmental conditions. In many situations, outside influences mask the genotype, thus the phenotype may be providing an imperfect measure of a plant's genetic potential. Research efforts must be applied to find standards that are not variable and that can be taken from the plant at all stages. Current laboratory techniques that can expand upon field testing procedures can be used. The technology most frequently used to detect genetic polymorphisms, or differences in a genome, between cultivars is called restriction fragment length polymorphisms (RFLP).

Working with RFLPs involves the application of molecular biological techniques to the basic concepts of transmission genetics. This technique relies on the use of restriction enzymes that recognize specific DNA sequences and "cut" the double helix (Figure 2).

Theoretically, if the DNA of samples does not contain the same genes or dissimilar ones, they are "cut" at different regions within the genome. The genetic differences detected are revealed after blotting (transfer of DNA fragments to a solid support) and hybridizations with sequence-specific probes. These probes or markers are single-copy DNA segments cloned from an identified gene coding region. Probes recognize homologous regions of the genome of the samples being analyzed. Linkages (homology) between the probes and the genomes of interest permit one to infer the presence of a gene with similarities to that of the probes.

In the area of plant genetics, RFLP work could serve a function as genetic markers. Although the applied use of RFLPs in plant breeding has been examined theoretically, investigations have been more limited. RFLP applications can be incorporated into existing plant breeding procedures, enabling researchers to access desirable traits more rapidly and with greater accuracy. The use of molecular probes should allow the plant breeder to make earlier decisions about his/her selection of (in our case potential heat tolerance) cultivars while examining fewer samples. The integration of RFLP markers into plant breeding programs can lead to other applications than just the probing with markers. For instance,





this technology can also be used to make the analysis of polygenic characters into single Mendelian factors, permit the transfer of novel genes from related wild species, and even organize relationships of reproductively dissimilar plants.

The potential of molecular biology is only beginning to be realized. As techniques are developed and perfected, the ability to produce turfgrass cultivars that are stress tolerant and pest resistant will be greatly enhanced. Stay tuned.

Acknowledgements: This research has received funding support from the United States Golf Association and The Ohio Turfgrass Foundation.

NEWS NOTES FOR MIDSUMMER

USGA Announces $3 Million Environmental Impact Study

USGA President Grant Spaeth has announced the funding of a three-year, $3 million research program that will focus on the impact of golf course activities on the environment. The effects of pesticide and fertilizer use on surface and subsurface water supplies and on people, wildlife, and other non-target organisms will be investigated as part of the study. This expenditure is in addition to the $2.4 million that will be spent over the same time frame as part of the USGA's continuing effort, in cooperation with GCSAA, to develop grasses for golf that are more pest resistant and stress tolerant than currently used cultivars and species.

The USGA's Turfgrass and Environmental Research Committee will oversee the program, which will run from 1991 through 1993. The committee is composed of technical specialists from American universities and industry, along with representatives from the USGA, the Golf Course Superintendents Association of America, the American Society of Golf Course Architects, and the Sports Turf Research Institute in England. Representatives from a governmental regulatory agency and an environmental organization are also being sought.

The Research Committee has requested research proposals from land-grant universities that address the following issues:

1) The fate of pesticides applied to golf courses.

2) The fate of fertilizers, particularly nitrogen and phosphorus, applied to golf courses.

3) Development of alternative (non-pesticide) methods of pest control.

4) The benefits of turfgrass and golf courses to humans, wildlife, and the environment.

At the Research Committee's recent meeting in July, 83 pre-proposals were reviewed. Detailed proposals from the finalists will be requested, and a final decision concerning projects to be funded will be made at the Committee's meeting in December. The pesticide and fertilizer studies will be done at several sites across the country, representing various soil, turf, and climatic conditions.

