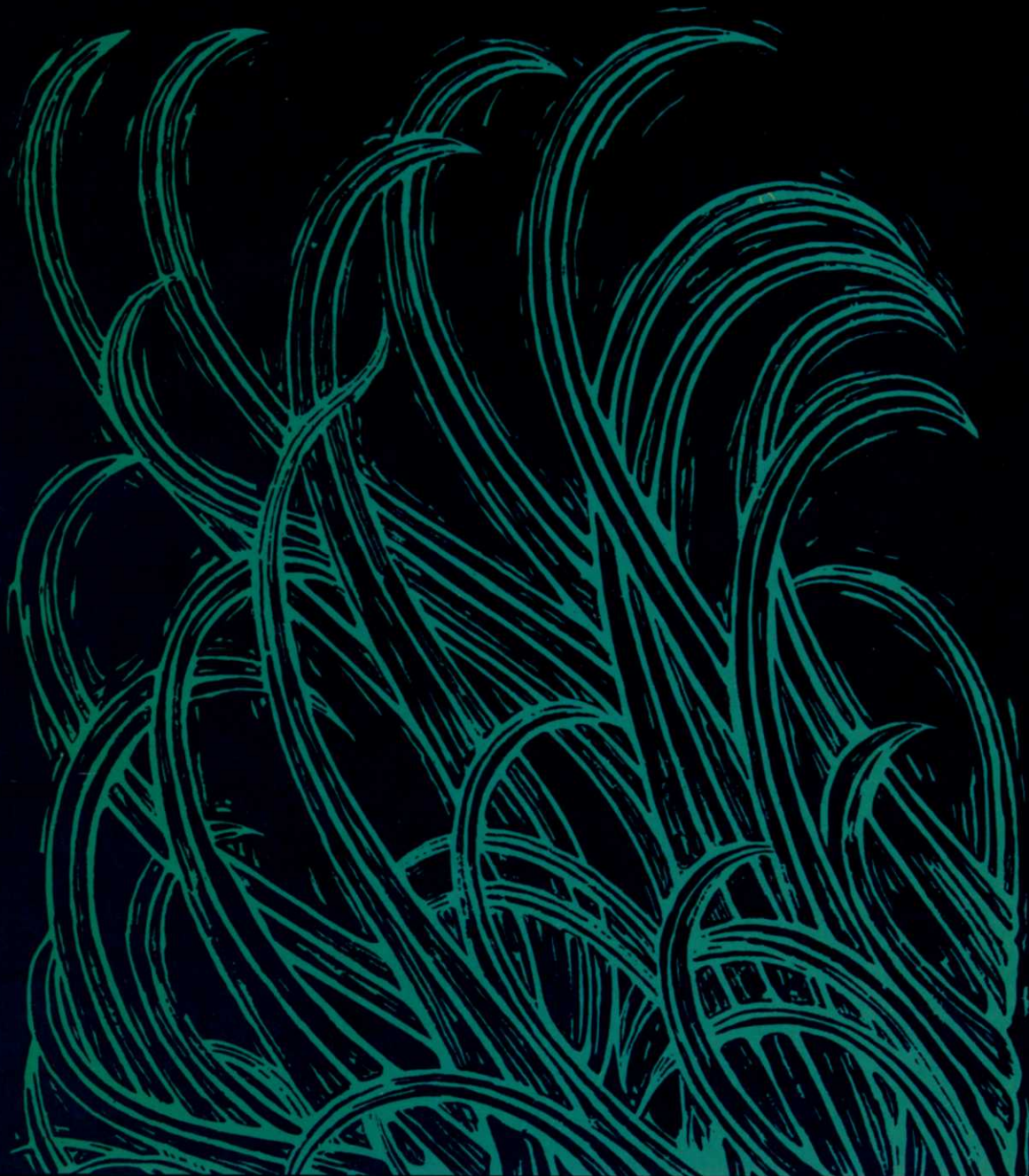


NITROGEN SOURCES FOR TURF FERTILIZATION

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NITROGEN: THE 'TNT' OF TURF FERTILIZATION PROGRAMS

By John R. Street, Associate Professor, Department of Agronomy, Ohio State University, Columbus, Ohio

Turfgrass growth is dependent on maintaining an adequate supply of all essential plant nutrients as well as properly managing a multiplicity of other cultural and edaphic factors. There are at least sixteen elements considered necessary for plant growth and development. Nitrogen is the essential element that receives the most attention in turfgrass fertilization programs. Nitrogen is the element to which turfgrass is most responsive. The nitrogen content of the turfgrass plant is usually higher than any other essential element (i.e. 3-6 percent on a dry weight basis). Nitrogen is a very dynamic element in the soil system. The concentration of soil nitrogen is in a constant state of change. Nitrogen depletion in soils may result from leaching, clipping removal, volatilization, denitrification, immobilization, or nitrogen fixation in the lattice structure of certain clays. Thus, nitrogen must be added to turfgrass sites on a routine basis in order to maintain a sufficient soil level for turfgrass growth.

Generally, nitrogen additions to the turfgrass system from clipping return, decomposition of organic matter, topdressing, nitrogen fixation, and rainfall are not sufficient to supply the needs of high quality turf. The main source of nitrogen is added by the application of nitrogenous fertilizers. Nitrogen fertilizer is initially added to the turfgrass system as ammonium (NH_4^+) and/or nitrate (NO_3^-) or some nitrogen carrier that eventually breaks down to ammonium. The turfgrass plant absorbs nitrogen from the soil as either ammonium or nitrate. Nitrate is the predominant form absorbed by the plant since ammonium is rapidly converted to nitrate by soil bacteria. This biological oxidation of ammonium to nitrate is called nitrification. Nitrification is a two-step process in which the ammonium is converted to nitrite (NO_2^-) by Nitrosomonas bacteria and then to nitrate by Nitrobacter bacteria. The process is temperature dependent and increases with soil temperatures from 32°F. to an optimum range of 85-95°F.

Once absorbed into the plant, nitrate can be stored in the cell, or reduced back to the ammonium form. The storage of free nitrate within the plant cells results in a luxury consumption of nitrate (absorption of more than is used). This is likely an inefficient use of nitrogen, especially if clippings are removed. Nitrate must be converted to the ammonium form before it can be further utilized by the plant. The reduction process (NO_3^- to NH_4^+) within the plant requires at least two enzymes (compounds that assist in the reaction). Nitrate reductase is the enzyme involved in the conversion of nitrate to nitrite. Nitrite reductase is the enzyme involved in the conversion of nitrite to

ammonium. In grasses, the reduction process predominantly occurs in the shoot or foliar portion of the plant, although some reduction may occur in the roots. The ammonium ion is then readily combined into various complex organic (carbon) compounds within the plant. Chlorophyll, amino acids, proteins, enzymes and vitamins are among some of the organic compounds containing nitrogen. Photosynthesis provides the source of carbohydrates or organic skeletons for the nitrogen assimilation processes.

