FORM, FUNCTION, FIT: which nitrogen source is right for you?

IT'S TIME TO PICK A NITROGEN FERTILIZER SOURCE for your sports field. How do you make that decision? Advertisements frequently tout nitrogen (N) fertilizer as the "slowest release," "the quickest green-up," or "the most available." Add technical terms such as methylene urea, ureaformaldehyde and controlled-release polymer, and the topic of nitrogen fertilizers starts to get complicated indeed. But, it's really not. The basic chemistries and manufacturing processes behind most of our commonly available N sources fall into five to six major groups, and you can sort out the ones you should use (and when to use them) from there.

Let's discuss the groups:

Soluble sources of N that are manufactured from inorganic (no carbon in the source) N sources.

Sources of water-soluble N include potassium nitrate (13-0-44, this and all other analyses are always expressed as percent N-P_2O_5-K_2O), ammonium sulfate (21-0-0), and, if you can still find it, ammonium nitrate (34-0-0). [Note: Since people are used to buying the analysis '34-0-0', some fertilizer dealers now sell a product with a '34-0-0' analysis that is actually created from urea, or it may be a blend of ammonium sulfate and urea. This is not an issue, it is simply a way to provide an analysis (34-0-0) that people are familiar with without having to deal with the legal complexities now associated with the sale of ammonium nitrate.] Any time you need a rapid turfgrass response, be it greening or growth, a soluble material should be in your spreader or spray tank. Soluble fertilizers provide quick turf green-up, which may be important when you need turf to grow and fill bare spots. Always apply water-soluble sources at lower rates (0.5 to 1 pound of N per 1,000 square feet per month of active growth) and water them in. This helps avoid the turf burn that can occur with heavier rates of soluble products. Care must be taken to not over-apply, especially if you are managing turf on sandy soils, and to not over-irrigate once the materials are out. Also, check your local and/or state regulations to make sure that you are applying your soluble N during months in which it is permitted.

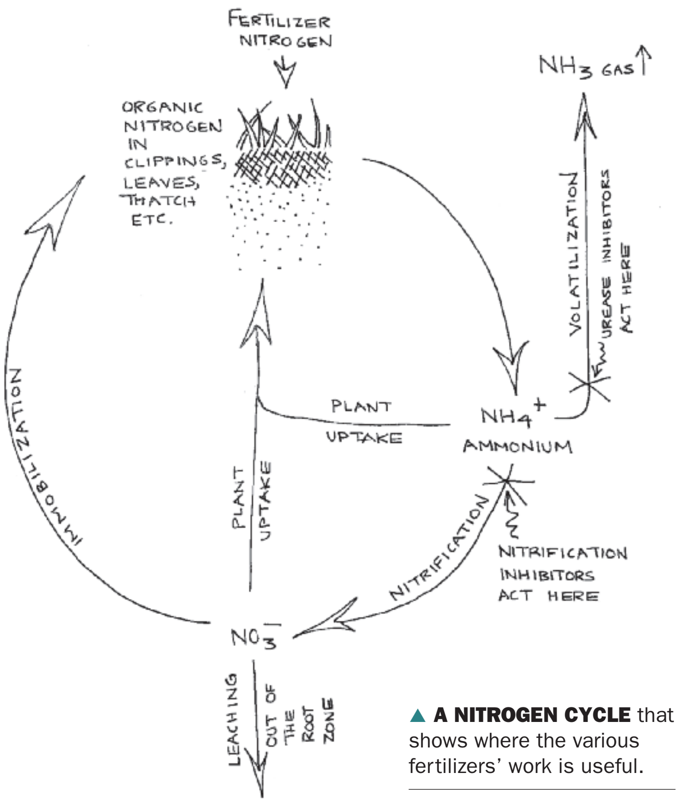
Soluble sources of N that are manufactured from a synthetic organic N source. We have one such source: urea.

Urea gets a separate mention because it is, by the broadest definition, organic (there is carbon in its formula – NH_2-CO-NH_2). But in reality urea can be lumped in with the inorganic soluble N sources, because it behaves like those sources—rapid turfgrass response, immediately available to the plant; watch overapplication as it can cause turfgrass burn and possible negative environmental effects. Urea is often the choice for use in foliar N programs, and it works well for that, with ample research showing that foliarly applied N is readily taken up by the turf, much of it within 12 hours of application. Urea is often the background fertilizer used for many slow-release N sources (discussed below).

Slow-release N sources that are slow-release because there is a physical barrier around a prill of soluble N fertilizer. Often, these are called "coated" fertilizers.

The oldest coated N fertilizer is sulfur-coated urea, or SCU (~32-0-0). Introduced decades ago, it still is a common product, and there are also newer generation materials that are both sulfur and polymer-coated. Sulfur-coated urea is made by spraying molten sulfur onto urea granules. Release of N from the sulfur-coated urea granule depends on the time it takes water and microorganisms to break down the sulfur coating. The thicker the coating, the slower the release rate. Release will be faster in warm, wet soil conditions that favor microbial activity. One problem with some forms of SCU is that the coating process creates larger granules, which are easily crushed or picked up by mowers. Newer micro-prill technologies have helped solve this problem, and SCU products remain a viable slow-release N source for turf.