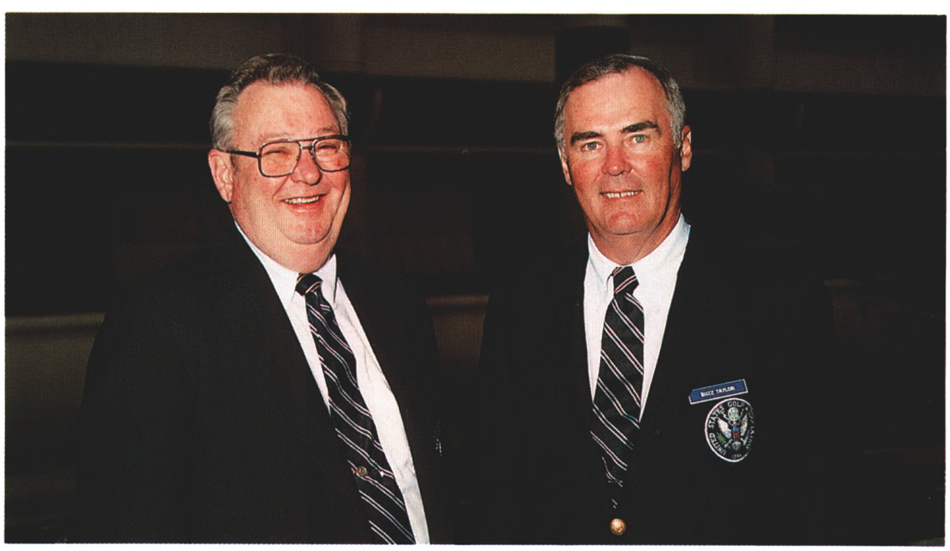
It is anticipated that the studies will broadly expand our understanding of the impact of pesticide and fertilizer use and other golf course activities on the environment, providing scientific documentation of these effects and offering responsible alternatives wherever necessary and possible. USGA staff responsible for administering the program include Jim Snow, National Director of the Green Section and Chairman of the Research Committee, Dr. Mike Kenna, Director of Green Section Research, and Dean Knuth, Director of Green Section Administration.

Raymond B. Anderson Named Green Section Committee Chairman

At its recent Executive Committee meetings held in conjunction with the U.S. Open Championship at the Medinah Country Club in Medinah, Illinois, the USGA announced the appointment of Raymond B. Anderson as chairman of the Green Section Committee. He replaces F. Morgan Taylor, who steps down to become chairman of the USGA's Equipment Standards Committee.

Anderson is no stranger to the activities of the Green Section and the turfgrass industry. As president of the Chicago District Golf Association, he was instrumental in establishing a turfgrass extension position with the CDGA that was filled by Dr. Randy Kane, a turfgrass pathologist.

In his new role as Green Section Committee Chairman, Anderson will be responsible to the USGA Executive Committee for overseeing the activities of the Green Section, including its Turf Advisory Service and research functions. He will serve as a member of the USGA's Turfgrass and Environmental Research Committee, which, in addition to its ongoing work in developing stress-tolerant and pest-resistant grasses, is currently developing a $3 million study concerning the impact of golf course activities on the environment. He will also lead a team of 113 volunteers who serve on the Green Section Committee to promote the Turf Advisory Service and other Green Section activities.



Raymond B. Anderson (left), incoming chairman of the Green Section Committee. F. Morgan "Buzz" Taylor (right), immediate past chairman.

George Manuel Appointed to Green Section Staff

The Green Section is pleased to name George B. Manuel as agronomist in its Mid-Continent Region. The appointment fills a new position on the Green Section staff, and comes in response to the increased use of the Turf Advisory Service by USGA member clubs in the region. Manuel will report to James Moore, director of the Mid-Continent Region.

George brings a broad background in the turfgrass industry to his new position with the Green Section. He has most recently been construction supervisor of the 4th Nine at the Sweetwater Country Club, in Sugar Land, Texas, where he previously served as golf course superintendent. He also spent several years in turf chemical and fertilizer sales, including a stint as a technical representative for Scotts.

George Manuel

George is a graduate of Texas A&M University, where he also gained some experience working on the research turf plots and on the university golf course. He has recently served as president of the Texas Turfgrass Association and as vice-president of the Lone Star GCSA.