Carbohydrates produced by photosynthesis are the necessary precursors for the formation of nitrogen-containing amino acids and proteins which are utilized in growth processes. The more turfgrass growth, the greater is the demand for carbohydrate. Carbohydrate is also the key source of energy for maintaining all the various growth and physiological processes within the plant. Carbohydrates are broken down into carbon dioxide and water through a process called respiration, and energy is released. Respiration therefore is a "carbohydrate-utilizing" process. When the rate of photosynthesis exceeds the rate of respiration and the requirement for growth, carbohydrates accumulate as reserves. Carbohydrate reserves are usually stored in the crowns, rhizomes and stolons of cool-season grasses. Carbohydrate reserves are desirable since they serve as an immediate source of energy and carbon skeletons for regrowth and recovery from defoliation or stresses that may injure or thin the turf. A "carbohydrate deficit" may develop when respiration rates are high and/or growth is rapid. Usually any factor that stimulates rapid topgrowth will deplete or drain carbohydrate reserves. The turfgrass manager should manipulate cultural practices so as to maintain an adequate level of carbohydrates within the plant for normal as well as unusual energy and growth demands. In essence, the carbohydrate status of the plant reflects the energy status of the plant.

Nitrogen fertilization has a definite effect on the carbohydrate status of turfgrasses. Nitrogen applications favor turfgrass growth. As nitrogen rates are increased, usually more topgrowth is produced. More topgrowth results in the use of more carbohydrate. Physiologically, under rapid growth conditions shoots take priority over roots and rhizomes for available carbohydrate. Shoot growth will usually continue to respond to higher nitrogen levels causing a distinct suppression in root growth and other growth processes.

These effects are well illustrated from a fertilization study evaluating the response of a Merion Kentucky bluegrass sod to incremental rates of nitrogen (Table 1) (3). Higher nitrogen rates resulted



NITROGEN SOURCES FOR TURF FERTILIZATION

in an increase in clipping yield (topgrowth) and nitrogen content of clippings. In contrast, sod strength (a reflection of root and rhizome growth) and rhizome weight decreased at the higher nitrogen levels. Thus, when most of the plant's carbohydrate was directed toward producing shoot growth, root growth and other plant growth processes suffered accordingly. Agronomists well recognize that a plant is no better than the root system that supports it.

Research has shown that a considerable amount of root initiation and root growth of cool-season grasses occurs in the spring (2). Liberal nitrogen fertilization in the spring will have a tendency to restrict root growth. The turfgrass plant will go into the summer with a shorter root system than where moderate rates of nitrogen fertilizer are used. Furthermore, high amounts of nitrogen will increase topgrowth and increase the need for more frequent mowing in the spring. The rapid topgrowth may result in the removal of large amounts of clippings at each mowing. The removal of excess foliage (i.e. more than a third of the foliage at any one mowing) is known to retard both tiller and root development. Thus, mismanagement of nitrogen during the spring can have a dramatic effect on the root system under the turfgrass going into the summer.

Liberal nitrogen fertilization also causes a lush, succulent plant growth that is characterized by decreased cell wall and cuticle thickness, increased cell size, and an increased level of plant tissue hydration. The thinner plant cell walls are most like the result of more rapid plant growth and the production of condition increases the severity of plant disease and lowers the hardiness of the plant to heat, cold, and drought. Lush, succulent tissue also contains high concentrations of nitrogen-rich storage compounds. The nitrogen-rich compounds accumulate in guttation fluid (leaf exudates). The guttation fluid serves as an ideal medium for the enhancement of many turfgrass diseases. Thus, mismanagement of nitrogen in the spring can take the plant into the summer in a soft growth condition in which it is more vulnerable to disease, heat, and drought.

Liberal nitrogen fertilization is known to in-

crease the severity of Pythium, brown patch, Fusarium blight, stripe smut, snow mold, and Helminthosporium (leafspot) diseases (5). Leafspot, a serious disease of both Kentucky bluegrass and bentgrass in the midwest, is much more serious at high nitrogen levels, especially in the spring. Kentucky bluegrass varieties like Park, Kenblue, and Delta are very susceptible to leafspot. Many lawns and older turfgrass areas have been established to these common-type Kentucky bluegrass varieties. Research at the University of Illinois (4) has shown the incidence of Fusarium blight in the summer to be greater with increasing nitrogen application rates in the spring. Nügget, Merion, Fylking, and Pennstar were highly susceptible to the disease when more than a total of two pounds of soluble nitrogen per 1,000 ft. was applied in the spring. Kenblue was affected by the disease at all the fertility levels. This information lends support to moderate levels of nitrogen fertilizer in the spring. It more specifically suggests a critical limit of no more than two pounds of total soluble nitrogen in the spring.

Liberal nitrogen fertilization is also critical during the summer (1). As seasonal temperatures increase, photosynthesis of cool-season grasses decreases and respiration increases. As mentioned earlier, carbohydrates are consumed during respiration. Respiration is known to increase with increasing nitrogen fertility levels. Thus, during periods of high temperature, liberal nitrogen fertilization may reduce carbohydrate reserves due to rapid growth and high respiration. Additional stress may result from lower photosynthetic rates. Because carbohydrates are produced at a slow rate and respiration is high during the summer, nitrogen should be applied at low rates for cool-season grasses.

Nitrogen is a necessary component of turfgrass fertilization programs. High quality turf exhibiting acceptable green color and density requires periodic application of nitrogen. Nitrogen however, is frequently referred to as the "TNT" of turfgrass fertilization programs. It can be just as detrimental as beneficial, if mismanaged. Proper timing and rate of application are important in successful long-term programs. Always remember! Greener is not always better. A happy medium must be met between agronomics and aesthetics.

WTT

Table 1. Nitrogen treatment effects on a Merion Kentucky bluegrass sod (3).

Nitrogen Rate	Annual Clipping Yield (dry wt.)	Nitrogen Content in Clippings	Sod Strength	Rhizomes
lb/A/month	lb/A	%	lb to tear	grams
0	463	3.0	146	99
15	1807	3.3	188	89
30	2555	3.6	130	120
60	5676	4.5	97	43
120	8447	5.4	67	14

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CHARACTERISTICS OF WATER SOLUBLE NITROGEN FERTILIZERS

By Roger Funk, Vice President of Research and Development, Davey Tree, Kent, Ohio

Nitrogen is the keystone of a lawn fertilization program, and both soluble and slowly soluble sources are available to the turfgrass industry. Soluble nitrogen fertilizers are less expensive than the slowly soluble sources but, in general, have a higher burn potential and are more likely to be lost through leaching and volatilization. These risks can be minimized, however, if the contributing factors are understood.

Fertilizer burn

Fertilizers contain salts that are similar to table salt (sodium chloride) except that fertilizer salts contain the elements essential for plant growth. When salts dissolve in water, they dissociate into positively and negatively charged ions, and it is in this form that nutrients are absorbed by plant roots. Soluble fertilizers are in the salt form when applied to turfgrass, which accounts for their immediate availability for absorption. Slowly soluble fertilizers may contain some soluble salts, but most of the nutrient salts are released over a period of time as the slowly soluble fertilizer is hydrolyzed or decomposed in the soil. Thus, a major difference between soluble and slowly soluble fertilizer is the release rate of the nutrient salts.

