20TH ILLINOIS TURFGRASS CONFERENCE

DECEMBER 18-20, 1979

Arranged and conducted by

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ILLINOIS TURFGRASS FOUNDATION

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This publication was compiled and edited by John R. Street,
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GOLF TURF SESSION (continued)

NITROGEN SYMPOSIUM

Fate of Nitrogen in Turf

A.J. Turgeon

Turf differs from annual-crop systems in at least three important respects: the turfgrass community is perennial; turfgrasses form dense communities that provide a nearly contiguous ground cover; and a semistable layer of residual biomass, conventionally referred to as thatch, frequently exists atop the soil surface. Because of these differences, the fate of nitrogen and other materials applied to turf may differ substantially from that observed in annual-crop systems.

The Turf Profile

Examination of the vertical profile of a newly established turf reveals the soil and roots of the young plant community growing within it. Where a rhizomatous turfgrass is used, the upper portion of the soil also contains the rhizomes, usually within the top few centimeters. On some sites, a layer of organic material, called "thatch," may eventually develop above the soil surface. Examination of this turf profile reveals many rhizomes and roots growing within the thatch layer (Turgeon, Hurto, and Spomer, 1977). In extreme cases, virtually all of the roots and rhizomes are contained within the thatch, and the turf is easily separated at the soil surface.

On greens and other turfs that receive frequent topdressing, the layer of organic material may contain so much soil that it differs little in appearance from the underlying soil. This combined medium of soil and thatch is called "mat." The frequency and amount of topdressing soil required are usually dependent upon the rate at which the thatch develops. Some golf course superintendents top-dress whenever the thatch layer accumulates to the thickness of a pencil, or about 6 millimeters. A given turf profile may contain from one to three distinct layers, including thatch, mat, and soil.

In research at the University of Illinois at Urbana-Champaign (UIUC), comparisons of thatch and Flanagan silt loam (soil) from a Kentucky bluegrass turf revealed that the thatch had considerably more aeration porosity and thus retained less plant-available moisture than did the soil (Hurto, 1978). Measurements of the cation exchange capacity (CEC) of thatch and soil showed that an essentially pure thatch (organic matter > 90 percent) was higher in CEC, expressed as milliequivalents per 100 grams (Danneberger, 1979). However, since the bulk density (BD) of the thatch was much lower than the soil BD, the CEC expressed as milliequivalents per 100 centimeters, or CEC•BD, was actually lower in the thatch than in the soil. Because plants grow in a specific volume rather than in a specific weight of medium, the CEC•BD is a more meaningful value for comparing different media. Therefore, the relatively low CEC•BD value of thatch indicates that its nutrient-retention capacity is also low.

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Where a specific amount of soil has been incorporated into a thatch layer, the CEC•BD of the resulting medium (mat) increases in proportion to the amount of soil added (Danneberger, 1979). Methods for incorporating soil into thatch include: topdressing; core cultivation followed by reincorporation of the soil cores into the turf; and vertical mowing to a depth that effectively brings the soil up to the surface. Depending upon the thickness of the thatch layer, it may be necessary to perform several shallow vertical mowings prior to soil incorporation in order to reduce the accumulation of organic debris; otherwise, a layered condition may result because of an incomplete mixing of the soil and thatch materials.

Pesticide-Induced Thatch

Several pesticides, including bandane and calcium arsenate, have been reported to induce thatch development in an otherwise thatch-free Kentucky bluegrass turf (Turgeon, Willis, and Freeborg, 1975). This effect was largely the result of the inhibiting effect of the pesticides on earthworm activity. Comparisons of adjacent thatchy and thatch-free plots revealed that the thatch predisposed the turfgrass to greater disease incidence and proneness to wilt. Also, fewer roots and rhizomes were evident in the soil underlying the thatch layer than in the surface soil from the thatch-free turf. Physical examination of the thatch revealed the presence of numerous roots and rhizomes in the thatch layer. Therefore, where thatch develops, turfgrass rooting and rhizome growth occurs preferentially in the thatch layer.

Subsequent measurements of water infiltration rates showed considerable reductions where thatch developed (Jansen and Turgeon, 1977). However, this result was determined to be caused by an altered physical condition of the soil underlying the thatch rather than by the thatch per se. Where thatch development was induced by the pesticides, physical measurements with soil cores extracted from the thatchy and thatch-free turfs revealed higher bulk densities, but substantial reductions in hydraulic conductivity, aeration porosity, organic matter content, and shrinkage upon drying.

Presumably, an effective means for controlling the thatch, either through physical removal or soil incorporation, would result in an amelioration of soil physical properties and improved rooting and rhizome growth.

Nitrogen Studies

Studies were initiated at the UIUC in 1976 to determine the relative rates of leaching and volatilization of nitrogen from urea and isobutylidene diurea (IBDU) applied to turf cores composed of either thatch or Flanagan silt loam. Results showed that leaching of the nitrogen was substantially greater from thatch than from soil, and that urea-N was much more prone to leach than was IBDU-N (Falkenstrom, 1978). Measurements of nitrogen retention by the media showed that almost no urea-N was retained by the thatch under the experimental conditions, whereas most of the IBDU-N was retained within the upper portion of the cores. Conversely, more urea-N and less IBDU-N were retained by the soil than when the same treatments were applied to thatch.

These results were consistent with the conclusions of Danneberger (1979) that thatch has poorer nutrient-retention properties than soil because of its low CEC•BD. Conversion of soluble urea to ammonium ions (NH_4^+) would result in adsorption of the NH_4^+ on negatively charged sites. Because of the relatively low numbers of these sites in a specific volume of thatch, less NH_4^+ would be retained than in a soil type with higher CEC•BD. Also, the abundance of aeration pores in thatch results in higher percolation rates and, therefore, more nitrogen leaching than in a soil of lower aeration porosity.

With a slowly soluble nitrogen carrier such as IBDU, the rate at which NH_4^+ ions are generated is considerably slower than for urea and is influenced by moisture, temperature, and possibly pH. Thus, regardless of the physical and chemical properties of the growth medium, nitrogen retention is induced by the fertilizer formulation; slowly soluble particles of the fertilizer become inbedded in the upper portion of the growth medium, and these particles "release" nitrogen at rates that are dependent upon local environmental conditions. Because moisture is such an important factor in the solubilization of nitrogen from IBDU, any drying of the upper portion of a thatch medium would reduce the solubilization rate. In contrast, prolonged periods of moisture retention by a silt loam soil would favor solubilization of nitrogen from IBDU and, therefore, result in less retention.

Results from volatilization studies have showed that more conversion of urea to ammonia (NH_3) occurred in thatch than in soil and that urea was much more prone to nitrogen volatilization loss than was IBDU (Falkenstrom, 1978). As with leaching, the efficiency with which nitrogen is used in turf is thus influenced by the nature of the carrier and of the growth medium to which it is applied. Further work is continuing to determine quantitatively the influence of various environmental and cultural factors on the percentages of applied nitrogen that are lost from turf through avenues such as leaching, volatilization, and denitrification.

Current Analysis of Nitrogen Fate in Turf

The efficiency with which nitrogen is utilized in turf is influenced by the type of nitrogen carrier employed and the environment immediately surrounding the turfgrass community. Slowly available nitrogen carriers, including slowly soluble and slow-release forms, are less susceptible to leaching and gaseous (volatilization) losses than are quickly available carriers, especially in coarse-textured media (thatch, sand) from which these losses are most likely to occur. Therefore, greater reliance upon slowly available nitrogen carriers in a fertilization program should improve nitrogen efficiency. Furthermore, any effective measures for increasing the CEC•BD and for reducing the excessive aeration porosity of coarse-textured media should result in an increase in nitrogen efficiency because of increased NH_4^+ and water retention.