In his new responsibilities with the Green Section, George will be relocating to Waco, Texas, with his wife Ginger and children Ashley, Joshua, and Kendall. He will be joining Jim Moore in making TAS visits to USGA member clubs in the Mid-Continent Region, including the states of Texas, Oklahoma, Arkansas, Missouri, Kansas, Nebraska, Colorado, Louisiana, Wyoming, and New Mexico. The Green Section joins in welcoming George Manuel as a member of its staff.

ALL THINGS CONSIDERED

Glitz and Glamour Golf

by AL RADKO
Former National Director, USGA Green Section

THE MORE I SEE of new golf course design and the new direction in golf course maintenance, the more I become disturbed about the future of golf in this country.

I'm not happy about the "Hollywood Glitz & Glamour" approach to new course construction now that the Tour Pros have become self-acclaimed Golf Course Architects (hereinafter referred to as Pro-archs). Most of their productions are maintenance nightmares — seemingly produced with but one aim — to replace Pine Valley as the #1 rated golf course in America. Maintenance costs for many of these Pro-arch courses have to be at least twice the cost of long-established 18-hole clubs . . . whose budgets no longer are considered small.

And this "Hollywood Glitz & Glamour" approach has now become ingrained into the maintenance of fairways — maintaining fairways more like putting greens through lightweight mowing and clipping removal . . . which again impacts significantly on the budget and labor force of all courses so involved. Lightweight mowing has its place in periodic cross-cutting *and* for some courses with special problems of terrain, bumpy fairways, etc., but continually on all courses? RIDICULOUS!

As an avowed traditionalist, I ask, "Is all this hoopla necessary? More important, is it good for golf? Does every fairway lie have to be picture perfect? Does all this mean that luck, chance, and "rub-of-the-green" situations no longer belong in the game? Isn't skill in golf the ability to play well from a variety of lies? Isn't this what adds to the challenge of the game? Does it matter to the majority of golfers (the so-called average golfers) whether their lies are 95% perfect or just 90% perfect? And where is all this leading?"

I for one believe all this glitz and glamour detracts significantly from the purpose, the spirit, and the challenge of the game . . . as well as the aesthetics of golf courses. All courses are beginning to play and look alike — robotic and stereotyped! As a result, golf is unnecessarily becoming so expensive that it will once again be known as a game for only the very rich. And with apologies to Churchill for taking liberty, "For the average golfer, golf is fast becoming an expensive walk with Nature spoiled!"

USGA GREEN SECTION RECORD
JULY/AUGUST 1990

TURF TWISTERS

GO "LOW-TECH"

Question: I have a new, well-designed irrigation system but still have dry areas on knolls in some greens and fairways. Any ideas? (Michigan)

Answer: Go Low-Tech and occasionally hand water the dry areas. When used in conjunction with spot aeration and wetting agent applications, this simple technique should help you overcome the dryness problems on these difficult-to-wet knolls.

TO REJUVENATE YOUR GREENS

Question: A local club fumigated their *Poa annua* greens a year ago and replanted them to creeping bentgrass. Now my membership wants me to do the same thing. Should we? (Ohio)

Answer: Quite a few clubs across the country have followed the regrassing procedure you mentioned, and it has proven to be a very effective alternative to rebuilding if certain criteria are met. It is only appropriate if the grass growing environment is reasonably good. Good internal drainage, air circulation, and sunlight penetration are musts. Without these three items, the likelihood of failure, even with the right grass, will be high. Regrassing is much cheaper than complete reconstruction, possibly as little as one tenth the cost. Thus, if the greens are structurally sound and you just want to replace the turf, regrassing may be worth considering.

AND CONTROL TRAFFIC

Question: We maintain a public golf course that receives more than 100,000 rounds of golf annually. There are quite a few thin, bare spots on the course, but some of our golfers want "country club" conditions like those seen on television each week. What is the single best way for us to provide better turf for our golfers? (California)

Answer: First of all, remind the golfers that the courses playing host to the weekly televised events often spend months or longer preparing for these tournaments. To answer your question, though, the single best way to improve the turf on your course would be to institute a good traffic control program. For many courses, this involves stakes, ropes, signs, painted lines, curbing, and a good marshalling program.