Polymer-coated-urea (PCU) products have fast become a major part of the slow-release N market. These products work by allowing urea to gradually diffuse through the polymer membrane at a rate that, depending on the exact technology, may vary according to temperature, moisture or coating thickness. These products provide a precise N-release rate, and some can even deliver N for an entire growing season. The release rates are widely variable, and products can have release times ranging from 45 to 270 days. Materials with longer release patterns (180 days or more) can be excellent for producing a long-term greening response without the fluctuations in turf growth that may occur with more frequent applications of soluble N. The science of polymer coating has gotten quite specialized,



▲ **A NITROGEN CYCLE** that shows where the various fertilizers' work is useful.

and while urea used to be the product that was almost always coated, other fertilizer sources may now be coated (such as potassium sulfate).

Slow-release N sources that are slow-release because urea has been converted via chemical processes into a slow-release N source.

Slow-release fertilizers created by chemical reactions all start as urea. The most common product currently on the market in the turfgrass industry is ureaformaldehyde (UF), formed by reacting urea and formaldehyde to produce chain molecules of varying lengths. The length of the chains controls N release, with shorter chains having quicker N release for turfgrass use. Ureaformaldehyde reaction products are also often called Methylene ureas (MU) (as if it was a synonym with UF) but it is really not. Specifically, methylene-ureas tend to be the group of ureaformaldehyde reaction products that are intermediate in chain length, and have an N content of 39 to 41%. In comparison, a ureaformaldehyde that has long been on the market, Ureaform, has the longest chains, and is thus very slow in the release of N for plant use.

Regardless of the chain length, N release occurs as microorganisms break the chains, releasing N which is available for plant use. The release patterns of ureaformaldehyde products are controlled by the length of the chains; the shorter the chain, the quicker the release. Additionally, some short-chain UFs are frequently marketed as liquid slow-release materials, such as triazone. Ureaformaldehyde fertilizers are quite popular in the turfgrass market, and there is a wide variety of products available for your use. Before choosing a specific fertilizer you should consult the fertilizer label to determine the relative N percentages that are rapidly or slowly available for plant use.

The other slow-release N fertilizer that is chemically slow release is isobutylidene diurea (IBDU). A combination of urea and isobutyraldehyde, IBDU does not depend on soil microorganisms for release but is broken down by water (hydrolysis) into urea. The rate of urea release from IBDU varies with particle size, temperature and moisture. The smaller the particle, the faster the release. The higher the temperature, the faster the release. Recent discussions with turfgrass managers reveal that few use IBDU, often because it is difficult to obtain. If available, it is an excellent material for cool-season use for long-term N supply because it does not require microbial activity for N release.

Slow-release N sources that are slow-release because they are a 'true' natural organic material in which the N must be released via the biological process of mineralization.

These natural organic slow-release N sources are generally manufactured from some type of waste material. Sometimes the material is composted to help reduce odors, or the material may be dried and granulated to improve handling and spreading characteristics. Common organic fertilizer waste materials include sewage sludge, poultry litter, meat-processing waste and other animal by-products such as fish or feather meal. Much of the N in such fertilizers is organic N in the form of relatively complex chemical compounds, and is not available for plant uptake until microbes have converted it into nitrate and ammonium.

Soil temperature greatly influences microbial activity and the rate at which N is mineralized from these organic fertilizers. In cold soils, little activity will occur; an organic N fertilizer applied during winter in the northern US will just sit there with little N available for plant use until the soil warms. By contrast, fresh poultry litter applied to turf during hot weather is relatively quickly available, as most of the organic N is rapidly converted to nitrate and ammonium.

Some relatively new N fertilizers on the market are blends of organic wastes, such as fish meal, feather meal or poultry litter, and a water-soluble inorganic N such as ammonium sulfate. Such a product would produce a rapid greening response from the inorganic N and an extended response from the organic N. These "hybrid" materials can still burn turf if you apply them at high rates, and the labels usually have a warning to that effect. Read the guaranteed

▲ **RESEARCH TRIALS** are often conducted to evaluate N release of various fertilizers over time. In this study, different N sources are applied to hybrid bermudagrass, and each week color, quality and clipping yield data is collected from each plot.

analysis on the back of the bag to determine the source of the N, and how much of it is soluble and/or slow-release.

Urea to which nitrification inhibitors and/or ammonia volatilization inhibitors have been added.

The majority of nitrogen must be taken up by the plant as nitrate-N or ammonium-N. Soluble N sources already have the N in that form, and slow-release sources either have that N "trickle" out via a physical barrier that degrades over time, or by being released from a chemical formula via hydrolysis or microbial breakdown. Sometimes, however, the plant available forms (nitrate or ammonium) can be converted into other N forms that are less desirable for the plant or surrounding environment. In one case, ammonium-N gets converted to nitrate-N by the microbial process called nitrification. The nitrate-N is still plant available, but because it is an anion it can be prone to leaching from the plant's rootzone. In the second case, another loss path is when N is lost as ammonia gas, out of the plant canopy to the atmosphere (this is volatilization, which is caused by the urease enzyme).

To slow down these processes of nitrification and volatilization inhibitors are added to the urea fertilizer. There is a separate nitrification inhibitor and urease inhibitor, but some fertilizers may contain both. Additionally, there are several different nitrification inhibitors on the market and thus you should carefully read the label to see what your fertilizer may contain. The most common nitrification inhibitor in turfgrass fertilizers is dicyandiamide (DCD), while the most common urease inhibitor is N-(n-butyl) thiophosphoric triamide, (NBPT). Use of a fertilizer with a nitrification inhibitor may help to limit N leaching, and use of a fertilizer with a urease inhibitor may help reduce N loss to the atmosphere.