Salts dissolved in soil solution increase the osmotic pressure that governs the flow of water across a root cell membrane. Water always moves

through a cell membrane from the side that has the lowest osmotic pressure to the side that has the highest pressure. Since root cells actively absorb nutrient salts, the osmotic pressure of the cell sap is normally higher than that of the surrounding soil solution — and water is absorbed into the root tissue. This process, in fact, is how plants absorb water. However, if excess fertilizer salts in the soil solution increase the osmotic pressure above that of the cell sap, water is drawn out of the roots, and the resultant injury is termed "fertilizer burn." Symptoms of fertilizer burn resemble those of drought injury since, in both cases, the immediate problem is lack of water in the plant.

The relative tendency of a fertilizer to release salts and increase the osmotic pressure of the soil solution is measured by the salt index. The higher the salt index value, the greater the tendency of a fertilizer to increase the osmotic pressure and the greater the burn potential. The salt indexes of common soluble nitrogen fertilizers are listed in Table 1, which also compares the adjusted salt indexes, based upon the total nutrient content.

Environmental factors such as temperature, humidity, and soil moisture also affect the burn potential of a fertilizer. As the air temperature increases and as the humidity decreases, the water requirement of plants increases. Because of the increased water requirements for plants, the level of soluble salts in soil solution that is "safe" during

Table 1. Solubility and Salt Indexes of Soluble Nitrogen Fertilizers

Fertilizer	Formula	Primary analysis (percent)			Total plant food ^a	Salt index ^b	Adjusted salt index ^c	Solubility ^d
		N	P ₂ O ₅	K ₂ O				
ammonia	NH ₃	82.0	—	—	82.0	47.1	57.4	90
urea	H ₂ NCONH ₂	46.0	—	—	46.0	75.4	163.9	67
ammonium nitrate	NH ₄ NO ₃	33.5	—	—	33.5	104.7	312.5	118
ammonium sulfate	(NH ₄) ₂ SO ₄	21.0	—	—	21.0	69.0	328.6	71
sodium nitrate	NaNO ₃	16.0	—	—	16.0	100.0	625.0	73
calcium nitrate	Ca(NO ₃) ₂	15.0	—	—	15.0	65.0	433.3	134
potassium nitrate	KNO ₃	13.0	—	46.0	59.0	73.6	124.7	13
monoammonium phosphate	NH ₄ H ₂ PO ₄	11.0	48.0	—	59.0	29.9	50.7	43
diammonium phosphate	(NH ₄) ₂ HPO ₄	18.0	46.0	—	64.0	34.2	53.4	25
ammonium polyphosphate (liquid form)	NH ₄ PO ₃	10.0	34.0	—	44.0	29.9 ^e	67.9	—

^aPercent N + percent P₂O₅ + percent K₂O (primary analysis).

^bRader, L. F., Jr., et al. 1943. *Soil Science* 55(3):201-18.

^cSalt index per unit of plant food = (2) x 100/(1).

^dParts in 100 parts pure water at 32° F.

^eTVA.

cool, humid weather may cause burn injury during periods of warm weather or low humidity or both.

Soil moisture is a major factor in determining the fertilizer's potential to burn. If the soil is relatively dry, a fertilizer will have a greater effect on increasing the osmotic pressure of the soil solution. Conversely, if the soil is saturated, the fertilizer salts will disperse and the osmotic pressure will not increase greatly. In addition, the evapotranspiration of water will help cool the plant and raise the humidity near the soil surface, effectively reducing the plant's water requirement.

Leaching

Nutrient leaching is the removal of soluble fertilizers from the root zone by the downward percolation of water. Most of the soluble fertilizer nitrogen will be present in one or more of three forms: ammonium (NH_4^+), nitrates (NO_3^-), and urea ($\text{CO}(\text{NH}_2)_2$).

Ammonium is water soluble, but the strong attraction between the positively charged ammonium ion and the negative sites on clay minerals and soil organic matter prevents leaching. Ammonium, however, is rapidly oxidized to nitrates when the soil temperature is above 50°F .

Nitrate is a negatively charged ion and, as such, is readily leached because it does not bind to soil particles. Leaching of nitrate from the rooting zone is a much greater problem in coarse-textured soils. Research has shown that nitrate may be leached about 1 inch of rainfall for each inch of rainfall in clay loam soils to 2.5 inches for each inch of rainfall in sandy loam soils.

Urea fertilizer is readily soluble when it is first applied to the soil, but when it changes to ammonium it is held by clay and humus in a form that is readily available to plants. Under favorable temperature and moisture conditions, urea hydrolyzes to ammonium carbonate and then to nitrate within less than a week.

Volatilization

Volatilization involves the conversion of nitrogen to ammonia gas, which is lost to the atmosphere. This process is favored by alkaline soils, dry soils, soils with a low exchange capacity, and warm temperatures. When conditions favor volatilization, 25 percent or more of the applied nitrogen may be lost to the atmosphere.

When ammoniac fertilizers and urea are placed in the soil, the ammonia gas that they release is held by the soil particles. However, when urea or ammoniac fertilizers are placed on top of the soil, the released ammonia does not have the clay or moisture to hold it from being partly volatilized.

All of the characteristics of nitrogen fertilizers should be considered when a turf fertilization program is planned. If the materials are applied properly to the existing soil and environmental conditions, soluble nitrogen fertilizer can be just as effective as slowly soluble sources in providing the turfgrass plant with the nitrogen it requires. **WTT**

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source rather than being due to a turf disease or a shift in species composition.

Turf stands developed in long-term N research studies provide sites with known histories. These areas can then be used for other research subjects such as physiological responses to various stresses, soil test calibration, diseases, and weeds.

Perhaps the greatest deterrents to and disadvantage of long-term studies are time and cost. One may wonder about the value of studies involving experimental materials that never reach the market. However, it is better that these materials are dropped after research rather than being dropped after they have been passed onto the public without adequate testing.

Representatives of a few companies want to make decisions after one season's results. At the university level we feel that long-term research gives us a much better basis for our opinions and extension recommendations. Representatives of other companies agree with this philosophy, and they often provide grants to help support these studies.

Results from Long-Term Research

Perhaps the best argument for long-term research can be provided by comparing initial results with those obtained later in an experiment. The results given here were obtained in studies at Penn State.

Lawn Fertilizer Test. Milorganite and ureaform were included in a test with various lawn fertilizers having lower amounts of water-insoluble nitrogen. In treatments in which 2 pounds of N per 1,000 square feet were applied in spring and fall for two years, Milorganite and ureaform gave relatively low yields and color response in the first year. The greatest response was obtained in the first year by fertilizers having lower amounts of water-insoluble N. By August of the second year, prior to fall fertilization, the best color was found on plots fertilized with these two N sources. Fertilizer was not applied in the third year, but clipping weights were taken for 13 weeks beginning in late April and ending in mid-July. The good residual effects of Milorganite and ureaform, and also of Scott's 23-7-7, were quite apparent in the third year.

N Source Test on Merion Kentucky Bluegrass.

Eight N sources were used to fertilize Merion bluegrass for 7 years. Nitrogen recovery in the clippings was calculated for the first 2 years. The inefficiency of Milorganite and Uramite (ureaform) was striking. Urex (a urea-paraffin matrix), ADM (plastic coated urea), and urea had higher recoveries.

