Theoretically, all of the granular fertilizers formed by reacting urea with formaldehyde are methylene ureas (MUs). However, the fertilizer industry recognizes three distinct groups or classes in a UF fertilizer. The classes MUs, MDU/DMTUs and ureaforms are based on the length of urea chains. Ureaforms have the longest urea chains, MUs are intermediate in length (primarily four- and five-urea chains), and MDU/DMTUs are shorter, having two- and three-urea chains. The release of N from these carriers is affected by moisture, which releases N from non-reacted urea and some of the shorter-chain compounds, and microbial activity, which influences the release of N from longer urea chains.

The ratio of urea to formaldehyde and the activity index are helpful when predicting how N will release from one of these carriers. For example, a fertilizer with a 1.3:1 U:F ratio has about 67% slowly soluble N and 33% cold-water-soluble (77 degrees F) N (CWSN). The CWSN fraction contains non-reacted urea and low-molecular-weight, short-urea-chain compounds. The cold-water insoluble (CWIN) portion of UF is not soluble in cold water.

Hot-water-soluble N (HWSN) is released slowly for a period of weeks. Hot-water-insoluble N (HWIN) is very slowly soluble, so slowly soluble that it may not be available to turfgrasses. The Activity Index, or A.I., is the fraction of CWIN that goes into solution in hot (212 degrees F) water. The higher the A.I. value, the more rapidly N becomes available.

Urea formaldehyde should have an A.I. of at least 40%. Granular UF fertilizers contain at least 35% N with 60% or more N in cold-water-insoluble (CWIN) form. Granular MU fertilizers contain 39 to 40% N with 25 to 60% in CWIN form. Granular MDU/DMTU fertilizers are at least 40% N with less than 25% in CWIN form. Two or more fertilizers containing ureaform, MU and DMU/TMDU can be compared based on their CWSN, HWSN and HWIN contents.

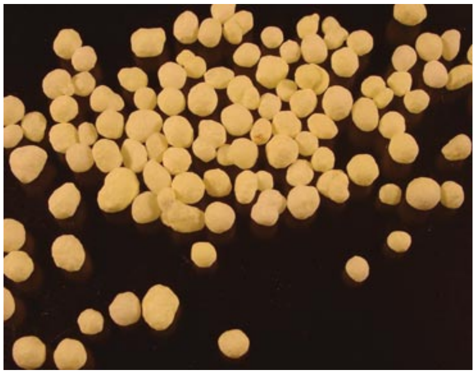
Urea can be coated to reduce its burn potential, and delay N release. Sulfur-coated urea is formed when granular urea is coated with molten sulfur. The Tennessee Valley Authority (TVA) began developing sulfur-coating technology in the 1960s. Pilot SCU manufacturing plants were constructed by TVA in the 1960s and 70s. Several plants were then built in the United States and Canada from 1975 to 1985. Sulfur-coated urea contains from 30-40% N and 10-30% sulfur.

The rate of release of N from SCU is influenced by temperature, soil moisture, coating thickness and the number of granules with broken coatings. If wax has been used to seal the sulfur coating, soil microorganisms also influence N release. The wax coating is degraded by soil microorganisms before N is released. The release of N among fertilizers containing SCU is often highly variable and may last from several days to months. Sulfur-coated urea may cause mottling if the coating is cracked during transport, handling or as the fertilizer is applied. If the sulfur coating is cracked, N releases too rapidly, a condition known as "burst."

>> **Figure 8.** Polymer-coated Urea.

A soil pH range of 6.0 to 7.0 usually favors microbial activity and N release from natural organics, UF and SCU with a wax coating. Since populations of many species of beneficial microorganisms are reduced at low pH, the release of N from these carriers may be delayed in strongly acid soils.

Polymer-coated fertilizer technologies vary among manufacturers. Several materials are used as polymer coatings including polyurethane, polyethylene and alkyd-resin. Depending on polymer chemistry and coating width, temperature and soil moisture level, the release of N from PCU (Figure 8) often lasts from one to two or more months. Unlike SCU which releases N through small, pin-hole-like micropores in the sulfur coating, the N in PCU releases by diffusion through the polymer coating as it swells. Nitrogen release is delayed until water penetrates the polymer coating and begins dissolving the N-rich granule inside. Nitrogen then diffuses out through the expanded polymer coating and is available for uptake by turfgrasses.



>> **Figure 9.** Polymer-coated, Sulfur-coated Urea.