In thatchy turfs, such measures would include core cultivation followed by reincorporation of the soil, topdressing with soil from a foreign source, and deep vertical mowing to bring soil up through the thatch layer.

Removal of clippings from mowing also removes the nitrogen contained within the leaf tissue; however, returning the clippings does not necessarily mean that all of the tissue nitrogen becomes available to the turfgrass. Depending upon environmental conditions, much of this nitrogen may be lost to the atmosphere as NH_3 in conjunction with decomposition of the clippings.

Additional research is required to quantitatively determine the influence of genotypic, atmospheric, edaphic, and cultural factors on nitrogen losses and to develop cultural strategies for optimizing nitrogen efficiency in turf.

References

Danneberger, T.K. (A.J. Turgeon, advisor). 1979. Edaphic properties of thatch and thatch-like derivatives in turf. M.S. thesis, University of Illinois at Urbana-Champaign.

Falkenstrom, K.E. (A.J. Turgeon, advisor). 1978. The influence of thatch on the mobility and transformation of nitrogen carriers applied to turf. M.S. thesis, University of Illinois at Urbana-Champaign.

Hurto, K.A. (A.J. Turgeon, advisor). 1978. Impact of thatch on herbicide activity and its characterization as a turfgrass growing medium. Ph.D. thesis, University of Illinois at Urbana-Champaign.

Jansen, I.J., and A.J. Turgeon. 1977. Indirect effects of a thatch-inducing herbicide on soil physical properties under turf. *Agronomy Journal* 69:67-70.

Turgeon, A.J., K.A. Hurto, and L.A. Spomer. 1977. Thatch as a turfgrass growing medium. *Illinois Research* 19(3):3-4.

Turgeon, A.J., W.N. Willis, and R.P. Freeborg. 1975. Thatch development and other effects of pre-emergence herbicides in Kentucky bluegrass turf. *Agronomy Journal* 67:563-65.

Development of a Microecosystem for Studying the Fate of Pesticides in Turf

B.E. Branham and A.J. Turgeon

Microecosystems have been shown to be effective tools in measuring the biological fate of pesticides in the environment. Use of radioactive compounds allows a balance sheet approach to pesticide fate. Metabolites that have been volatilized, leached, or degraded can be easily measured. The turf microecosystem at the University of Illinois at Urbana-Champaign has been under development for the past two years and is undergoing final testing in preparation for experiments on the fate of DCPA and other preemergent herbicides.

The microecosystem consists of a media base, atmospheric chamber, automatic irrigation, analytical trapping devices, thermocouples, and a data logger for continuous environmental monitoring. The media base is constructed of brass and includes a ½-inch thick porous ceramic plate supporting a turf slab measuring 12 x 12 x 12 inches (length times width times depth). A drainage tube connects the 1/8-inch free space beneath the filter to a leachate flask and to a vacuum pump. Under continuous suction, water movement through the turf slab will approximate that occurring in field turf. Periodic sampling of the turf slab followed by sectioning and analysis will enable us to monitor the movement and metabolism of topically applied pesticides over time.

The atmospheric chamber, constructed from plate glass and measuring approximately 1.2 cubic feet, sits atop the media base. Holes drilled near its base and at the top allow air movement into and out of the chamber. A 3/8" teflon tube brings the airstream out of the chamber and through a calcium sulfate trap to remove any water vapor in the airstream. A flowmeter is used to measure and regulate the volume of air leaving the chamber.

The analytical trapping system consists of a U-tube immersed in a dewar cold trap and two bubblers filled with sodium hydroxide solution. The U-tube will condense a volatilized pesticide or its metabolites, and the bubblers will trap carbon dioxide released from complete metabolism of the pesticide. Preliminary experiments show a 93 percent trapping efficiency of released carbon dioxide. Each microecosystem has two analytical trapping systems to allow continuous monitoring without interruption for sampling. Thermocouples positioned within the microecosystem continuously monitor soil and air temperatures. All thermocouples are connected to a Fluke 2240B datalogger for measurement and recording of temperature and moisture data. Four systems are housed inside a large growth chamber to provide environmental control and regulation.

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Nitrogen Fate Studies in Turf

W.A. Torello and A.J. Turgeon

A microecosystem has been developed to observe the fate of agricultural chemicals in closed, controlled environments, closely mimicking the natural system. These systems enable the researcher to develop a "balance sheet" for nitrogen (N), accounting for all avenues of N-loss within the system. It is well known that only 50 percent or less of applied N is taken up by the plant under most circumstances. Overemphasis has been placed upon nitrate leaching losses, N immobilization, and plant uptake, after which the remainder of N loss is assumed to be gaseous. The recent development of more sensitive analytical tools has renewed interest in directly measuring gaseous loss. These findings indicate that gaseous N losses have been greatly underestimated and, in some cases, may be as high as 40 percent of the applied nitrogen. The newly developed microecosystems make possible quantitative recovery of applied N lost through nitrate leaching, ammonia volatilization, and denitrification as well as accounting for N immobilized in the soil.

The turf microecosystem developed at the University of Illinois at Urbana-Champaign consists of a brass base fitted with a porous ceramic plate elevated 1/8 inch above the bottom to allow natural flow of leachate, which is vacuum pumped into a leachate flask for continuous N analysis. Water movement stimulated by the continuous suction closely approximates turf field conditions. Acetylene is continuously flushed through the turf slab from perforated copper tubing placed directly under the turf. A 1.0 to 5.0 percent concentration of acetylene in the soil inhibits the reduction of nitrous oxide to N_2 and thus allows complete trapping and quantitative analysis of gaseous N evolved through denitrification.

An atmospheric chamber constructed from plate glass and measuring approximately one cubic foot is placed on each brass base, forming a tight seal. Holes drilled near its base allow air movement into the chamber and over the turf. Suction of 1 liter per minute originating at the top of the chamber pulls out all incoming air as well as gaseous nitrogen effluxes from the turf slabs into various chemical traps to capture water vapor, carbon dioxide, ammonia, and nitrous oxide. Ammonia and nitrous oxide evolving from the turf slab are analyzed during every 24-hour period. Periodic sampling of thatch, underlying soil, and turf clippings provides data on immobiiization and uptake of N.

A total of six systems were placed within a large controlled environment chamber so that temperature and light could be controlled for each experiment. Efficiency tests were performed in each atmospheric chamber by slowly dripping 15 milliliters of 1.0 normal sodium hydroxide into a beaker containing 0.3 grams of ammonium sulfate (63.0 milligrams N). Over a 24-hour period, all nitrogen as

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ammonium sulfate was converted to ammonia within the chambers and subsequently trapped in 3.0 percent boric acid. Titration of the boric acid with dilute sulfuric acid (0.0138 N) exhibits nitrogen recoveries of between 96.5 and 99.8 percent.

Preliminary investigations using a more primitive but similar system were performed to determine the percentage of N lost from turfgrass clippings. Samples consisting of 15 grams of Kentucky bluegrass clippings alone or mixed in soil were incubated under gas trapping chambers for 14 days. The chambers were continuously swept with ambient air into 3.0 percent boric acid to capture ammonia. The results are shown in Table 1. Ammonia losses increased to a maximum in 10 days, after which a slow decline was observed. Clippings mixed with soil exhibited lower losses of N (8.6 percent) than clippings placed on top of soil (24 percent). These results suggest that turfgrass clippings may not return all of the nitrogen to the soil but may lose appreciable amounts to the atmosphere as ammonia and, possibly, other nitrogen-containing gases. Further analysis using the turf microecosystems should provide more insight into this problem.