The study was continued for 5 more years. To cut expenses, nitrogen analyses of clippings were discontinued. However, clipping yields, which give almost as good an indication of N use by the grass, were continued. Average fresh-weight yields

showed that 3 pounds of N from urea produced greater yields than 5 pounds of N from IBDU in the first year and more than 5 pounds of N from ureaform and Milorganite in the first two years. The residual effects of IBDU were noted in the second year, but with ureaform and Milorganite it took longer for the response to reach that obtained from other sources.

In the summer of 1973, tests for soil N, turf color, and clipping yield showed that the greatest residual effect was obtained from ureaform. Milorganite and IBDU ranked second and third.

At least two findings in this research tie in with the actions of turf managers. First, the slow start from ureaform has been the reason for their dropping it from consideration after short-term use. Second, long-term users of ureaform and Milorganite have been able to reduce application rates as residual N has built up. Occasionally we hear of superintendents drastically reducing N rates and still maintaining adequate turf. If a man who has been using 6 or 8 pounds of N per 1,000 square feet can successfully drop to 3 pounds of N, it may be because of the N reserves that have accumulated in the soil.

Evaluation of Sulfur-Coated Urea Formulations.

Not all sulfur-coated ureas are the same. Different coating methods and thicknesses are used during their manufacture. A study was started in 1974 to evaluate five TVA formulations and Gold N, a product of ICI in England. Spring applications of 4 pounds of N per 1,000 square feet were made. Initial response decreased as the coating weight of the material increased. Response was also slower when a sulfur-only coating rather than a sulfur-plus-wax coating was used. We thought that the slower releasing materials would come on during the fall. They did not. Then we thought that perhaps the residual effects would show the next spring. They did not. We applied 4 pounds of N again in 1975, expecting that we would observe some residual response if we continued for another year. It did not happen. In May of 1976, we sampled the plots for residual sulfur-coated urea and found as much as 37 percent of the applied material still there. We applied another 4 pounds of N that spring. Still no striking residual effect occurred. We sampled for residual pellets that fall, again in 1977, and twice in 1978. No more fertilizer was applied after 1976.

The difference in residual N release over a two-year period (11/76 to 11/78) was as high as 2.5 pounds of N per 1,000 square feet. However, no visual effects from residual N were noted during this time. The first visual effect noted was in August of 1979, when SCU-17 treated plots had significantly less dollar spot and better color than Gold N plots. The slight differences observed at this time were not significant. Additional studies are now being conducted to characterize the release of N from different N sources.

WTT



UREAFORM: FIRST SYNTHETIC SLOW RELEASE FERTILIZER

By John T. Hays, Research and Product Development Specialist, Boots Hercules Agrochemicals Co., Wilmington, Delaware

Fertilizers based on the reaction of urea with formaldehyde have been known for a long time. Solutions containing urea and formaldehyde were marketed by the du Pont Company in 1939. The pioneering work on the solid condensate was done by Dr. K.G. Clark of the U.S. Department of Agriculture (USDA), as reported in publications beginning in 1946. He coined "ureaform" for this product, and this name seems to us to be far preferable to "urea-formaldehyde" to distinguish the odorless, stable fertilizer from the noxious urea-formaldehyde resins made with a large excess of formaldehyde. There is no free formaldehyde in ureaform (as exemplified by Nitroform slow release fertilizer), and it cannot liberate formaldehyde under use conditions.

Manufacture of solid ureaform was begun by the du Pont Co. and the Nitroform Corporation in the mid-1950's. Hercules purchased the Nitroform Corp. in 1960 and marketed Nitroform slow release fertilizer until early this year, when Boots Hercules Agrochemicals Company (formed jointly by Hercules Incorporated and the English firm Boots) took over marketing this product. Du Pont has discontinued manufacture, so Nitroform slow release fertilizer is the only solid ureaform manufactured in this country at present. O.M. Scott utilizes urea-formaldehyde solutions in the manufacture of mixed fertilizer, but these products are technically not ureaforms.

In addition to designating ureaform as the "oldest" synthetic source of slowly available nitrogen, we might add that it is also the longest lasting (in the agronomic sense).

Ureaforms and natural organics undergo decomposition by soil microorganisms to form ammonia (ammonification), which may be converted to nitrate (nitrification). Variables, such as temperature, soil pH, and aeration have a great effect on these reactions. The microbiological reactions are less sensitive to particle size and soil moisture. Generally, conditions that favor plant growth also favor microbiological reactions.

Quality factors

According to the "Specialty Fertilizer Labeling Format" proposed by the American Association of Fertilizer Control officials and widely adopted: "When a fertilizer infers or connotes that the nitrogen is slowly available through use of *organic, organic nitrogen, ureaform, longlasting*, or similar terms, the guaranteed analysis must indicate the percentage of water-insoluble nitrogen in the material."

Unfortunately, specification of minimum WIN and its source, which is all that is required by the labeling format, gives no indication of agronomic availability; a fertilizer can appear to be of high quality on the basis of its WIN but be of little value because of low availability. In the case of ureaforms, solubility determinations can be used to calculate the Activity Index (AI), which gives an indication of agronomic availability.

Ureaform Specifications

The specifications for commercial Nitroform ureaform fertilizer are:

Total nitrogen—38.0 percent (minimum)

WIN—27.0 percent (71 percent of 38 percent total nitrogen)

AI—40 (minimum) (percent WIN soluble in hot water)

The AI thus supplements the WIN determination by indicating the percentage of the WIN that is readily available (soluble in hot water). The AI does not give the complete picture: it gives no measure of the cold water-soluble fraction, and it does not indicate the availability of the fraction insoluble in hot water. Nevertheless, an AI of 40 in the normal WIN range will assure availability of a major portion of the ureaform.

The solubility approach is not directly useful for other types of slowly available fertilizers. For sulfur-coated urea, dissolution rate or coating thickness is needed to indicate availability. For IBDU, particle size and soil moisture content are needed. For natural organics, the permanganate value is of some use.

Rate of Release—Nitrification Studies

When a fertilizer containing organic nitrogen is incubated with soil, micro-organisms in the soil convert the nitrogen to ammonia. Under favorable conditions (near neutral pH, adequate aeration), the ammonia formed is quickly oxidized by soil bacteria to nitrate (nitrification). Measurement of the nitrate produced under carefully controlled conditions is thus a good laboratory indication of the rate of release of nitrogen from ureaforms and other organic nitrogen fertilizers.

We have found the nitrification method to offer a good qualitative basis for comparison of slowly available nitrogen fertilizers. Generalizing from a large number of laboratory experiments at 86° F (30° C), we arrive at the following projection of rate of nitrogen release from commercial Nitroform ureaform.

This pattern allows application of a relatively large amount of nitrogen in a single application, provides gradual release for up to 24 weeks, and leaves a portion for carry-over and utilization in the next growing season. To get an early response comparable to that from a soluble source, it is necessary to apply more ureaform nitrogen initially, or as is frequently done, to add a soluble source along with the ureaform.

Product Grades Available

Nitroform ureaform is available in both granular and powder forms. The granular form, Blue Chip nitrogen fertilizer, is designed for direct application in mechanical spreaders. It is also used in balanced fertilizer (N,P,K).