So, those are six basic groups of N fertilizers. Things get more complicated when other nutrients are added and blends are created. With variations in nutrient ratios, coating types, type and proportion of slow-release N and other characteristics, you can see how the number of possible (and actual) products can become so large.

So how do you pull all this information into a coherent plan for selecting a fertilizer? First, think about what you want your N to do. Do you need to heal worn spots and grow turf? In that case, use a soluble and readily available source to promote growth. Or, do you simply need a background green color with minimal growth? A long-chain MU or polymer coat with a long release pattern might work well. Do you have an environmentally sensitive area, one with a high sand content, in an area with intense rainfall? Consider adding slow-release or materials with inhibitors to protect the environment. Last, calculate your cost per pound of nutrient. Comparing N sources on a price per pound basis removes the percent N content from the equation, helping you make a cost effective decision. ■

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Keeping cool-season turf through the playoffs

The number of events, shorter days, and inclement weather can make it challenging to keep turf cover through the middle of a football field through the playoffs. Though challenging, 100% cover can be achieved with careful planning and execution throughout the growing season, not just in season.

Regardless of the turf of choice, there are five key aspects that must work in concert to achieve a safe, playable surface that will maintain acceptable cover through the playoffs:

Proper grade/drainage. A proper laser-graded crown, minimum 1% - maximum 2%, based on soil type, etc. Proper drainage based on soil type.

Mowing. Maintaining the turf at the correct height throughout the growing season.

Fertilization and pesticide program. Ensuring the turf is maintained at a level to lessen stress throughout the growing season by applying the proper products at the proper rates and the proper times.

Aerification/overseeding/topdressing. Core aerification with a PTO-driven aerifier, maintaining 100% cover though seed banking and topdressing to manage thatch, create a seedbed and maintain a smooth surface.

Irrigation. Necessary to maintain proper soil moisture to maintain turf cover, germinate seed and provide a forgiving surface to the athletes.

Achieve three or four of the five aspects above and the turf has a chance to be good, but not great. Complete all five, the turf will be strong and able to withstand a tremendous amount of traffic.

PRE-SEASON/EARLY SEASON MAINTENANCE:

To achieve 100% cover through the playoffs begins in the off-season much like the athletes who play on the field begin with off-season workouts. Starting in the early spring, core aerification along with topdressing and overseeding with a minimum of 50/50 Kentucky bluegrass/perennial ryegrass at a relatively high rate (6-8 lbs per 1,000 sq ft) begins the season. Seed heavier through the hashmarks and along the sideline/bench areas. Seeding early allows for a late spring liquid application of pre-emergent products that will control the majority of crabgrass and goosegrass. To learn more about topdressing athletic fields and creating a sand cap, look up the re-

To achieve 100% cover through the playoffs begins in the off-season much like the athletes who play on the field begin with off-season workouts.

search from Drs. Alec Kowaleski and Trey Rogers at Michigan State University.

SUMMER MAINTENANCE

During the summer maintain the turf at the in-season cutting height and work to keep the turf as stress free as possible. Irrigate on an as-needed basis to ensure that the turf is not too dry. Fertilize with organic fertilizer or a synthetic fertilizer that contains at least 50% slow release nitrogen in late-May and again in early August. Consider applying fungicides as needed to keep disease pressure at a minimum and apply grub control in July. Furthermore, deep tine aerification and/or another core aerification should be considered in early June followed by a light topdressing. Overall, the goal of the summer season is to keep the turf as healthy as possible.

IN-SEASON MAINTENANCE

The games begin, where will the wear take place? The same places that wear took place in previous seasons. With that said, create a seed bank across the playing surface, with the concentration taking place in the anticipated wear areas. I have a saying, "If you wait until you see wear in wear areas, it is too late!" Seed early and seed often. As far as type of seed used, I prefer using a seed blend that consists of bluegrass and perennial ryegrass. Why? The ryegrass is necessary to take immediate traffic. At the end of the day, these plants will probably be removed by traffic each week. The time to establish straight bluegrass is in a dormant seed situation or in the early spring. A general rule of thumb is applying one 50 lb bag of ryegrass through the hashmarks every week during the playing season. This equates to a seed rate of 3.14 lbs of ryegrass per 1,000 sq ft per week. Along with overseeding, a light topdressing can follow or simply let the athletes "cleat the seed in." Consider reading a research project from Dr Dave Minner at Iowa State to learn more about seed bank research.

A simple pre-game and post game plan: Thursday, overseed hashmarks with one 50 lb bag of perennial ryegrass (optional light topdressing); Friday (or game day), blow off/sweep surface using a pull behind blower or pull behind sweeper. Mow field and fill divots and lightly roll field to push in any plants that may have been slightly pulled from the soil. Irrigate playing surface to alleviate plant stress

POST-SEASON MAINTENANCE

After the games are completed, core aerify and topdress the playing surface. Consider using 3/4 inch coring tines and tight spacing. This is the one time to aggressively cultivate the field and topdress. Fertilize with a product containing 100% water soluble fertilizer at a rate of 1.5 lbs/1,000 sq ft. When weather demands, winterize the irrigation system and get ready for next year. ■

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Which Kentucky bluegrass cultivars perform better with less water?

▲ **FIGURE 5**. Well-watered plots at beginning of dry-down study (4 June, 2007) (left). Plots at two months into the study (4 Aug., 2007), in which drought stress is evident in plots of Kentucky bluegrass (right). Plots were sheltered from precipitation by the rainout shelter (upper left in each photo), which automatically moved on the tracks to cover the plots during rainfall. Photos by Jason Lewis.