Table 1. Evolution of Ammonia from Decomposing Clippings Taken from a Baron Kentucky Bluegrass Turf [a,b]

	Incubation time (days)						
Source	3	7	10	11	12	14	Total
			(milligrams nitrogen)				
Clippings above soil	3.4	12.3	18.8	4.5	5.4	2.2	46.9
Clippings/ soil mixture	0	2.2	10.2	0	0	4.3	16.8

[a] Kjeldahl analysis of the clippings revealed 5.3 percent nitrogen on a dry weight basis.

[b] All treatments consisted of 15-gram samples (wet weight) and were replicated three times.

Controlled-Release Pesticide Formulations for Annual Grass Control in Turfgrass Sites

David R. Chalmers and A.J. Turgeon

Commercial formulations of preemergence herbicides are applied in a readily available form, free to react with environmental components of the turfgrass ecosystem. Applications are made to achieve a concentration that is above a certain level needed to control germinating annual grasses (the threshold concentration for efficacy, or TC_e) but below a level that would cause injury to the turf community (the threshold concentration for phototoxicity, or TC_p). The period of time during which the herbicide concentration remains above the TC_e is termed the effective period of control (EPC). The EPC for any herbicide will depend upon its biological activity. Biologically active herbicides can be depleted through volatilization, leaching, sorption by organic matter, absorption by plants, and chemical, photochemical, and microbial degradation. Reductions in herbicide activity with time decrease the EPC. Using a biologically active preemergence herbicide usually necessitates the use of repeat applications before the initial application is reduced to concentrations below the TC_e. This practice inevitably results in increased labor costs.

A possible alternate method of extending the herbicide activity is to regulate the bioavailability of the active ingredient through the use of controlled-release preemergence herbicide formulations. Lewis and Cowsar (1977) defined a controlled-release formulation as a combination of a biologically active agent and an excipient, usually a polymer, arranged to allow the delivery of the agent to the target at controlled rates over a specific period. Controlling the bioavailability also controls those avenues through which biologically active compounds can lose their effectiveness. Controlled-release formulations therefore have the potential of requiring less active ingredient, thus reducing the phytotoxic effects of marginally safe materials and eliminating the need for repeat applications of short-lived compounds.

At the University of Illinois at Urbana-Champaign, in cooperation with USDA personnel from the Northern Regional Research Center, research is being conducted to evaluate the potential for use of controlled-release preemergence herbicide formulations for annual grass control in turf.

The controlled-release carrier under study is starch xanthide, a granular material made from corn starch. The starch xanthide formulation physically encapsulates the herbicide within a granular porous matrix. Release of the herbicide occurs by diffusion through the pores and by decomposition (microbial or physical) of the starch matrix. These avenues for releasing the active ingredient can be altered by varying the ratios of the chemicals used during synthesis. Starch xanthide, then, is a controlled-release carrier that can be formulated to produce a wide variety of compounds that possess different release characteristics.

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Results obtained with starch-xanthide-encapsulated preemergence herbicides are dependent upon herbicide release rates under field conditions that are sufficient to control germinating annual grasses in turf. Commercial formulations (CF) of preemergence herbicides have all of their active ingredients in a bioavailable form that upon application immediately brings the herbicide concentration above the TC_e. Starch xanthide formulations, however, effectively remove the herbicide from the environment until it is released. It therefore will take longer than the CF to supply a concentration of herbicide above the TC_e. If weed seeds germinate before the TC_e is reached, control will not be achieved. It may therefore be unreasonable to require a controlled-release formulation to possess both fast release characteristics to control early germinating weeds and then to release at controlled rates above the TC_e to gain extended control. To overcome this potential obstacle in turf, it may be necessary to combine the beneficial effects of the commercial formulation (good initial control) with the starch-xanthide-encapsulated formulation (increased EPC) to achieve a bimodal-type release from one application.

Controlled-release formulations show excellent potential for developing herbicide application systems that are safe and effective without being prohibitive in cost. However, before they can become an accepted herbicide application technique for turf, more research is needed to predict how starch xanthide formulations will react under a variety of environmental conditions.

Literature Cited

Lewis, D.H., and D.R. Cowsar. 1977. Principles of controlled release pesticides. *ACS Symp. Ser.* 53:1-16.

Damage to Turfgrass Areas by Wildlife

Ron Ogden

Several species of wildlife cause damage to lawns, golf courses, and other turfgrass areas. Waterfowl (which includes ducks, geese, and coots) often feed on grassy areas that are adjacent to lakes, ponds, or streams. This use usually occurs during the spring migration when large numbers of birds are concentrated together and the grass has just begun to grow. The damage is usually not severe unless soil conditions are such that heavy grazing causes compaction or the grass plants are pulled up by the roots. Sometimes people build homes or apartment buildings around lakes or ponds that attract ducks and geese. The birds loaf around on the people's lawns, leaving feathers and droppings that can become quite unsightly.

In most cases you can easily scare waterfowl from damage areas by using propane exploders and cracker shells. Where they become domesticated around housing developments, they can be fenced in or out, as the case may be. Sometimes we have trapped and removed the offending birds.

The starling is the only other bird species that I have had complaints about regarding damage to turfgrass. Flocks of starlings were feeding on grubs on the greens of a golf course. In doing so they left the entire green covered with little cone-shaped holes. Using a good turf insecticide stopped this damage quickly.

The number of mammal species causing damage to turfgrass areas is more extensive than for birds, but most of the damage is caused by two species.

The number-one culprit is the mole. An individual mole can damage a sizeable area in search of food. When several moles are together, they can cause extensive damage. You can often control moles by using a good soil insecticide because they feed heavily on grubs and earthworms. The lack of good food causes them to leave the area. (This sometimes, however, makes your neighbor unhappy.) Trapping is an effective way to control small populations of moles. Toxicants are sometimes used but are more dangerous.

The pocket gopher can also cause extensive damage to grass areas. The mounds are unsightly and are hard to mow over. It is difficult to control gophers over large areas without using a burrow builder. This tool creates a tunnel at the same depth as the gophers' underground runways and automatically dispenses toxic bait into the tunnel. Small areas can be treated with a toxicant using a probe. The toxicant most widely used is strychnine, which is now on the restricted-use pesticide list. Strychnine baits are safe when placed in underground runways, where they are not available to nontarget animals. Trapping can also be effective as a controlling method.

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Ground squirrels, mainly the thirteen-lined variety, sometime get into lawns and fairways. They can be trapped easily or, for a large infestation, the toxicant discussed for gopher control can be used. For ground squirrels, however, the toxicant must be placed directly into the open burrow.

Other animals damaging turfgrass areas include woodchucks, tree squirrels, muskrats, field mice, and deer. Tree squirrels will sometimes bury their collected food in lawns and other grassy areas. Muskrats tunnel into banks and cause cave-ins along ponds and streams. They also feed on dandelion roots, which they dig from lawn areas. Field mice may infest heavy grass areas but are not a problem where the grass is mowed short, exposing their surface trails and runways. Deer tracks in moist or newly seeded sod can be a problem on golf courses and other critical areas.

Most of this type of damage can be stopped by removing the offending animal. You can trap all except the deer after you have received a permit from the Illinois Department of Conservation. Deer can be fenced out or scared away by using a repellent. Tankage placed in small cloth bags works in most cases. Other commercial repellents are available.