Powder Blue nitrogen fertilizer is the powder form. It is well suited for use in liquid-application equipment. One gallon of water will carry 1 pound of Powder Blue in a power sprayer. Screens should be removed from the spray system to avoid clogging, and a nozzle with a large orifice (9/64 inch or larger) should be used. Other fertilizer materials (P,K) normally applied in liquid form can be used along with Powder Blue as desired.

Another advantage of applying the powder form, in addition to its ready application in water suspension, is that it is somewhat more readily available than the granular form. Our nitrification data have indicated that the powder releases 1.3 to 1.65 times as fast as the granular.

Recommended amounts

On fairways, lawns and other similar turf areas, application of 10 to 15 pounds of Nitroform fertilizer per 1,000 square feet or 400 to 600 pounds per acre is recommended. Split applications are preferred with the heaviest application at the most important phase of the growth cycle. For cool-season grasses (bluegrass, fescue and bent) apply $\frac{2}{3}$ in the fall and $\frac{1}{3}$ in the spring. For warm-season grasses (bermuda, zoysia, centipede, and St. Augustine) apply $\frac{2}{3}$ in the spring and $\frac{1}{3}$ in the fall. For seedbed application, the year's supply is worked into the top 2 to 4 inches of soil.

On bentgrass greens, three applications of 7 to 10 pounds of Nitroform fertilizer per 1,000 square feet are recommended: the first in early spring, the second in early summer, and the third in early fall. A fourth application at half this rate may be needed in mid-summer until the residual nitrogen has built up. For seedbed application on average-size greens, use 25 pounds of Nitroform fertilizer worked into the top 3 inches of soil.

A striking feature of these recommendations is the relatively large amounts of nitrogen used in a single application. Thus 10 to 15 pounds of Nitroform fertilizer (3.8 to 5.7 pounds of actual nitrogen) is routinely put on turfgrass and other plants in a single application. Contrast these amounts with those of soluble fertilizer, where the rule of thumb is to use no more than 1 pound of nitrogen per 1,000 square feet in a single application and then to take the precaution of watering it in.

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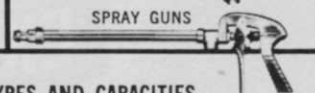
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METHYLENE UREA: DIFFERENCES IN UREA FORMALDEHYDES NOTED

By **George McVey** Senior Technical Associate, O.M. Scott & Sons, Marysville, Ohio

The development of nitrogen products derived from condensing urea with formaldehyde represented a significant advance in nitrogen fertilizer technology. It provided the basis for developing nitrogen-containing fertilizer products with some properties similar to natural organic nitrogen sources. These similarities include: (1) a controlled release of nitrogen and (2) a low burn potential. Additional beneficial properties provided by urea-formaldehyde (also known as methylene urea, MU) condensation products that are more beneficial than those provided by natural organics nitrogen sources include: (1) high nitrogen analysis (38 percent versus less than 10 percent nitrogen), (2) excellent consistency, (3) improved flexibility in adjusting nitrogen release characteristics, (4) lack of odor, and (5) economy.

Chemical properties

The nitrogen release characteristics of MU can be controlled by the method of manufacturing that is selected. Analytically the release characteristics are classified by the solubility of this product in water varying in temperature. Two temperatures are selected: (1) room temperature (22°C.) and (2) boiling water (100°C.). Based on the solubility at these two temperatures, the biological activity can be predicted. As the percent of the cold water insoluble nitrogen (CWIN) that is soluble in hot water decreases (NAI), the nitrification rate (conversion of MU to nitrates) decreases. The nitrification rate is dramatically reduced as compared with ammonium sulfate and urea. This rate can be reduced to a point that is relatively inactive biologically.

One of the primary benefits of MU is attributed to its low salt index. The low salt index at equal rates of material is dramatically reduced as compared with conventional fast release nitrogen sources. These differences are even more dramatic when compared on an equal nitrogen basis. Since the salt index is a measure of burn potential, it is obvious that on an equal weight or equal nitrogen basis, MU would have a much lower burn potential as compared with soluble nitrogen sources.

MU's slow release characteristics are also reflected in the rate of conversion to ammoniacal and nitrate nitrogen in the soil. The ammoniacal nitrogen level in the soil solution is up to four times higher when treated with urea as compared with the MU treatment. After 6 weeks, the ammoniacal nitrogen level is essentially zero regardless of the nitrogen source. In contrast, the nitrate nitrogen level dramatically increases as the ammoniacal ni-

trogen level decreases. This increase was only evident if the nitrogen source was MU. The nitrate nitrogen level continued at a high level for 120 days (50 to 100 ppm) if the soil was treated with MU. In contrast, soil treated with urea never had a nitrate level greater than 30 ppm. Urea readily leached from the media before conversion of urea to nitrates was realized, resulting greater pollution potential than with MU.

Biological properties

Controlled release nitrogen sources are often characterized by improved safety, increased residual, a more uniform growth pattern, and less total clipping removal as compared with turf treated with soluble nitrogen sources.

As the percent of cold water insoluble nitrogen increases, the degree of injury decreases. These differences are more dramatic when the fertilizer is applied to wet turf; however, they are still apparent on dry turf. At a CWIN of 42 percent, injury was not objectionable at all rates (1 to 4 pounds of nitrogen per 1,000 square feet) or methods of application (wet versus dry foliage). In contrast, complete formulations containing only 2 percent CWIN caused extreme foliar injury when applied to wet foliage using only 1 pound of nitrogen per 1,000 square feet under the conditions of this study (applied in late August under high temperatures).

When we compared two MUs relative to turf response, a substantial difference in turf color was noted. The spring greening response from a late fall fertilization was very slow when turf was treated with ureaform (Category 1) but was dramatically increased when treated with MU (Category 2). In this same experiment, the nitrogen source IBDU was also included. The initial response was comparable to that with ureaform whereas the residual of MU and ureaform was longer than for IBDU.

Spring applications of IBDU and MU (Category 2) were compared. In this study, initial greening was very slow when the turf was treated with IBDU even though rates of 2 pounds of nitrogen per 1,000 square feet were applied. In contrast, turf treated with MU exhibited a rapid spring greening response. The residual characteristics of these products were similar.

The residual of the MU (Category 2) was compared with that for urea. The initial surge of growth was reduced from 1.9 grams for turf treated with urea down to 1.1 grams when the turf was treated with MU (a 42 percent reduction in fresh weight).

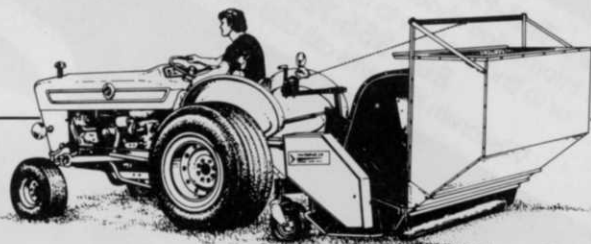


NITROGEN SOURCES FOR TURF FERTILIZATION

The reduction in initial surge growth is reflected in the residual. The differences from only one application, however, are not dramatic. When repeat applications of MU from Category 2 were used, the residual characteristics became more apparent. In this study, the fertilizer program was discontinued in the fall of the second year. Clipping fresh weights in the spring of the third year dramatically reflected the residual characteristics when MU containing 42 percent CWIN was compared with a product containing 2 percent CWIN. The color of the turf treated with the controlled release nitrogen source (23-7-7 42 percent CWIN) was comparable to that of turf treated with the fast release nitrogen source (10-6-4 2 percent CWIN) in 27 out of 32 observations over a 2.5-year period.