Field research at Kansas State University indicates that water requirements may differ significantly among cultivars of Kentucky bluegrass (KBG), depending upon desired turfgrass quality. Given the certainty of periodic drought, limited water availability, and increasing irrigation costs, having choices of KBG cultivars that may maintain better quality with less water is an attractive option. Ideally it would be helpful to select a turfgrass that can perform well with less water.

A helpful concept when discussing KBGs is their classification into phenotypic groups. Individual cultivars of KBG are classified into phenotypic groups based on common growth and stress performance characteristics gathered from field trials. Previous research has indicated that such groupings may be useful in predicting drought tolerance. Because cultivar turnover is rapid in the turfgrass industry, determining the relative irrigation requirements of phenotypic groups may enable researchers to predict irrigation requirements of cultivars not included in any particular study.

Using a rainout shelter (Fig. 5), we compared seasonal irrigation amounts among 28 KBG cultivars for two growing seasons. By shielding plots from rainfall, water could be withheld until wilt symptoms were evident. Our objectives were to identify KBG cultivars and phenotypic groups that maintain better visual quality with less irrigation, using wilt-based irrigation. We hypothesized that if visual quality was good at the beginning of the season, we could maintain minimally acceptable quality in KBG (for example, for a moderately-maintained lawn or golf course rough with in-ground sprinklers) by irrigating when at least 50% of a given cultivar showed signs of wilt. Two hybrid bluegrasses were also included in the study.

METHODS

This study was conducted at the Rocky Ford Turfgrass Research Center near Manhattan, KS. Data were collected for 105 days in 2007 (June 19 - Oct. 1) and 108 days in 2009 (June 22 - Oct. 7). Turfgrasses included 28 KBG cultivars and two hybrid bluegrasses (Table 1). Commercially available cultivars of KBG were selected to include representatives from major KBG phenotypic groups (Note: In the results section, only groups with three or more cultivars were used when comparing groups.) Also, because visual quality was of interest, cultivars were selected based on performance in National Turfgrass Evaluation Program (NTEP) trials.

The plots were maintained well watered until the study began each year. Thereafter, water was withheld until 50% or more of a plot displayed drought stress. Water (2.54 cm) was then applied by hand to the individual plots. Turfgrass quality and drought stress symptoms were evaluated daily. This process continued until the end of the study, after which all plots were re-watered and allowed to recover. Plots were mown weekly at 7.6 cm.

Turfgrass quality evaluations, based on color, density, and uniformity of the canopies, were made using a visual rating scale of 1 to 9, with 1 = brown turf, 6 = minimally acceptable for a home lawn or golf course rough, and 9 = optimum turf. Drought stress was defined as the turf displaying wilting, failure of the canopy to remain upright after foot traffic, and a general darkening color of the turf. Because changes in drought stress were sometimes rapid from day to day, particularly under conditions of high temperatures, it was not unusual for irrigation to be applied when greater than 50% of a plot (for example, up to 70 or 80%) displayed drought stress.

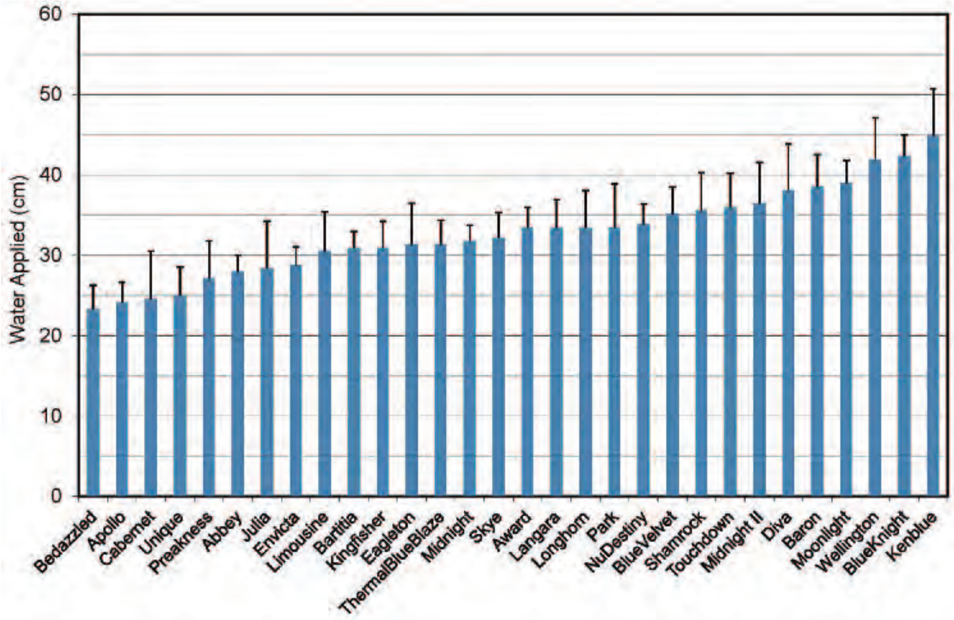
RESULTS

Total Water Applied and Days to Wilt between Irrigation Cycles.

Water applications, averaged over the ~3.5 month period in each year of the study, ranged widely from 23.3 cm (mean=2.2 mm/day) in Bedazzled to 44.9 cm (4.2 mm/day) in Kenblue (Fig. 1). In Bedazzled, Apollo, Cabernet, and Unique, 25.0 cm (2.3 mm/day) or less of water was applied, which was significantly less than Kenblue, Blue Knight, Wellington, Moonlight, Baron, Diva, Midnight II, Touchdown, Shamrock, and Blue Velvet; in the latter 10 cultivars, 35.1 cm (3.3 mm/day) or more of water was applied. However, there were no statistical differences among the 15 cultivars that received the least amount of water (Fig. 1, Bedazzled through Skye).