My office publishes leaflets on control of most of the species mentioned:

AC 302 "Controlling Field Mice in Tree Plantations"
AC 303 "Controlling Field Voles (Field Mice)"
AC 306 "Controlling Muskrats"
AC 307 "Controlling Pocket Gophers"
AC 324 "Controlling Tree Squirrels"
AC 325 "Controlling Woodchucks or Groundhogs"
AC 404 "Controlling Deer"

You can obtain these leaflets by writing or calling my office: U.S. Fish and Wildlife Service, Room 105, 600 East Monroe Street, Springfield, Illinois 62701 (telephone 217-525-4308). You can also get them from your local county Extension office. Copies of the leaflets are included in this proceedings following this paper.

The Turfgrass Seed Industry—Looking into the Crystal Ball for 1980

Richard Hurley

To understand seed availability you must analyze the harvests for all the major turfgrass production areas in the world. With respect to the United States, the major production areas are the northwest states of Oregon, Washington, and Idaho. A combination of factors makes these states ideal for seed production. They have a climate with a distinct rainy season during the winter months and a predictable dry season in June, July, and August, when minimal rainfall is anticipated. Because the harvest takes place during these months, there is less chance of crop loss due to heavy rains and severe thunderstorms. When seed is produced in other climates with less predictable weather patterns, heavy rainstorms can dislodge and shatter the seed from the delicate panicles. Once on the ground the seed is lost and cannot be harvested.

Low humidity is also important during harvest because the crop is normally swathed first, set in wind rows, and allowed to dry in the fields. High humidity and dampness from rain for extended periods, while the crop is wind rowed, can cause rotting of the seed, lower seed germination, and increased incidence of disease that can destroy the entire crop. (See Tables 1 and 2).

Key factors affecting seed production are:

1. Grass farmers have several alternatives—the production of grass seed, wheat, or a similar crop. If wheat prices are relatively high, the farmer wants more money for growing grass seed, or he may plow out the existing crop and plant wheat or some other field crop.
2. Many of the improved grass varieties are produced in one geographic location. The chance of inconsistent yields due to extremes in weather conditions is therefore greatly increased. A few of the improved varieties, however, are produced in three to four areas that provide for more consistent production from year to year. Realistically, consistent production can only be accomplished with varieties being grown in large quantities.
3. Field burning is an extremely important procedure that is necessary to attain maximum yields in species such as Kentucky bluegrass and the fine fescues. Burning is necessary because it reduces debris and stubble, thus keeping plants from becoming thatchy and sod bound. After burning, the plants become "rejuvenated" because regrowth occurs uniformly across the row instead of only from the edges in an unburned row. Burning also destroys weed seeds and temporarily kills surface pathogens.

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Some seeds are currently in short supply. The shortage that will affect the industry the most during the next year is of the elite varieties of Kentucky bluegrass (see Table 3.) With many varieties of Kentucky bluegrass, the shortage is the result of an extremely wet and cold fall last year. The outcome was poor field burns, which affected this past summer's yield. Without a good burn or as a result of a late burn, good fall regrowth did not occur. Fall regrowth is necessary because initial induction of the reproductive mechanisms occurs during the fall and provides the next year's harvest. Compounding the above problems was the fact that many of the improved varieties are being produced in only one area; thus the poor fall weather affected all the production. Some elite varieties like Baron are produced in three to four distinct growing regions in two or three different states, which greatly reduces the risks of producing in only one location.

Because of the shortage of popular Kentucky bluegrass varieties, we can anticipate greater usage of the fine leaf turf-type perennial ryegrasses and of common Kentucky bluegrass as a partial substitute. We can foresee shortages of certain varieties of the elite ryegrasses, but in general supplies should meet demand. With regard to the bluegrasses it would be a wise investment to purchase what is needed for spring and early summer because we expect most of the elite proprietary Kentucky bluegrasses to be sold out by spring. Remember, what we have now is what we will have to work with until next August's harvest.

Table 1. Major Turfgrass Seed Production Areas for Cool Season Turfgrasses

Country	Turf seeds produced	Comments
United States		
Willamette Valley, Oregon	Bentgrass Kentucky bluegrass Perennial ryegrass Annual ryegrass Fine-leaf fescues Tall fescue	*Poa annua* and bentgrass contamination is a constant concern for production in this area. Good climate for seed production with irrigation not as necessary as in other production areas.
Madras, Oregon	Kentucky bluegrass Perennial ryegrass	Area free of *Poa annua* and bentgrass. Good yields depend on irrigation.
La Grande Valley, Oregon	Kentucky bluegrass Fine-leaf fescues	Area free of *Poa annua* and bentgrass. Good yields depend on irrigation.
Spokane, Washington Northern Idaho border areas	Kentucky bluegrass Perennial ryegrass	Area free of *Poa annua* and bentgrass. Ryegrasses and tall fescues may winterkill, which limits extensive plantings. Good yields depend on irrigation.
Minnesota	Kentucky bluegrass	Big area for the production of the Park variety, also common Kentucky bluegrass.
Missouri, Kansas, Arkansas, and adjacent states	Tall fescue	Seed typically harvested off of grazing fields to increase a farmer's income. Little effort put into seed production.
Canada		
British Columbia and Manitoba	Creeping red fescue Kentucky bluegrass	Big source of commons.
New Zealand	Perennial ryegrass	Big source of pasture types. Seed sold primarily in Europe and Australia.
Europe		
Holland, England, Denmark, and Germany	Perennial ryegrass Bentgrass Fine-leaf fescues Kentucky bluegrass	*Poa annua* contamination severely limits United States import potential. Seed sold primarily in Europe.

Table 2. 1980 Seed Availability for the Major Cool Season Turfgrass Species

Species	Availability	Price
Kentucky Bluegrass		
Improved varieties	Extremely limited Many varieties sold out	Much higher
Common	Limited	Higher
Perennial ryegrass		
Fine-leaf turf types	Adequate	Stable
Common	Limited	Higher
Note: Annual Oregon perennial ryegrass production is approximately 20 million pounds per year, with the 1979 crop being about average.		
Fine-leaf fescues		
Improved varieties and Pennlawn	Limited	Higher
Creeping red fescues and Chewings	Limited	Higher
Note: Oregon fine-leaf fescue production is normally 15 to 17 million pounds -- 1978 production—8 to 10 million pounds -- 1979 production—about average although acreage was down; total harvest, approximately 12 million pounds -- Canadian fine-fescue crop—normally around 20 to 30 million pounds -- 1979 Canadian production—10 to 12 million pounds		
Tall fescues	Adequate	Recent sharp increases have leveled off. Prices have stabilized.
Bentgrass	Limited	Variable depending on variety
Note: For 1979 yields were generally poor. -- Seaside—poor yield and very high price -- Highland—extremely limited -- Astoria—difficult to find, much seed exported -- Emerald—adequate availability probably due to selling off of last year's inventory because this year's crop was disappointing -- Penneagle and Penncross—prices high, availability adequate		

Table 3. 1980 Availability of the Improved Kentucky Bluegrass Varieties

Good supply	Baron
Fair supply	Victa, Parade
Limited supply	Ram I, Glade, Fylking
Extremely limited supply	Majestic, Cheri, Columbia, Shasta, Emmundi, Birka, Sydsport, Merit, Vantage, Nugget, Touchdown, Adelphi, Bonnieblue
Not available	Brunswick, Pennstar, Sodco, Georgetown

A Present Evaluation of New Perennial Ryegrass and Fine Fescue Cultivars for Turfgrass Seeding Operations

W.A. Meyer

Our breeding and evaluation program on perennial ryegrasses and fine fescues is based in the Willamette Valley in western Oregon. This valley is a unique area for grass seed production. Our mild wet winters and dry summers are ideal for the growing and harvesting of high-quality grass seed. Varieties developed in western Oregon, however, must be tested in many different areas throughout the United States during their development to assure that they will be widely adapted. Rust is our most serious disease problem on turfgrasses during the summer periods. Leaf spot, *Fusarium nivale*, and red thread are our most serious winter diseases.