Turf growth is another measure of the controlled release properties of MU. The total fresh weight of clippings can be substantially reduced when turf is treated with MU as compared with urea. The weight of clippings removed over a 6-week period was reduced by one-third when Kentucky bluegrass was treated with MU as compared with treatment with urea. The lower weight of clippings removed is reflected in the fact that there is less tendency for scalping because of delayed mowing, a reduction in mowing frequency, and less labor for collecting and removing clippings. **WTT**

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IBDU: NITROGEN RELEASE IS UNIQUE FOR SLOW RELEASE

By Robert Rehberg, National Sales Manager, Estech General Chemical Corp., Winter Haven, FL

Proper management of nitrogen fertility is one of the keys to successful turf management due to its many effects on physiological processes. IBDU® is the trademarked name for Isobutylidene Diurea, a slow release fertilizer containing 31 percent nitrogen, marketed in North America by Estech General Chemicals Corporation. The n-release characteristics and properties of IBDU are uniquely different from those of other slowly available fertilizers and this discussion will highlight factors governing nitrogen availability and use from IBDU.

Preparation-The manufacture of IBDU is a simple mixing of isobutyraldehyde (IBA), which is a liquid, with solid urea. The product is then screened and bagged into two size ranges, a 0.5-1.0 mm. fine and a 0.7-2.5 mm. coarse.

The finished IBDU product is a small white granule which is not hygroscopic and will store indefinitely.

N Release Mechanism-IBDU particles dissolve and the molecule splits to give:

(a) isobutyraldehyde which volatilizes or is used as a food source by microorganisms.

(b) urea, which would undergo normal conversions to ammonium and nitrate forms.

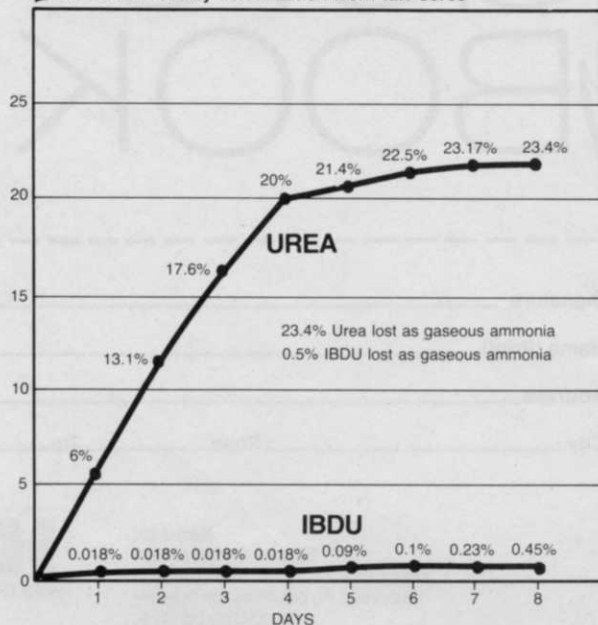
The hydrolysis of urea to ammonium carbonate occurs quickly in soils according to the following equation: $CO(NH_2)_2 + 2H_2O \rightarrow (NH_4)_2CO_3$ urea water ammonium carbonate.

Nitrobacteria could then convert the ammonium nitrogen to nitrate if temperatures are about 40° or above and other environmental factors are favorable. However, turf can utilize nitrogen in either form. The urea conversion would be the same regardless of parent material, UF, SCU or IBDU; however, the rate determining step for IBDU conversion to plant available forms is solubility, which is independent of bacterial activity. This distinguishes IBDU from UF which requires bacterial conversion, a highly temperature dependent process, and SCU which becomes available as a result of holes in the coating, cracking of particles, microbial oxidation of the sulfur coating, osmosis, or other factors.

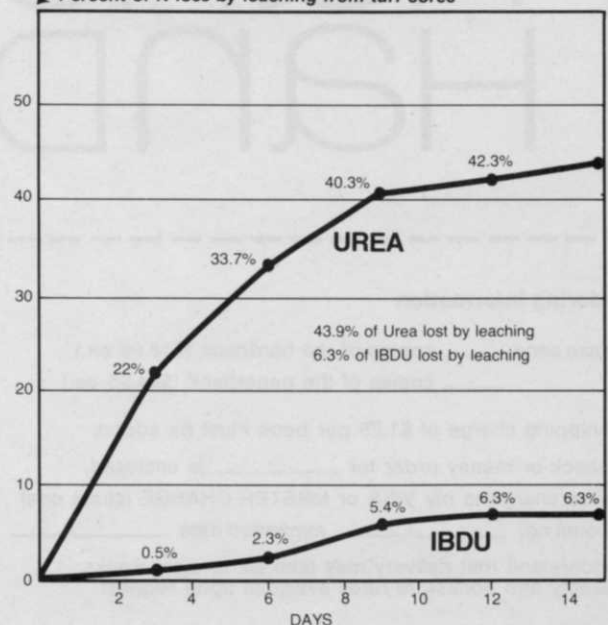
IBDU release is temperature dependent only as temperature effects solubility, so at constant 40° F and 80° F temperatures approximately 50 percent and 75 percent of the nitrogen would be released respectively over a three month period. Freezing temperatures would stop water movement and shut off IBDU. This relationship works well for the turf manager; the grass plant does not grow as rapidly in cool weather so not as much N is required. IBDU will release longer into fall and sooner in the spring during the important carbohydrate assimilation period, resulting in greener, healthier turf.

We are often asked the question, "What happens

Percent N loss by volatilization from turf cores

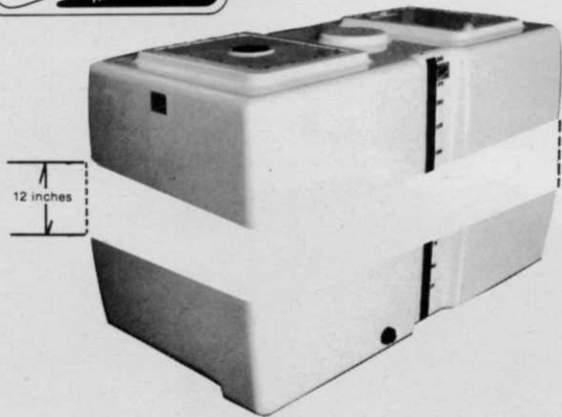


Percent of N loss by leaching from turf cores





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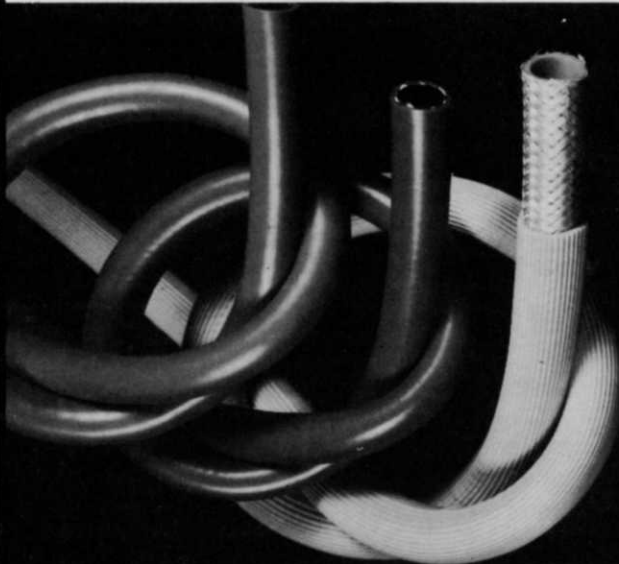
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if we get a heavy rain?" The answer is: some IBDU will dissolve. Continuous leaching tests in glass cylinders show that 36 in. of water is needed to dissolve powdered IBDU and about 80 in. water is required to dissolve a 1.4 - 1.6 mm. size. Therefore, a five in. deluge of rain would release about six percent of the N from coarse IBDU or about 0.1 lb. of N from a 1.5 lb. N/1000 ft.² application.