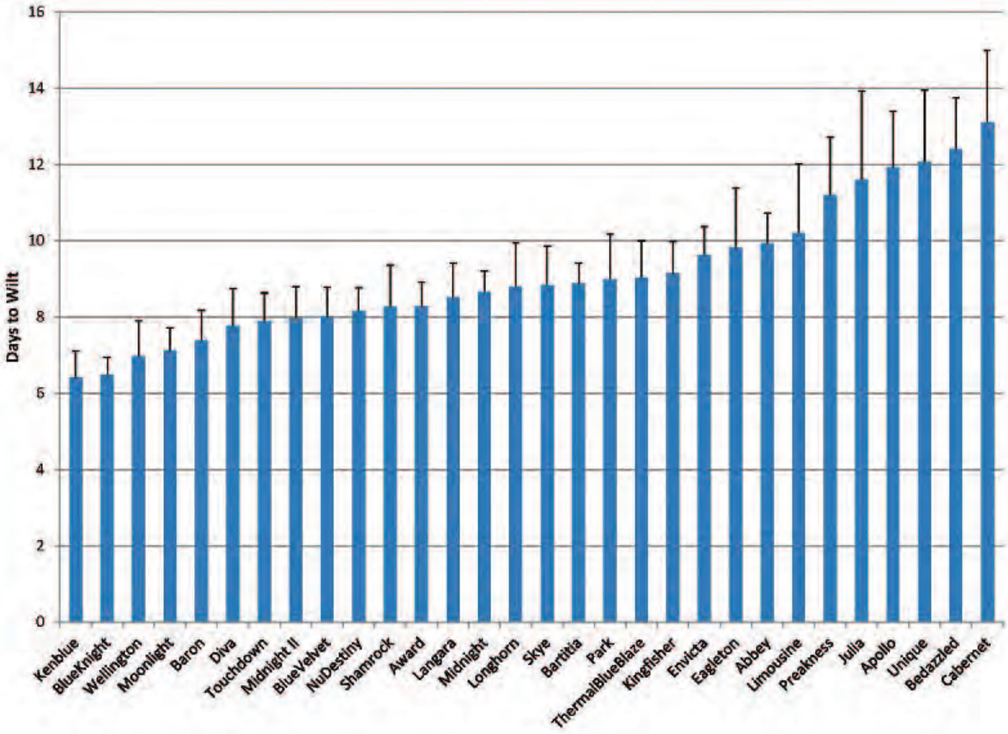
Days to wilt between irrigations, which was roughly inverse the amount of water applied (r= 0.91), ranged from 6.4 d in Kenblue to 13.1 d in Cabernet, a difference of nearly one week (Fig. 2). Days to wilt was greater in Cabernet, Bedazzled, Unique, and Apollo (11.9 to 13.1 d) than in the 18 bluegrasses with the least days to wilt (6.4 to 9.0 d; Kenblue through Park in Fig. 2). These intervals provide the practitioner with an estimate of irrigation frequency required to maintain the various KBGs at a performance level similar to this study, at least in the transition zone of the US. In addition to less frequent irrigation, cultivars with more days to wilt have a greater likelihood of receiving rainfall between irrigations; this could result in further water conservation and reduced irrigation costs.

Notably, all cultivars in the phenotypic group Mid-Atlantic (Cabernet, Eagleton, and Preakness) and four of five in the Compact America group (Apollo, Bedazzled, Kingfisher, and Unique) were among the 15 cultivars that received the least amount of water (Table 1; Fig. 1). When averaged over all cultivars within each phenotypic group, 27.3 cm of water was applied to Compact America types and 27.7 cm to Mid-Atlantic



▲ **Figure 1. WATER APPLIED TO KENTUCKY BLUEGRASS CULTIVARS AND HYBRID BLUEGRASSES**, averaged over the periods 19 June to 1 Oct. 2007 (105 days) and 22 June to 7 Oct. 2009 (108 days), at Manhattan, KS. Error bars denote standard error.

types (both about 2.6 mm/day), which was less than the Common, Compact, and Compact Midnight groups (Fig. 3). The Common types received more water (40.1 cm, 3.8 mm/day) than all other groups except Compact. Days to wilt was also greater



▲ **Figure 2. DAYS TO WILT BETWEEN IRRIGATIONS** among Kentucky bluegrass cultivars and hybrid bluegrasses, averaged over the periods June 19 - Oct. 1, 2007 (105 days) and June 22 - Oct. 7, 2009 (108 days), at Manhattan, KS.

in Mid-Atlantic and Compact America than in all other groups (Fig. 4), indicating cultivars in Mid-Atlantic and Compact America could generally go longer without irrigation.

VISUAL QUALITY

With the exception of the Common types in 2007, the visual quality of all bluegrasses was acceptable (>6) at the beginning of the study in each year (Fig. 5, top). In all bluegrasses and in both years, however, visual quality declined to below what was considered minimally acceptable (Fig. 5, bottom). This indicates waiting until 50% wilt to apply irrigation was insufficient to maintain acceptable visual quality in KBG, at least for turf managers who desire a moderate standard of quality in the stressful climate of the transition zone. Perhaps visual quality could have been maintained at acceptable levels by applying water when only 25% of the plot exhibited symptoms of drought stress; further research is required. Our method may be appropriate, however, where the primary concern is water conservation and some dormancy is acceptable. Visual quality in all bluegrasses generally remained above four and recovery was rapid in the fall after resuming irrigation.