Perennial Ryegrasses

Manhattan and Pennfine were the first improved turf-type perennial ryegrasses. They have finer leaves, better density and persistence, and better disease resistance than common or Linn perennial ryegrass. They have been widely accepted for use on athletic fields, playgrounds, home lawns, and overseeding of dormant bermudagrass golf greens.

Many other new perennial ryegrasses have been developed. Table 1 shows data collected from trials in western and eastern Oregon and southern California and from research reports and personal communications with Dr. Reed Funk of Rutgers University.

Brown patch is a serious disease problem throughout the United States in areas with hot and humid summers. Red thread is most serious during cool wet periods under low fertility. Dollar spot can also be serious under low fertility; Citation and Regal appear to have moderately good resistance to this disease. Brown blight is most serious in United States coastal areas under moist, cool conditions when little leaf growth occurs. Crown rust usually occurs during the fall, and damage can be reduced by applying fertilizer. All of the perennial ryegrasses have less cold hardiness than Kentucky bluegrasses and fine fescues. Compared with other varieties, Manhattan has performed well under cool growing conditions.

Table 1 shows that none of the present varieties has high ratings in all categories. It is important to consider blending grasses to compensate for the weaknesses found in individual varieties.

Seed Quality of Perennial Ryegrasses

When you buy seed of the new turf-type perennial ryegrass varieties, you should insist on certified seed that is free of unwanted weeds and other crop seed. Annual ryegrass can be a serious contaminant. Fortunately, it can be detected in seed lots by the fluorescence test routinely conducted in seed testing labs. The roots of annual ryegrass or annual X perennial ryegrass hybrids fluoresce (glow)

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when placed under ultraviolet light. The new turf-type varieties have been developed to be free of fluorescing seedlings. Any fluorescing seedlings found in such lots are considered contaminants.

Fine Fescues

Fine fescues are well known for their ability to tolerate low fertility, acid soils, and dry shaded conditions better than most other turfgrasses. High nitrogen fertility, intense irrigation, and poorly drained soils discourage the development of good-quality fine fescue turf. There are four different types of fine fescues commonly used for turf purposes. Table 2 lists some general comments about these types of fine fescues.

Many old lawns throughout the state of Illinois have chewings fescues growing under shade trees, so these grasses apparently can compete with tree roots. Since chewings fescues are bunch-type grasses without rhizomes, they do not recover well from injury and are very competitive with bluegrasses in mixtures. We are striving to develop chewings fescues that have better leaf spot resistance and heat tolerance. Shadow (tested as Syn W) is a new chewings fescue that has shown good powdery mildew resistance and should be useful in shade mixtures.

Dawson is an example of a slender creeping fescue. This group of fine fescues produces a limited number of rhizomes. The variety Dawson has been used successfully in mixtures with perennial ryegrasses for overseeding dormant bermudagrass. In the northern United States it is very susceptible to dollar spot.

The spreading or creeping fescues produce rhizomes and have been found to be very compatible with Kentucky bluegrasses in mixtures. These grasses produce extensive rhizomes and can recover from summer injury better than chewings fescues. Pennlawn has usually been classified in this group. My observations on Pennlawn would indicate that it consists of more than just the true rhizome-forming type of fine fescue. All of the spreading or creeping types need better leaf spot and red thread resistance and better heat tolerance.

The hard fescues have been consistent performers in turf trials and better than the other fine fescues in most tests. The varieties C-26, Scaldis, and Waldina are examples of good varieties of this species. These varieties have shown good leaf spot and red thread resistance and adequate summer performance. The hard fescues have been very difficult to handle in seed production fields to date. Our research efforts on hard fescues are centered on solving the seed production problems. They are slower to establish than the other fine fescues but should perform better than other fine fescues in mixtures with Kentucky bluegrass.

Summary

The development of improved turf-type perennial ryegrasses over the last 12 years has had a tremendous impact on the turf industry. These new grasses have been used widely and have exhibited very good wear tolerance. Improvements are still needed on disease resistance, mowing quality, and winter hardiness.

With the present concerns for reducing the energy required to maintain turf areas, the fine fescues should become more widely used because of their lower nitrogen requirements. If economical seed production can be worked out for the new hard fescues, I feel that they will have a real impact as improved fine fescues for turfgrass seeding operations.

Table 1. Relative Performance of Perennial Rygrasses

Cultivar	Leaf texture[a]	Color[b]	Brown patch[c]	Red thread[d]	Brown blight[e]	Crown rust[f]	Cold tolerance[g]	Heat tolerance[h]
Annual ryegrass	2	2	1	4	3	3	1	1
Birdie	7	6	7	6	4	7	5	7
Caravelle	6	10	3	6	6	4	3	3
Citation	7	9	8	7	3	6	5	8
Derby	7	7	7	5	5	4	6	7
Diplomat	8	7	7	4	7	6	7	7
Eton	5	6	5	4	4	4	7	4
Game	4	5	2	4	4	5	3	2
Linn	3	4	2	4	3	4	3	2
Loretta	8	5	4	6	5	8	6	4
Manhattan	7	6	6	4	8	4	8	5
NK-200	6	6	4	4	4	3	7	4
Omega	7	8	7	5	7	5	7	7
Oregreen A X P	4	4	-	5	5	5	3	4
Pelo	4	5	3	5	7	6	5	4
Pennfine	7	7	7	6	4	6	5	7
Regal	7	7	7	7	5	3	6	7
Yorktown	7	8	6	5	7	4	7	6
Yorktown II	8	7	8	4	7	7	7	7

[a]Relative leaf texture in mowed turf, (10-1) 10 = fine, 1 = coarse.
[b]Relative color, (10-1) 10 = very dark blue, 1 = yellow green.
[c]Brown patch caused by *Rhizoctonia solani*, (10-1) 10 = resistant, 1 = susceptible.
[d]Red thread caused by *Corticium fusiforme*, (10-1) 10 = resistant, 1 = susceptible.
[e]Brown blight caused by *Helminthosporium siccans*, (10-1) 10 = resistant, 1 = susceptible.
[f]Crown rust caused by *Puccinia coronata*, (10-1) 10 = resistant, 1 = susceptible.
[g]Cold tolerance in mowed turf, (10-1) 10 = best, 1 = poorest.
[h]Heat tolerance in mowed turf, (10-1) 10 = best, 1 = poorest.

Table 2. Fine Fescue Characteristics

Type	Chromosome number	Flowering time	Spread	Leaf texture	Seedling vigor	Heat tolerance	Competitiveness in mixtures with Ky. bluegrass	Ability to tolerate below 1" cut	Powdery mildew	Examples of varieties
									resistant	Shadow
Chewings	42	daybreak	very little	fine	good	fair	high	good	susceptible	Jamestown Highlight Banner
Slender creeping	42	mid-afternoon	slight	fine	very good	fair	high	good		Dawson
Creeping or spreading	56	late afternoon	much	broader like Ky. blue	very good	fair	compatible	poor	resistant	Fortress Ruby Boreal
Hard	42	daybreak	very little	fine	fair to good	good	intermediate	intermediate	resistant	C-26 Scaldis Waldina

Growth Regulators—Present Status and Future Perspectives

R.P. Freeborg

The growth of turfgrass or other plants may be regulated by repeated mechanical trimming, by controlling the level of nutrition, by breeding for desired dwarf growth characteristics, or with growth control chemicals. Progress has been made in the selection of cultivars that tend to produce medium to low growing plants, especially in ornamentals. However, turfgrass breeders must do more to develop dwarf turfgrasses with the necessary vigor and disease resistance. Chemical control of turfgrass growth continues to offer the potential for effective reduction of costs that are related to equipment use and depreciation, labor, and fuel through the inhibition, retardation, or regulation of turfgrass growth.