Efficiency-A nitrogen source is efficient if most of applied N is absorbed by the plant and not lost in the environment by leaching past the root system, volatilization, or other factors. The preceding two graphs are a result of the work of Falkenstrom and Turgeon at the University of Illinois comparing leaching and volatilization of IBDU to Urea.

The first graph demonstrates the amount of nitrogen lost by volatilization from turf cores over an eight-day period. Over this time 23.4 percent Urea - N was lost as gaseous ammonia versus only 0.5 percent N loss from IBDU.

The second graph shows leaching losses of 43.9 percent from soluble urea and only 6.3 percent from the slow release IBDU over 14 days.

These studies were conducted in a laboratory microecosystem apparatus that monitored all gases and liquids entering and leaving the system.

The results of field studies by Brown, Duble, and Thomas of Texas A&M were published in the January 1977 USGA Green Section Record. They found on sand greens, as much as 22 percent of the N from soluble sources was lost by leaching in the first three weeks giving high nitrate contamination of leachate water. Less than two percent of the nitrogen applied as IBDU was lost.

It is obvious from these studies that nitrogen from IBDU trickles slowly past the root system, increasing the total uptake over time resulting in better nutrient efficiency and less nitrogen pollution of water when compared to soluble N sources.

Another efficiency factor of IBDU is that it is a single compound and not composed of polymers as is the case with ureaformaldehyde materials. All the nitrogen from IBDU is available in a single growing season. Some UF polymers may require several years to break down and become available.

Lawn care applicators have especially been pleased with this property of IBDU since with UF they may be investing 15-25 percent of the fertilizer cost for a competitor's benefit if they lose the customer.

Dormant Fertilization- Our research results from seven different universities were unanimous in showing IBDU to be a superior nitrogen source for producing excellent turf in the spring after an application the previous fall on cool season grasses. The best program, varying somewhat by location, is three applications of 1-1½ lbs. N per 1,000 ft.² per year; May-June, August-September, and November-December. The last application should be applied when vertical growth has stopped or approximately 30-40 days before expected ground freezing.

IBDU also works well on overseeded Bermuda-grass in southern areas.

WTT



SULFUR-COATED UREA: COVER CONTROLS NITROGEN RELEASE

By **S.E. Allen**, Research Agronomist, Tennessee Valley Authority, Muscle Shoals, Alabama

Potential benefits from controlled-release nitrogen (N) fertilizers include: 1. More efficient crop use of N (control of luxury uptake) 2. Decreased leaching of nitrate 3. Lower toxicity (reduced ammonia or salt injury or both) 4. Longer lasting, more uniform nutrient supply (fewer applications needed) 5. Reduced volatilization losses to the atmosphere (ammonia or gaseous products of denitrification).

Most controlled-release fertilizers, both synthetic and natural, fall into one of three classes: 1. Biodegradable organic compounds yielding ammonia or nitrate or both through the action of soil microorganisms (ureaform and natural fertilizers) 2. Organic compounds of low water solubility that slowly hydrolyze to form urea, which is then converted to ammonia and nitrate (IBDU) 3. Coated soluble sources that release the nutrient through membrane rupture or diffusion of solutes through pores or imperfections in the coating (SCU).

This paper is primarily concerned with the mode of action of SCU and its relationship to crop response.

Sulfur-coated urea is now available from three suppliers in North America. All use the process developed by TVA at Muscle Shoals, Alabama. In its simplest form, the process involves heating urea (granules or prills) to approximately 140°F., followed by spray application of molten sulfur (S) at 300°F. in a rotating drum apparatus. A sealant coat of polyethylene oil or microcrystalline wax is applied, and the final product is conditioned with diatomaceous earth or some other suitable conditioner. Typical products contain about 36 percent N, 16 percent S, and 5 percent sealant plus conditioner. Since an S coating of finite thickness is required, large and small granules of SCU often contain less or more S, respectively, than the average value reported. By varying coating weight or sealant or both, products differing in initial solubility may be prepared. For quality control purposes, products are often characterized by determining the amount of N released in 7 days in water at 100°F. Thus, SCU-30 refers to a product in which 30 percent of the N is released under the prescribed conditions. The 7-day dissolution value is primarily a measure of the relative number of imperfectly coated granules. Release of N from the insoluble fraction involves other variables to be discussed later.

The dissolution pattern may be estimated by extending the 7-day test over a longer period with analysis of N released at appropriate intervals. The results obtained, however, may be difficult to in-

terpret in terms of expected field performance. More useful data have been obtained from experiments involving placement of SCU in soil under varying conditions followed by recovery and analysis of undissolved granules at appropriate intervals. Many trials have been conducted, all of which support the premise that individual granules release N rapidly once all the coating fails and water gains access to the substrate. Thus, controlled release of N results from many granules that supply N at different times rather than from gradual release of N from all granules at the same time. Once this fact was established, it was possible to characterize the dissolution pattern by recovery and analysis of undissolved granules. That portion of applied N not recovered is assumed released to the soil as water-soluble urea.

It has been shown by this procedure that many factors regulate release of N from SCU; a brief summary of the more important variables follows: 1. Release of N from SCU is accelerated in warm soil, which suggests that soil microorganisms are at least partially involved in coating failure. It has not been determined whether biodegradation of sealant or S is the dominant process. However, soil microorganisms do oxidize the S coating, yielding crop-available sulfate. Following coating failure, the flow of urea solution into the soil is primarily an osmotic process, which is much less sensitive to changes in soil temperature. 2. Experiments conducted in controlled environment regimes show that soil moisture stress increases the rate of dissolution of SCU. Thus, the rate of release in a silt loam soil at 75°F. was in the order: dry (10 percent H₂O) > alternating moist/dry > continuously moist (20 percent H₂O). Lowering the temperature to 55°F. slowed dissolution but did not change the ranking of soil moisture regimes. 3. Experiments conducted in both field and laboratory suggest faster dissolution with surface placement than with mixed placement. This effect is believed to be related to much wider ranges in soil temperature and moisture stress at the soil surface. 4. Root action apparently accelerates dissolution of SCU. This conclusion is based on recovery of undissolved SCU from fallow soil, as compared with cultures cropped with bermudagrass. 5. Dissolution was not affected by soil pH in the range 5 to 8. 6. That portion of SCU not dissolved is protected from loss during leaching incidents.