Although visual quality declined to less than six in all cultivars, the time required to do so ranged widely from 8.1 d in Kenblue to 44.8 d in Blue Velvet. The decline was slower in Blue Velvet, Award, Midnight, Cabernet, Unique, and Nu Destiny (36 to 44.8 days) than in Park, Baron, Wellington, and Kenblue (8.1 to 14.2 days). Thus, four of five cultivars in the Compact Midnight group maintained quality longer than all cultivars in the Common group (Table 1).

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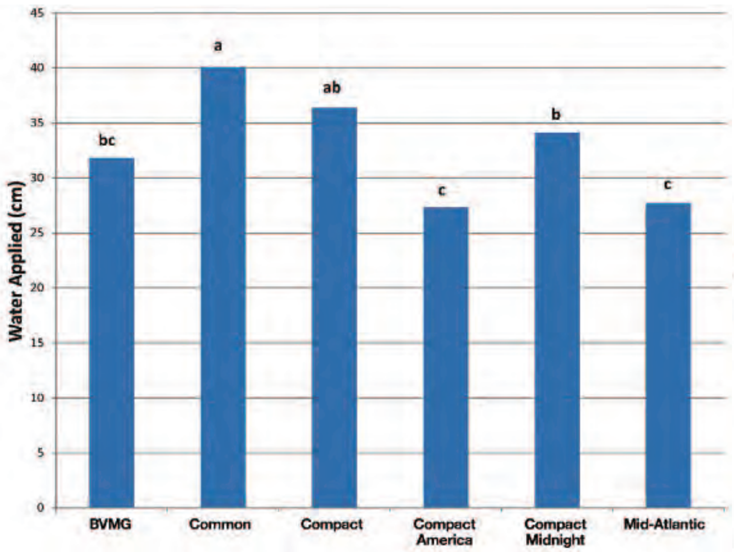

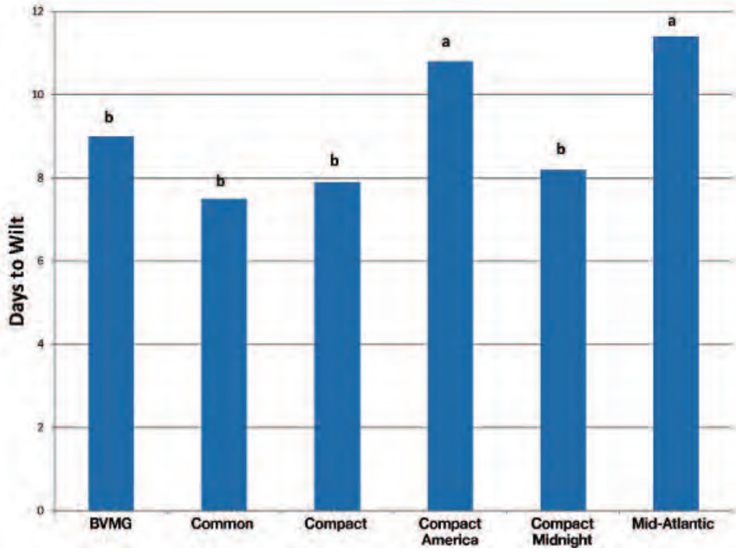

▲ **Left: Figure 3. WATER APPLIED TO KENTUCKY BLUEGRASS PHENOTYPIC GROUPS**, averaged over the periods 19 June to 1 Oct. 2007 (105 days) and 22 June to 7 Oct. 2009 (108 days), at Manhattan, KS. The same letter above bars denoting different phenotypic groups indicates no significant difference. **Right: Figure 4. DAYS TO WILT BETWEEN IRRIGATIONS AMONG KENTUCKY BLUEGRASS PHENOTYPIC GROUPS**, averaged over the periods 19 June to 1 Oct. 2007 (105 days) and 22 June to 7 Oct. 2009 (108 days), at Manhattan, KS. The same letter above bars denoting different phenotypic groups indicates no significant difference.

Irrigation water quality guidelines for sports turf

IRRIGATION WATER QUALITY is becoming more important for managers of sports turf and grounds. With the demand for potable water increasing, users of irrigation water are considering alternatives sources, such as recycled or effluent water. Because water quality can influence soil quality and turfgrass performance, it's advisable to test irrigation water periodically.

Recently, Penn State's Agricultural Analytical Services Lab began an irrigation and drinking water testing program, with a special program just for turfgrass irrigation water. Below are guidelines used in our test program; these can be followed when interpreting results of irrigation water analyses.

pH

The pH of irrigation water should be determined in a laboratory and listed in your test report. Water with a pH in the range of 6.0 to 7.0 is most desirable for use on turfgrasses. Water with a pH value outside of this range may not directly influence turfgrass performance, but indicates a need to evaluate other chemical components of the water.

BICARBONATES AND CARBONATES

Bicarbonate (HCO_3^-) and carbonate (CO_3^{-2}) are common constituents of irrigation water, and can influence soil properties and turfgrass performance. If bicarbonate and/or carbonate levels are high (>120 and 15 ppm, respectively), these ions can react with calcium and magnesium in the soil to form insoluble calcium carbonate and magnesium carbonate (lime). This reaction reduces the amount of free calcium and magnesium in soil, allowing sodium to compete for and occupy negatively-charged sites on clay particles. Excess sodium in clay results in destruction of soil structure and reduced water percolation though the soil profile. This effect is referred to as the sodium permeability hazard.