There is a continued interest throughout the agricultural chemical industry in the development of plant growth regulators for use on all turfgrass sites. The growth regulators that are currently available have some limitations in their use because of either their phytotoxicity or their potential to thin or to cause excess periods of inhibited growth because of some unforeseen environmental stress.

One of the early examples of controlled growth in turf was the use of phenylmercuric ammonium acetate (PMA) to reduce moisture loss by transpiration from a plant leaf. PMA prevents the leaf stomates from opening by inhibiting the guard cells, thereby reducing the transpiration rate. As much as a one-third reduction in moisture loss has been observed the first day after application. PMA is, however, immobile in the plant, so only the foliage that is sprayed is affected. Thus, as a new growth develops, additional applications are necessary.

In the turf industry, the first effective inhibitor to control plant growth and to inhibit seedhead formation was maleic hydrazide (MH). It was available as MH30 (a dimethyl amine salt) and MH40 (a sodium salt formulation).

MH has several special uses:

1. Controlling seedheads
2. Thinning fruit in orchards
3. Decreasing loss of sugar in stored beets
4. Extending the life of cut flowers
5. Decreasing frost damage to citrus trees
6. Preventing corrosion of steel

Several problems are common to turfgrass growth inhibitors-retardants. The following, identified for MH, are examples. It is slowly absorbed through both the upper and lower leaf surfaces. It penetrates the leaf surfaces faster if the leaf cells are turgid, under conditions of high humidity; wilted plants absorb

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little, if any. Once inside the plant, however, it is quite mobile, which explains its ability to prolong a state of dormancy for many months. Data also show that a water spray volume in excess of 50 gallons per acre is too much for best results. Late-afternoon applications have been more effective than those early in the morning.

MH is more effective on young plants. Also, the higher the temperature, the faster and more vigorous the effects and the shorter the duration of plant response to MH. In addition, more MH is absorbed when a wetting agent is used, especially during periods of high humidity. It therefore appears that such factors as temperature, time of application, volume of spray solution, and use of a wetting agent are all effective in increasing the activity of MH in plants.

Probably the greatest use of MH has been to inhibit grass growth along roadsides, thereby reducing mowing frequency and, as a result, some of the costs of roadside maintenance. Its use on fine turf has been limited because of phytotoxicity and excessive inhibition under stress. It is estimated that by 1965 approximately three million pounds of growth regulators had been used in the United States. MH accounted for about 90 percent. By 1975, however, newer growth inhibitors-retardants were estimated to have accounted for more than 50 percent of the total market.

In 1977 MH was placed under Rebuttal Presumption Against Registration (RPAR) review by the Environmental Protection Agency (EPA) because of some concern about its *potential* for toxicity to users. The current risk review within RPAR has not been completed, so currently the use of MH is not restricted.

The new growth retardants for use on turf include a family of compounds identified as chlorofluorenols. They are available in formulations such as Po-San A and CF125. Another compound, Sustar, was eventually replaced with Embark. Although similar to Sustar, Embark is a more active formulation and will be discussed later in this paper.

The chlorofluorenols effectively retard many grasses and many broadleaf weed species. Most activity is on the young, tender parts of the plant, those that develop after treatment. In broadleaf species these chemicals act systemically and are translocated from the leaves and throughout the plant to younger developing tissue. Their movement in grasses tends to be upward. The fluorenols can also interrupt the growth of trees, shrubs, and vines.

Recently a combination of MH with the chlorofluorenols has been used to inhibit seedhead development in *Poa annua*, annual bluegrass. Combinations are available as Po-San A + B or as Maintain 3 + CF125. Under optimum conditions seedheads are almost totally inhibited. Thus, subsequent weed development is potentially reduced. Applications are made in spring to *Poa annua* to prevent a spring seed crop development. Additional late summer—early fall applications can further reduce seed production. There is also evidence that foliar development in *Poa annua* is retarded more than that of the other perennial grasses, thereby reducing somewhat the ability of the *Poa annua* to compete.

Timing of application is important. MH + fluorenols should be applied before seedhead formation in *Poa annua*. Under ideal cool, moist growing conditions, the correct time may include only a few days.

The most recent growth retardant made available to the industry is Embark. An advertisement from the formulator, 3M Company ("12 years and 12,325 compounds later . . . a triumph in grass growth suppression"), indicates that Embark was the 12,325th compound synthesized by the 3M chemists over a twelve-year period. So, one out of 12,325 compounds has some commercial value. It should thus be obvious that formulators run a tremendous cost-risk when they develop any new product for agricultural use, whether in turf or other crops. The result is that fewer new products are developed, especially for the professional turf industry, which has a relatively small market. Those products that do enter the turf market are usually developed after the product has been commercially accepted in another larger crop such as soybeans or corn.

The three commercially available turf growth inhibitors-retardants—MH, the chlorofluorenols, and Embark—are recommended for use on sites where regular mowing and trimming maintenance are difficult and expensive, such as under security fences and guard rails; around sign posts and trees, culverts, rights of way, and median strips on roadsides; around ponds and ditches; and on steep banks—sites where some moderate discoloration or thinning would be acceptable.

Growth may be controlled for four to six weeks under normal growing conditions. With weather stress such as drouth and higher temperatures, this control may continue for eight weeks or longer. Excess or undue periods of inhibition may be overcome with an application of gibberellic acid, which at low rates (7 to 28 grams per acre) acts as a turfgrass growth stimulant. Additional nitrogen applications to stimulate regrowth have also been effective in reducing the effects of growth regulators.

Disease and insect problems as well as drouth and hot weather, all of which are associated with restricting plant growth, can result in excessive turf thinning. This thinning is especially a problem on fine turf, where uniform color and density are so important.

Turfgrass growth control has not been acceptable on recreational sites where turf wear is evident. The inhibited grass is unable to produce adequate new growth to recover from foot traffic and so is gradually thinned until little or no vegetation remains.

It has also been observed that fine turf, when treated with the available growth inhibitors-retardants, will slow down or stop new growth and leaf production but that death of the plant will continue at a near normal rate. Therefore, without new leaf growth to mask the older dead and dying surface leaf cover, the turf begins to lose its uniform green color. Then the brown surface vegetation becomes visible. Thus the turf becomes unsightly, often as though the retardant had been phytotoxic, although it may not have been.

Another problem that needs to be resolved is related to mixed stands where the perennial ryes and blue and red fescues are found to respond differently in the degree of retardation. Rye may be retarded less than the bluegrass or red fescue, so an irregular surface cover develops because of these variations in species response.

Light intensity also has an effect on plant response to the growth retardants. Some evidence indicates that the grasses are most susceptible to greater degrees of inhibition and to potential phytotoxicity under a low light intensity such as shade or semishade.

Interest continues, however, in the development of a true turf growth regulator with the potential for use on fine turf sites. This plant growth regulator should permit active growth of roots, rhizomes, tillers, and horizontal leaf growth yet retard upright or vertical leaf growth. It would then permit continued new growth (including the new leaves that are essential to maintain a uniformly green, dense turf resistant to wear, disease, and insect damage) and be able to overcome hot weather or drouth stress. It would also reduce or eliminate the need to mow.