Polymer-coated, sulfur-coated urea (Figure 9) combines both polymer- and sulfur-coating technologies. Sulfur is usually applied to urea before the polymer. The sulfur coating of PCSCU is most often thinner than that of SCU. Similarly, the polymer coating of PCSCU is usually thinner than that of PCU. As a result, PCSCU is often less expensive than PCU and the coating weighs less than that of SCU. The release of N from PCSCU depends on both diffusion and capillary action. For example, Water first diffuses through the polymer layer. Then, as it encounters the polymer-sulfur interface, water penetrates the micropores in the sulfur coating by way of capillary action. Once inside, the urea granule begins dissolving and N makes its way through both coatings.

Reactive Layer Coating, or RLC, is a fairly new technology that creates a very, very thin polymer coating as two reactive compounds are applied simultaneously to fertilizer granules in a “continuous coating” drum. Several N carriers including ammonium sulfate, MAP, potassium nitrate and urea are available with RLCs. The RLC encapsulating a urea granule may weigh as little as 1% of the total weight of the coated urea granule. This process often costs less than several other coating processes and, like PCUs, and PCSCUs, the release of N from RLCs is influenced by temperature and soil moisture.

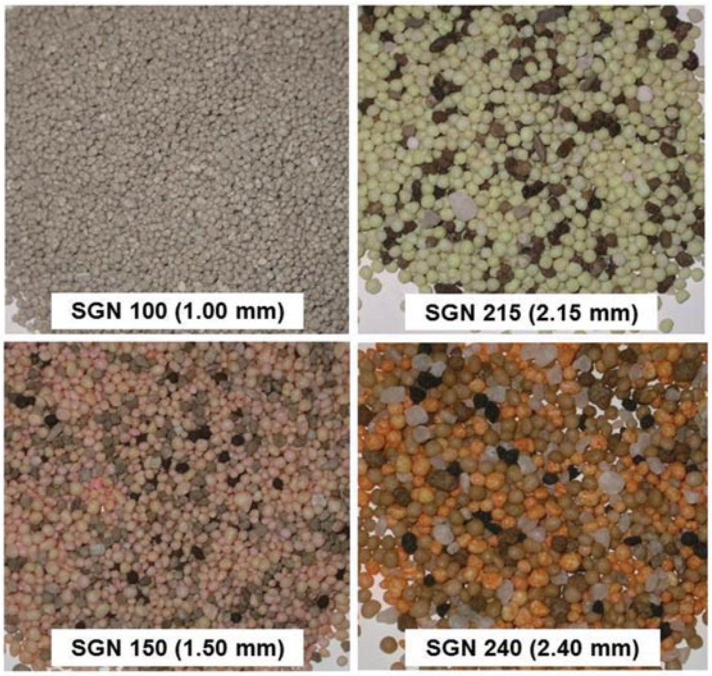
PHYSICAL PROPERTIES

In addition to the chemical properties of N carriers, the size and uniformity of granules deserve consideration when comparing turf fertilizers.

Size Guide Number. The size guide number, or SGN, is a measure of fertilizer quality developed by the Canadian Fertilizer Institute. It represents the average or median particle size diameter in millimeters multiplied by 100. To calculate SGN, the sieve opening (in millimeters) that retains or passes 50% of the weight of a fertilizer sample is determined and is then multiplied by 100. Turf fertilizers often have SGNs ranging from 80 to 280 (Figure 10). Greens fertilizers have a low SGN (for example, 80 or 90) compared to fertilizers formulated for turfs maintained at greater cutting heights with SGNs often ranging from 145 to 230 or more.

Uniformity Index. The uniformity index (UI) is a means of de-

>> **Figure 10.** A Comparison of Fertilizers with Size Guide Numbers of 100, 150, 215 and 240. Photo Credit: Brad Jakubowski.

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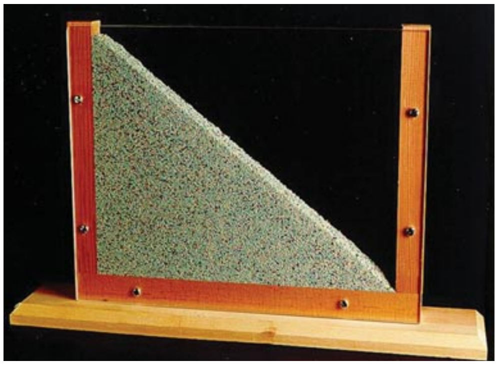

>> **Left: Figure 12a.** Calculating the Size Guide Number and Uniformity Index of a Fertilizer. **Right: Figure 12b.** Testing for Fertilizer Granule Segregation.

termining how consistent the diameter of granules within a bag or lot of fertilizer is. To calculate the UI, the size of the sieve opening in millimeters that retains 95% (or passes 5%) of the sample is divided by the size of the sieve opening that retains 10% (or passes 90%) of the sample. This fraction is then multiplied by 100. For example, a fertilizer with a uniformity index of 50 contains a range of variable-sized particles with the average small particle being one-half the size of the average large particle. The average smallest size granule in a fertilizer with a UI of 33 is one-third the size of the largest particle. Sports turf fertilizers often have a UI of 40 or more.