Results from many experiments conducted under widely varying conditions suggest that 5 to 30 percent of applied SCU may not dissolve during the season of application. There is evidence that

most of the carryover becomes available to crops in later years.

Crop Response to N in SCU

The chief objective of SCU research has been to improve crop yields by more efficient utilization of applied N. A wide variety of field and greenhouse experiments has been conducted with many crops throughout the world. This discussion is limited to results from forage and turfgrasses. The following brief summary is concerned with principles, rather than data from individual experiments: 1. More uniform seasonal growth usually results from SCU than from a single annual application of soluble N sources. In numerous experiments, the growth pattern has been similar to that obtained from multiple applications of soluble N. 2. In some greenhouse experiments, total yield from SCU has exceeded that from soluble N sources. Calculation of N uptake suggests that control of luxury uptake in early clippings is the dominant factor. 3. In other experiments, total yield from SCU has been less than that from soluble N. Recovery of undissolved SCU shows that the difference may be explained by rate effects produced by incomplete dissolution of SCU in the season of application. 4. Since dissolution of SCU is temperature sensitive, products with higher initial dissolution have given better results in northern areas; less soluble formulations may be preferred in the South, where soil temperature is higher and the growing season is longer. 5. Less than one-third of the total N applied from SCU is readily soluble. Thus, turf damage from SCU has been less than that from comparable rates of soluble N sources. 6. Losses of ammonia from surface application of N fertilizers are difficult to measure under field conditions. However, N recovery studies suggest that such losses may be reduced by use of SCU.

Crop Response to S in SCU

The coating in SCU is elemental S, a form not available for crop use until it is oxidized to sulfate by soil microorganisms. Sulfur oxidation studies invariably show that finely divided S mixed with the soil is oxidized in a few weeks, while prills or granules oxidize very slowly. The difference in oxidation rate is related to the surface area of S particles in contact with soil. On this basis, one would predict delayed availability of S in SCU. The N:S ratio in SCU is about 2:1; thus, normal N rates supply two to five times the S requirement for most crops. Greenhouse studies with low-S soils where crops respond to both N and S permit the following conclusions: 1. Oxidation of S in SCU commences rapidly in warm soil, and crop response to S in SCU has been measured in 2 months. Since the rate of S is higher than necessary, oxidation of a small portion of total S apparently supplies crop needs. 2. Yield response and uptake of N and S clearly show that SCU is an excellent controlled-release source of both nutrients. 3. On a long-term basis (6 months of cropping), yield of bermudagrass not limited by N supply was greater from SCU than from Na_2SO_4 . The difference was attributed to control of luxury uptake of sulfate in early clippings. 4. Increase in soil acidity by the H_2SO_4 formed through oxidation of S in SCU should not be a problem in most soils.

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FORMOLENE: SHORT CHAIN UF PROVIDES STABLE SOLUTION

By John Dietrich and Robert Doberneck, Specialty Fertilizer Department, Ashland Chemical Co., Columbus, Ohio

Nitrogen fertilizers have been around for a long time. **Solution** fertilizers have been around for a long time. But until recently, these solution fertilizers were really suspensions, not true solutions. Formalene™ is a true solution, controlled-release nitrogen fertilizer manufactured by Ashland Chemical Company.

Formalene™ is contained in a water solution of "short-chain" urea formaldehyde compounds, principally methylol-urea along with urea.

During the manufacturing process for producing these and other urea-formaldehyde products a large quantity of urea containing a high percentage of nitrogen is reacted with a small quantity of formaldehyde at moderately high temperatures in the presence of catalysts for a precise time period. This reaction causes the formation of a number of urea formaldehyde compounds which, as "short chain" methylol ureas, methylene diureas, and dimethylol ureas, will remain in water solution when kept alkaline at around 9 to 10 pH.

Some manufacturers elect to continue the polymerization process converting these soluble "short chain" compounds into "longer chain" urea formaldehyde water insoluble polymers which are subsequently chipped or powdered and bagged for distribution to the marketplace.

Whereas, "short chain" water soluble UF materials, methylol ureas, are shipped as bulk or drummed liquid concentrates. This concentrate contains only 15 percent water, has a nitrogen concentration of 30 percent, and does not salt out until the temperature drops below minus 20 degrees F.

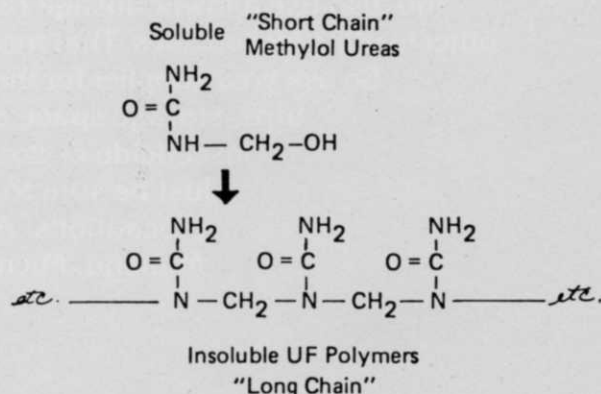
A straight urea solution contains 57 percent water, 43 percent urea, 20 percent nitrogen, and salts out below 30 degrees F. This relatively high saltout temperature requires storage tanks to be heated or insulated to prevent saltout. This generally not necessary for Formalene™.

Also, urea solutions are a neutral pH while Formalene™ is kept usually around a pH of 9 or 10 for it to remain as a stable water solution.

Formalene™ is both a foliar and root feeding liquid nitrogen. While it is possible to burn grass with "short chain" methylol ureas, their nitrogen phytotoxicity potential is significantly lower than with urea solutions; and when they are applied at rates of one to two pounds of nitrogen per 1,000 square feet, burn has not been a factor when used with normal water dilutions.

The moderate initial response of Formalene™ reduces the tendency for disease problems associated with the excessive burst of growth frequently experienced with urea applications particularly in the spring. The nitrogen release period is around 8-12 weeks. Also, it appears that there is a higher

FORMATION OF UF POLYMERS



degree of nitrogen utilization according to our first commercial year experience. If proven, this would permit a reduction in total applied nitrogen to still get the desired results. A reduction from 4 lb. per year per 1,000 square feet to 3 lb. may be possible.

Some quantity of Formalene™ must be stored at your shop. But, the task of handling many bags of dry material is eliminated. A liquid storage facility is required.

The most important advantages of a liquid fill system over a system using dry material from bags include: reduced labor, reduced mixing and loading time; and increased accuracy with liquid metering.

Formalene™ holds promise for fertigation applications and as an additive to organic manure mixtures.

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**Formolene™ Fertilizer
Comparative Performance Properties
(After Application)**

Property	Formolene Solution	UF Powder Suspension	Urea Solution
Burn Potential	Low	None	Med-Hi
Initial Response	Moderate	None-Low	High
N-Release Period*	8-12 Weeks	2-3 Years	4-8 Weeks
N-Utilization* (by the plant)	85-95%	70-80%	50-85%

*Estimates pending verification in continuing university and field tests.