Problems still must be resolved before plant growth control can be an effective management tool on fine turf. Although new products are scarce, industry continues to be interested in the development of turfgrass growth regulators. In a ten-year period at Purdue, 32 formulations have been evaluated. Embark was one of the most promising. Three compounds are currently undergoing evaluation in our turf trials. Two are in the early experimental stages. The third, ethephon, has some potential for early product release. These compounds have given good to excellent growth regulation and have maintained good color and density in our irrigated turf plots. Greenhouse evaluation of these products has shown good root and tiller growth. These products must be evaluated under a wide range of conditions before we can be assured of their efficacy. They are, however, the forerunners of new products to be developed. It is apparent that in the future growth regulators will be available for a wide range of uses in agriculture, including the effective chemical growth control of turfgrasses even under the most demanding situations.

Rhizoctonia Brown Patch Disease On Kentucky Bluegrass—Is It a Problem?

B.G. Joyner

The first disease on turfgrass caused by *Rhizoctonia solani* was discovered in 1914 at Philadelphia (Howard, Rowell, and Keil, 1951). Since that time, brown patch has been known to occur in most turfgrass growing areas of the world. In the past the disease has been especially severe on highly maintained turfgrasses, such as those on golf course greens. However, with improved varieties and increased maintenance practices, the disease has become important also on other turfgrasses, such as those used in home lawns. Today, there appears to be confusion as to how much of a problem Rhizoctonia brown patch is to Kentucky bluegrass. This uncertainty is due in part to the lack of available information and to the frequent misidentification of this disease. This confusion also exists because of the great variability of the pathogen and the possibility that more than one pathogen is involved.

The discussion here will be limited to the methods for correctly diagnosing the problem and the factors involved in determining the significance of the problem on Kentucky bluegrass.

Diagnosis

Diagnosis of turfgrass problems caused by *Rhizoctonia solani* has been somewhat hampered because of the varying symptoms expressed and the possibility of more than one pathogen's being involved. Add to this the introduction of new turfgrass cultivars and varying management practices, and the problem of diagnosis becomes even more understandable. Generally, diagnosis is based on the symptoms expressed, the host affected, the time of occurrence (environmental conditions existing), and the pathogen identified.

Symptoms

Two types of symptoms are generally expressed: brown patch (blighting) and leaf spot. These two symptoms may occur together or separately.

Typical symptoms of brown patch will occur on Kentucky bluegrass as circular patches ranging from several centimeters to several meters in diameter. The center portions of these patches may, and often do, recover and create rings or "frog-eyes." These "frog-eyes" are generally larger than those of Fusarium blight. The advancing edges of the patches may be a light, yellowish green before turning light brown to tan (Joyner, Partyka, and Larsen, 1977). These symptoms primarily occur with temperatures in the range of 26 to 29° C (80 to 85° F) and with plenty of moisture available.

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Atypical symptoms of brown patch have also been noted on Kentucky bluegrass. These atypical symptoms occur at temperatures from 15 to 25° C. The circular patches in this case range in size from 35 to 50 centimeters. Again, the circular patches often contain healthy green grass in the center surrounded by a circle of light brown grass. These patches often look very similar in size, color, and shape to Fusarium blight (Joyner, Partyka, and Larsen, 1977).

In both of these symptom patterns, the lower leaf sheaths of single plants often turn brown and collapse. The crown tissue, however, is generally still intact and viable. The lower plant tissue, the area near the crown, is often covered with a network of fungal mycelium and sclerotia. This network can be observed with the naked eye or with the aid of a 10X hand lens and can often be used as a diagnostic aid.

Leaf lesions may also result when the turfgrass is infected by Rhizoctonia. Lesions have been noted on most turfgrasses, including Kentucky bluegrass. The leaf spot generally begins as an irregular water-soaked area. Later the center of the leaf spot turns a straw or ash brown. Most often the leaf spot is surrounded by a dark border. The size of the leaf spot will vary, but generally it is slightly smaller than the width of the leaf blade. It looks much like dollar-spot lesions, except with darker margins.

Host

Very little information is available on the susceptibility to brown patch of the various Kentucky bluegrass cultivars. Similarly, information on the symptoms expressed by the various cultivars is lacking. One can only speculate that the various Kentucky bluegrass cultivars vary in their susceptibility to brown patch. Therefore, the symptoms expressed will vary as well as the severity of the damage caused by the disease. Diagnosis is also difficult because turfgrass areas often consist of unknown cultivars or blends.

Timing (Environmental Conditions)

In the past, Rhizoctonia has been considered a warm-, wet-weather disease or a summer disease in the north. Temperatures that generally favor rapid development of brown patch occur between 26 and 29° C (80 and 85° F) (Dickinson, 1930). Recently, however, various reports indicate that Rhizoctonia-induced (or Rhizoctonia-like) problems occur during much cooler temperatures. Symptoms of brown patch have been observed on Kentucky bluegrass at temperatures of 15 to 25° C (60 to 78° F) (Joyner, Partyka, and Larsen, 1977). Zoysia (Dale, 1978) and bentgrass (Sander, Burpee, and Cole, 1978) have also been shown to have problems with Rhizoctonia brown patch at lower temperatures. Thus, in diagnosing Rhizoctonia-induced problems the difficulty is even greater, and all factors must be considered.

Although Rhizoctonia can occur at relatively low atmospheric humidity, a moisture-saturated atmosphere greatly enhances disease development (Couch, 1973).

Pathogen Identification

Identifying the pathogen is important in any disease situation and is one of the steps in diagnosis. It is essential, however, in the diagnosis of a disease problem such as brown patch because the symptoms, hosts, and environmental conditions vary and overlap with other disease problems.

Much of the confusion with this disease problem, as with others, is due to the lack of identification of the pathogen. In the past, identification of

Rhizoctonia solani has been very crude and based on factors that vary. The misidentification of Rhizoctonia pathogens has also been a problem in other areas outside of turf. This problem has led to some excellent work on the identification of Rhizoctonia and Rhizoctonia-like fungi. Identification now is based on the perfect stage and on the nuclear condition as well as on the standard cultural characteristics (Sander, Burpee, and Cole, 1978; Butler and Bracker, 1970; Parmeter and Whitney, 1970). The identification of the pathogen, coupled with symptomatology, host range, and environmental conditions, should make diagnosis a more meaningful art.

Is It a Problem?

Rhizoctonia brown patch was reported to be a problem on Kentucky bluegrass as early as 1932 (Howard, Rowell, and Keil, 1951) and has continued to be a problem. It probably occurs just as often as Fusarium blight on Kentucky bluegrass (Midwest). However, several factors make brown patch a less severe problem than Fusarium blight. First, brown patch generally occurs where irrigation is practiced or during periods of rainfall (1979 being a good example of widespread occurrence of brown patch). However, because of the available water, the turf generally can survive the damage caused by brown patch. Fusarium blight, on the other hand, generally occurs during periods of drought stress. Second, Rhizoctonia brown patch rarely kills the crowns; therefore, the chance of recovery is good. With Fusarium blight, the crowns are often killed.

The recovery of the turf is important in considering control measures. Successful control of Fusarium blight is often difficult because of the low recoverability of the turf. Control of brown patch, however, is more successful because of the recoverability of the turf.

Considering the above factors, Rhizoctonia brown patch ranks at the top with Fusarium blight in occurrence on Kentucky bluegrass. However, when one considers severity of damage and control, Fusarium blight still ranks as the number one turf *disease* problem of Kentucky bluegrass.

Conclusion

Rhizoctonia brown patch is a problem on Kentucky bluegrass and in many ways just as important as Fusarium blight. The disease can be confused, and often is, with other disease problems. Therefore, correct diagnosis is important and should be based on all factors: symptoms, host, timing, and pathogen identification.