Granule Segregation Test. One way to observe the variation in the relative size of granules in a fertilizer is to construct a box 24 in. long, 2 in. wide and 18 in. high from clear plastic (for example, Plexiglas) and wood, and perform a granule segregation test (Figures 12a and b). When fertilizer is poured through a funnel positioned just above the top left corner of the box, larger and heavier granules move further to the right than smaller and lighter granules. For most uniform application, granules in turf fertilizers should be nearly the same size and weight.

By evaluating each N carrier used in the fertilization program in addition to the overall turfgrass quality and field performance from one year to the next, sports turf managers can make sure that they are getting the most from their granular N fertilizers. ■

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Dbacks
Grant Trenbeath
Head Groundskeeper
Chase Field

Precision Turfgrass Management for athletic fields

PRECISION TURFGRASS MANAGEMENT (PTM) is a new concept for the turfgrass industry; but, it is based on the same principles as Precision Agriculture (PA), which has been evolving since the early 1990's. Both PTM and PA are based on these foundational principles:

• Site-specific management is the first premise of PA and PTM, the application of inputs (water, fertilizer, cultivation operations, salinity leaching fraction, etc.) *only where needed, when needed, and at the amount needed*. The idea is to foster more precise and efficient application of inputs by management on a smaller area basis than the current practice, such as at the single irrigation head area of influence or a sub-area on a sports field.

• "Intensive" site-specific information is necessary to make wise site-specific decisions. Site sampling is across the whole area, not just selected locations, and on a close sample-grid in order to define the degree and nature of spatial variability for all measured parameters.

• Key soil and plant properties must both be measured to allow accurate definition of spatial variability and to allow investigation of the relationships of measured parameters. For example, PA did not rapidly advance until mobile platform devices were developed that could determine key soil factors that could be related to plant data from remote sensing or crop yield mapping.

• Mobile, multiple-sensor devices are necessary to measure multiple factors in a timely manner on a close spacing and across the whole site. Unfortunately, the mobile devices developed for PA are not well-adapted to turfgrass situations, so lack of appropriate devices has hindered PTM development.

• All data are GPS-labeled (global positioning system), which allows the data to be imported into powerful geographic information system (GIS) programs for geostatistical analysis, comparing measured parameters at specific locations, and in order to develop detailed map presentation.

Recently, the Toro Company has developed mobile, multiple-sensor units specifically designed for turfgrass sites that supports several PTM field applications that are discussed later (Figure 1, top). The Toro Precision Sense 6000 device has a mapping speed of 2 mph, which covers about 2.5 acres per hour using a grid of 8 x 8 feet sample grid or approximately 900 samples per high school football field.

Parameters for Performance Testing of Sport Fields

COMPREHENSIVE Site-Assessment parameters that can be determined with mobile PTM devices are noted by a * for currently available devices or with a ** for those with a high potential for a device to be developed in near future.

Soil Surface Characteristics. Each determination should be conducted under two field conditions, namely: during dry period with irrigation system is used; and field capacity such after a rain to produce field capacity conditions across the field.

• Surface hardness/resiliency (Clegg Impact Tester)*
• Surface hardness/compaction. Surface penetrometer (< 1.0 inch)*; deep
• penetrometer (4 inch)*
• Surface levelness. Any minor or major depressions**
• Traction (torsion device with twisting action)**
• Shear strength/stress (divot device)**
• Soil moisture content – surface 0-4 inches*

SOIL PROFILE

• Soil type and clay type
• Soil physical lab analysis
• Profile description. Surface or subsurface layers
• Infiltration
• Surface drainage – slope, contouring patterns (flat field, crowned, pocketed);
• Subsurface drainage – tiles, slit trenching
• Soil fertility tests

TURFGRASS COVER

• Turf type
• Turf uniformity and density**
• Grass sward height
• Stress indice – NDVI (plant density and color; degree of stress)*
• Bare ground – precent, wear patterns*
• Weeds – precent and types
• Rooting depth
• Thatch or mat

IRRIGATION WATER AUDIT

First Phase – system maintenance

• Evaluate and "maximize" system performance
• Determine head to head spacing measurements and effect on water distribution*
• Determine malfunctioning sprinklers, nozzles, system pressure, head alignment, etc. *
• Scheduling settings and capability
• Irrigation water quality test

Second Phase – water distribution (two options)

• Catch-can assessment (traditional water audit approach) – determines water distribution as affected by irrigation system design and performance
• Soil moisture distribution based water audit (i.e., new soil water audit approach) using GPS, GIS, mobile sensor platforms* – determine soil moisture spatial distribution as affected by irrigation system, soil texture/organic matter content, wind, drainage, and any factor affecting soil moisture content.