RESIDUAL SODIUM CARBONATE (RSC)

The sodium permeability hazard for irrigation water is usually assessed when bicarbonate and carbonate levels are >120 and 15 ppm, respectively. Residual sodium carbonate (RSC) is a common means of assessing the sodium permeability hazard, and takes into account the bicarbonate/carbonate "and" calcium/magnesium concentrations in irrigation water. RSC is important because it's not the absolute bicarbonate and carbonate concentrations that are important, but instead, the relative concentrations of bicarbonate and carbonate compared to concentrations of calcium, magnesium, and sodium.

RSC is calculated as follows: RSC (meq/L) = (HCO_3^- + CO_3^{-2}) - (Ca + Mg)

Note that for this equation, all concentrations are expressed in meq/L. Typically, water with a RSC value of 1.25 meq/L or lower is safe for irrigating turf. RSC values between 1.25 and 2.5 meq/L is marginal, and above 2.5 meq/L is considered excessive.

ELECTRICAL CONDUCTIVITY (EC) AND TOTAL DISSOLVED SOLIDS (TDS)

EC is a measure of the degree in which water conducts electricity. It is determined by passing an electrical current through a water sample and recording the resistance in mmhos/cm or dS/m. EC is used to estimate the concentration of TDS in water, using the following equation:

TDS (ppm or mg/L) = EC (mmhos/cm or dS/m) × 640

TDS is occasionally referred to as total dissolved salts (also abbreviated TDS), or total soluble salts (TSS), and both are determined using the same equation.

Acceptable TDS concentrations for turfgrass irrigation range from 200 to 500 ppm (EC = 0.31 to 0.78 mmhos/cm). TDS concentrations higher than 2,000 mg/L (EC = 3.1 mmhos/cm) can damage turfgrasses. If using irrigation water with a TDS concentration higher than 500 mg/L, attention should focus on irrigation duration and frequency, drainage, and turfgrass species selection.

SODIUM

Sodium exists in nearly all irrigation water and is not necessarily a cause for concern unless high concentrations are present. High concentrations (> 70 ppm) can be

Table 1. Guidelines for nutrient concentrations in irrigation water (mg/L).

Macronutrient	Low	Normal	High	Very High
Nitrogen (N)	<1.1	1.1 - 11.3	11.3 - 22.6	>22.6
Nitrate (NO_3^-)	<5	5 - 50	50 - 100	>100
Ammonium (NH_4^+)	<2	2 - 75	75 - 100	>100
Phosphorus (P)	<0.01	0.1 - 0.4	0.4 - 0.8	>0.8
Potassium (K)	<5	5 - 20	20 - 30	>30
Calcium (Ca)	<20	20 - 60	60 - 80	>80
Magnesium (Mg)	<10	10 - 25	25 - 35	>35
Sulfur	<10	10 - 30	30 - 60	>60
Micronutrient	**Acceptable range**	**Suggested maximum concentration**		
Iron (Fe)	2.4 - 4.0	5.0		
Manganese (Mn)	<0.2	0.2		
Copper (Cu)	<0.2	0.2		
Molybdenum (Mo)	<0.1	0.1		
Zinc	<0.3	2.0		
Boron	<2.0	2.0		

Guidelines based on the suggestions of Duncan, R.R., R.N. Carrow, and M. Huck. 2000. Understanding Water Quality and Guidelines to Management. USGA Green Section Record. September-October, pp. 14-24.

detrimental to both turf and soils. Sodium in irrigation water can be absorbed by roots and foliage, and foliar burning can occur if sufficient amounts accumulate in leaf tissue.

SODIUM ABSORPTION RATIO (SAR)

The relative concentrations of sodium, calcium, and magnesium are important determinants of irrigation water quality. Calcium and magnesium play a major role in maintaining structure of clay-containing soils. If water with excess sodium and low calcium and magnesium is applied frequently to clay soils, the sodium will tend to displace calcium and magnesium on clay particles, resulting in breakdown of structure and reduced permeability.

SAR is used to assess the relative concentrations of sodium, calcium, and magnesium in irrigation water and provide a useful indicator of its potential damaging effects on soil structure and permeability.

Typically a SAR value below 3.0 is considered very safe for turfgrasses. Over time, water with a SAR of 9.0 or above can cause significant structural damage to clay soils. Sandy soils are not as susceptible to structure and permeability problems, and can tolerate higher SAR values (up to 10 in most cases).

CHLORIDE

Chloride contributes to salinity of irrigation water, and when concentrations are high enough, can be toxic to plants. Turfgrasses are not particularly sensitive to chloride, and can tolerate levels up to 100 ppm. Turfgrasses can sustain injury when irrigated with water containing >355 ppm of chloride. Grounds managers should be aware that some ornamental plants are sensitive to chloride concentrations above 70 ppm.

BORON

Boron is essential for plant growth at very low concentrations. However, it can be quite toxic to some ornamental plants at concentrations as low as 1 to 2 ppm in irrigation water; with symptoms appearing as necrosis on margins of older leaves. Turfgrasses are more tolerant of boron, but to be safe, it's best to use irrigation water with boron concentrations < 2 ppm for watering sports turf.