Fixtures and Surrounds. Factors that may affect player safety.
• Goals, fences, etc
• Sprinkler placement & maintenance
• Surrounds – spatial mapping may be of use in some cases, drainage

John Mascaro's Photo Quiz

John Mascaro is President of Turf-Tec International

Can you identify this sports turf problem?

Problem: Small mounds on turf
Turfgrass area: High school baseball field
Location: Homer, Louisiana
Grass Variety: 419 Bermudagrass

Answer to John Mascaro's Photo Quiz on Page 33

Background illustration courtesy of istockphoto.com

>> **Figure 1. MOBILE SPATIAL MAPPING** devices for sports fields. Top: mulitple sensor device to map soil moisture, salinty, penetrometer resistance, turf quality, and topographic relief. Bottom: accelerometer device that is similar to the Clegg Accelerometer to determine surface hardness (images courtesy of The Toro Co.).

The multiple-sensor device determines several parameters, all with GPS labeling, namely: a) soil volumetric water content (%VWC) in the surface 0 to 4 inch zone; b) soil salinity in the surface 0 to 4 inches; c) surface hardness by penetration resistance as force to insert the probes in top 0 to 4 inch; d) plant performance by normalized difference vegetative index (NDVI), which is a measure of plant density and color; and e) topography slope and aspect at one foot intervals using current GPS data, but more refined topography information is possible with more expensive GPS units. Additionally, a mobile accelerometer similar to a Clegg Impact Soil Tester is in final testing and other measurement devices are in development (traction, shear, surface levelness, etc.) that can be attached to the mobile platform (Figure 1, bottom).

APPLICATIONS OF PTM IN SPORTS TURF

Performance Testing and New Soil-Based Water Audit Applications. An evident application of the scientific methods and protocols of PTM to sport fields would be performance testing, the determination of key surface conditions for various purposes, including: a) assessing current conditions relative to player safety and field playability (benchmarking); b) developing field standards; c) guiding maintenance operations; and d) as a key component in formulating a site-specific, comprehensive "sustainable sports turf management program."

Determining surface standards is not a new research area, but started with considerable efforts in the 1980's and continues to the

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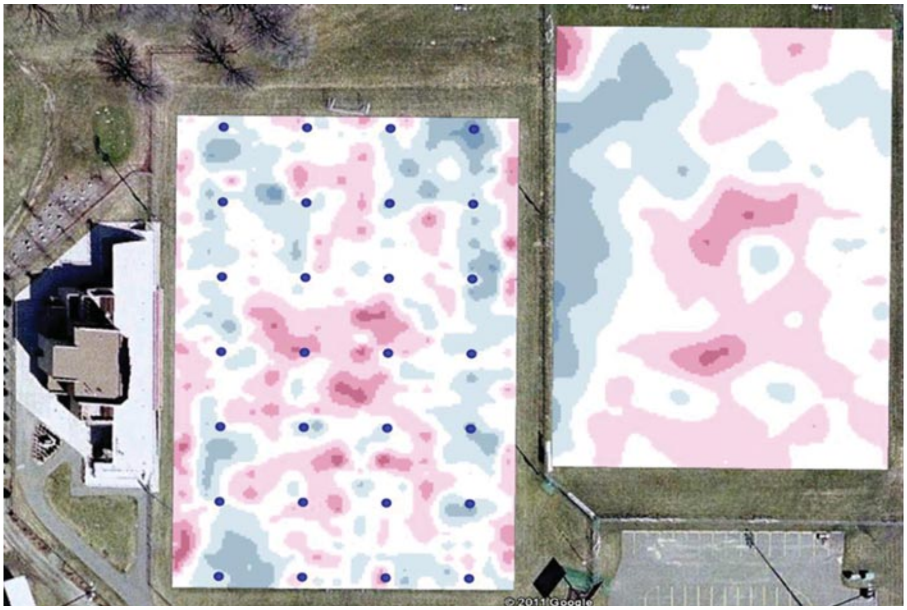


>> **Figure 2. SOIL HARDNESS** determined by the Toro accelerometer presented in standard deviation format maps that illustrate the lowest and highest hardness areas in a field. These can often be related to soil moisture and traffic patterns. Blue dots are irrigation heads.

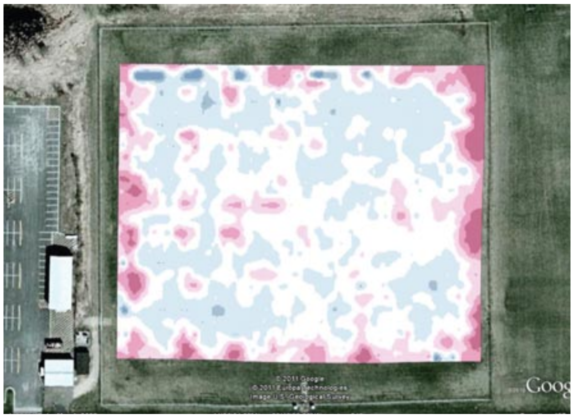
current time. However, in recent times the term "performance testing" has been used to describe assessment of surface conditions of sport fields.

Regardless of the terms used, a common theme of almost all surface characterization research to date has been to sample only 4 to 6 sites on a sports field due to: the necessity of using several individual hand-held instruments to obtain the necessary multiple soil and plant information; difficulty in inserting hand-held instruments into the soil surface; and high labor/time/cost requirements for sampling which precluded closer grid-sampling. These limitations are reflected in current approaches for performance testing such as the PASS system which is low tech but also results in much less information.

An exception of using only a few sample sites is a study by Miller on hardness of soccer fields where an 80 sample grid was used and geostatistical analysis techniques were applied, but only Clegg Impact hardness was measured. There has also been the occasional use of mobile spectral reflectance devices to determine plant performance primarily as NDVI across the whole sport field surface area, but without associated soil data. The PTM approaches and technology provide the opportunity for performance testing to evolve to a more geospatially precise assessment of sports field playing surfaces along with better mathematical treatment of relationships of measured parameters and detailed GIS-based visual presentations in spatial maps (Figure 2).

An overview of the site information obtained in a comprehensive, sports field site-assessment can aid in understanding how PTM concepts and technology can be integrated into performance testing. Henderson and Stiles et al. provide excellent reviews of various hand-held devices that have been used for surface assessment. Of the soil surface characteristics, soil hardness, traction, and shear strength are the most important factors for player safety and playability. Soil hardness as determined by a Clegg Impact Tester or by penetrometer resistance is a function of soil moisture (most important factor), compaction, percent clay, thatch/mat, and soil organic matter content. As soil moisture decreases below field capacity, soil hardness dramatically increases. Thus, spatial variability in soil hardness should first be determined under normal irrigation conditions during dry periods since uniformity of irrigation water application, as affected by system design and scheduling, dramatically influences soil moisture spatial distribution, and thereby, soil hardness. But, to determine how soil hardness is affected by traffic-induced soil compaction, data should be obtained at field capacity, i.e. to eliminate the influence of irrigation system on soil moisture uniformity. Soil compaction spatial variability is a function of traffic patterns, soil type, and soil structure. Traction and shear strength are also strongly affected by soil moisture as well as grass type, degree of coverage, thatch/mat/OM content, soil texture, and soil structure (compaction). Thus, traction and shear strength should also be determined under both drier and field capacity conditions.

Because soil moisture has such a dominant influence on soil hardness, traction and shear strength, a new, soil-water audit approach is especially useful for investigating the spatial relationships of soil moisture level versus these surface characteristics (Figures 3, 4). The new water audit is based on spatial mapping with the Toro Precision Sense 6000 of soil VWC during a dry-period when the irrigation system uniformity of water application would be exhibited. In contrast to the traditional catch-can audit, the soil VWC-based audit considers any factor influencing soil moisture distribution (irrigation system design and performance, wind distortion, runoff, high ET areas, etc.) and mapping is of the whole area and surrounds if necessary. A proprietary GIS-based software program allows geostatistical analysis of spatial variability of soil VWC and other measured parameters as well as GIS map display at three critical spatial levels, which are: a) across the whole sports field (Figure 3); b)



>> **Figure 3. SOIL MOISTURE** variability of a soccer field presented in standard deviation format to reveal the areas with the lowest and highest soil moisture (see std dev legend). The arrow identifies irrigation head No. 13.