NUTRIENTS IN IRRIGATION WATER

Irrigation water contains plant nutrients in varying concentrations. Depending on concentrations, nutrients can influence fertility programs and have an environmental impact on ground and surface water. Nitrogen has a significant influence on plant growth, and may present a hazard for drinking water sources if nitrate levels are 10 ppm or more. Phosphorus concentrations should be as low as possible (lower than 1.0 ppm) to avoid causing algal blooms in holding ponds and phosphorus loading in surface streams and lakes. Guidelines for nutrient concentrations are provided in Table 1. ■

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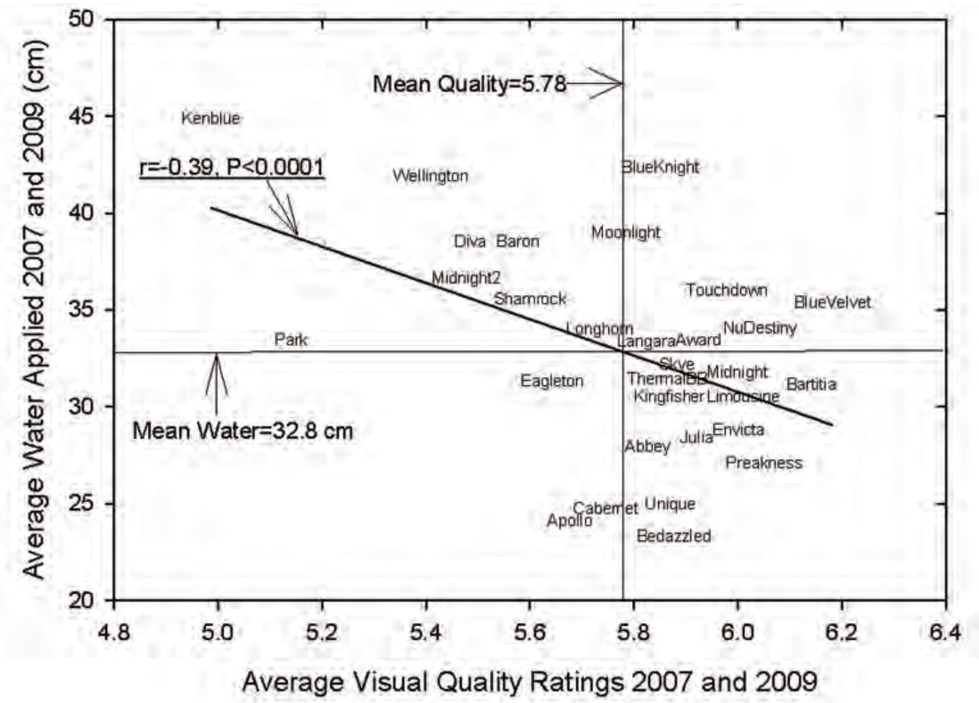
As a group, the Compact Midnight types remained above a quality of six for longer than the Common as well as the BVMG types, but also received more water than the Compact America and Mid-Atlantic groups (Fig. 3).

RELATIONSHIPS BETWEEN WATER APPLIED AND VISUAL QUALITY

Ideally, cultivars or groups that require the least water would also have the highest visual quality. Those relationships are illustrated in the scatter biplot in Fig. 6, in which cultivars with the most favorable characteristics appear in the lower right section. In general, irrigation applications were greater in bluegrasses with poorer quality (Fig. 6, upper left section). This pattern probably resulted from improved cultivars with morphological properties that both enhanced turf quality and reduced evapotranspiration (water use). Such improved properties include compact or dwarfed growth habits, horizontal leaf orientation, and greater shoot density. All 15



▲ **Figure 6. WATER APPLIED TO KENTUCKY BLUEGRASS CULTIVARS AND HYBRID BLUEGRASSES** versus average visual quality ratings on a 1-9 scale with 9=optimum and 1=brown turf. Data were averaged over the periods June 19 - Oct. 1, 2007 (105 days) and June 22 - Oct. 7, 2009 (108 days).

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bluegrasses with the lowest water applications were also ranked among those with the highest visual quality (Fig. 6; there were no statistical differences among cultivars with average visual quality greater than 5.5). The amount of water applied to these 15 cultivars with superior turf quality was also below the mean water applied to all 30 bluegrasses (32.8 cm). Similarly, visual quality in 12 of the 15 bluegrasses that received the least water was greater than the mean of all 30 bluegrasses (5.78), although all 15 were statistically similar.

In contrast to the 15 top performers, six cultivars were ranked within the group that received the most water and had the lowest visual quality (Fig. 6). Those six cultivars, which included Kenblue, Wellington, Midnight II, Baron, Diva, and Shamrock, had neither the high visual quality nor low water requirement traits we were screening for in this study.

CONCLUSIONS

Cultivar selection in KBG had significant impacts on water requirements and visual quality ratings. Among cultivars, differences in seasonal water applications were as great as 21.6 cm and differences in days to 50% wilt between irrigations were as great as 6.7 days, nearly 1 week). Based on statistical range tests, only 15 of the 30 cultivars were in the group that both received the least water and had the greatest visual quality. Results indicated that, under conditions similar to those in our study, KBG in the Compact America and Mid-Atlantic phenotypic groups can be selected for their lower irrigation requirements without sacrificing visual quality, and types from those two groups may represent the best selections for breeding efforts to achieve such goals.■

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This article was reprinted with permission from Sports Turf Manager, Vol 26, No 1, Spring 2013.

This research was funded by United States Golf Association, Turfgrass Producers International, and the Kansas Turfgrass Foundation. The technical assistance of Tony Goldsby was greatly appreciated.