Literature Cited

Butler, E.E., and C.E. Bracker. 1970. Morphology and cytology of *Rhizoctonia solani*. In *Rhizoctonia solani, biology and pathology*, ed. J.R. Parmeter, Jr., pp. 32-51. Los Angeles: University of California Press.

Couch, H.B. 1973. Rhizoctonia brown patch. In *Disease of turfgrasses*, 2d ed., pp. 56-63. Huntington, New York: R.E. Krieger Publishing Company.

Dale, J.L. 1978. Atypical symptoms of Rhizoctonia infection of zoysia. *Plant Dis. Rep.* 62:645-47.

Dickinson, L.S. 1930. The effect of air temperature on the pathogenicity of *Rhizoctonia solani* parasitizing grasses on putting-green turf. *Phytopathology* 20:597-608.

Howard, F.L., J.B. Rowell, and H.L. Keil. 1951. *Fungus diseases of turfgrasses.* Univ. R.I. Agric. Exp. Stn. Bull. 308.

Joyner, B.G., R.E. Partyka, and P.O. Larsen. 1977. Rhizoctonia brown patch of Kentucky bluegrass. *Plant Dis. Rep.* 61:749-52.

Parmeter, J.R., Jr., and H.S. Whitney. 1970. Taxonomy and nomenclature of the imperfect state. In *Rhizoctonia solani, biology and pathology*, ed. J.R. Parmeter, Jr.. pp. 7-31. Los Angeles: University of California Press.

Sander, P.L., L.L. Burpee, and H. Cole, Jr. 1978. Preliminary studies on binucleate turfgrass pathogens that resemble *Rhizoctonia solani*. *Phytopathology* 68:145-48.

Suitability of Subsoil Material for Turfgrass—An Agronomic Viewpoint

Ivan J. Jansen

Application of topsoil material has routinely been recommended when a turf is to be established on exposed subsoil material. As a general recommendation, topsoiling is appropriate. There are situations, however, where topsoiling, although desirable, is not necessary. One can reduce his costs by learning to recognize those sites where a quality turf can be established directly on exposed subsoil material.

A crucial point to consider is that not all soils are alike. In some areas in Illinois, most sites would be suitable for establishment of a turf without topsoil replacement. Other areas have many problem sites where topsoiling would be well worthwhile. Each site should be evaluated individually.

First, consider the character of the exposed subsoil material. An exposed subsoil material that is medium textured and has favorable chemical properties has the potential for supporting an excellent turf. On the other hand, it would be difficult to establish and maintain a turf on an exposed subsoil that is excessively sandy or clayey. Do not attempt, however, to judge clay content from soil color; most subsoil materials are low in organic matter and hence light colored. Published soil surveys, where available, are your best source of information concerning soil properties. An on-site evaluation by a qualified soil scientist would be safest where the scope of the project justifies it. In general, clay contents of 30 percent or less are desirable, and any material with more than 40 percent clay should be considered a problem material to be covered with topsoil. Silt loams, loams, clay loams, and silty clay loams have generally favorable texture. Sandy loams and sandy clay loams would also be acceptable.

Where deep excavation has been done, the exposed material might well be calcareous. Common turf grasses will perform well under careful management in calcareous soils, but some ornamental shrubs will not. The problem can be avoided by selecting only plant materials that will do well in calcareous materials or spot treating areas that will have nontolerant plants.

Careful fertility management is usually more critical when no topsoil is present, although most fertility problems can be corrected with commercial fertilizers. Because nitrogen release in soils is almost exclusively from the organic fraction and most subsoil materials are very low in organic matter, a newly established turf will be almost totally dependent on fertilizer nitrogen. Regular applications of fertilizer nitrogen, particularly during the first year or two following establishment, is one of the keys to success in establishing grasses on subsoil material. Phosphorous availability might also be a problem, particularly

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where the subsoil material is calcareous, but it can also be controlled with fertilizers. Toxicity problems are not common on subsoil material but must be considered. When encountered, toxicities can often be corrected by adjusting the soil pH through liming or acidification, as the need may be.

Seedbed preparation is more difficult in subsoil materials because of the low organic matter content and poor tilth. The soil structure, where present, is commonly less stable in the subsoil material than in most top soil, making it prone to crusting. The inherent physical problems are commonly aggravated by the compaction resulting from traffic around construction sites. Deep tillage (preferably several weeks before planting) followed by shallow tillage just before planting can be helpful. A good watering program will do much to minimize the effect of the tilth and crushing problems.

The quality of the available topsoil should also be considered. Well-structured silt loam topsoil that is high in organic matter would justify more effort to save than would a light-colored, clayey topsoil. One needs to be particularly cautious when purchasing topsoil to determine that it is of good quality. One might easily pay to have material hauled on that is no better than what was there before.

Grass will grow well on good-quality subsoil, although it is harder to establish in subsoil than in good-quality topsoil. The subsoil will be low in organic matter and might have poor structure. Seedbed preparation is more difficult. Fertility management is more critical and sometimes more difficult. Top soiling is still good advice for the novice who is not skilled in turf establishment and management, but those with a bit greener thumb will have no trouble establishing and maintaining a good turf in good-quality subsoil. Poor-quality subsoil materials should always be covered with topsoil before turf establishment.

The Commercial Lawn-Care Industry—A Site Diagnostic Approach

Sherry L. Roethe

We in the commercial lawn-care industry have had to develop reliable, uniform field diagnostic techniques because of the lack of history for home lawns we service. Specific techniques have been developed for isolating the most damaging home-turf diseases--striped smut, fusarium, and the Helminthosporium species. Those techniques include a thorough analysis of the site conditions prior to diagnosing particular lawn problems and presenting our proposal for any alteration of the home environment.

Over a 2-year period we observed over 2,000 lawns in the Chicago suburbs under widely different environmental and cultural conditions. From June through September of 1976 and from March through September of 1977, we diagnosed an average of 192 lawns each month. We then made random follow-up observations from March 1978 through September 1979 on about 10 percent of the lawns that we had originally surveyed.

Critical physical factors include: the composition of the turf species, the depth and density of the thatch, fluctuations in the soil composition and quality, alterations of wind patterns, changes in the moisture distribution, and variations in the light quality, duration, and density.

The cultural practices we considered relevant include: mowing height and frequency, equipment maintenance, watering regularity and timing, and fertilization timing, amount, and composition. We could only evaluate the pesticides that had been applied after our company had begun servicing the lawn.

When familiar with the locations serviced, experienced lawn-care diagnosticians can infer additional pertinent information about a lawn, such as: its relative age; the method of turf establishment; the applicability of the village's watering restrictions; how children, pets, or heavy traffic affect damage patterns; if a family member is home during the day to care for the lawn or if limited care is given on evenings and weekends; and the overall pride in a well-maintained lawn as evidenced by both the specific lawn and the general neighborhood. Also, by observation of weed species in the lawn, inferences can be made regarding cultural care and unobservable physical conditions.

Some information must be obtained from the lawnowner, including: the season of and preparation for the establishment of the lawn, the specific turf varieties and soil conditions, and any chemical application to or spills onto the lawn.

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Striped Smut

We have developed important criteria as aids in the field diagnosis of striped smut, particularly during hot, dry weather:

1. The presence of large, roughly circular patches of quackgrass in the center of the lawn as smut thins infected rhizome growth
2. A distinctly uneven growth pattern, resembling the clumpiness associated with traffic damage, even when sufficient moisture is present to permit active turf growth
3. A dramatic decline in lawn density when a sustained, irrigated turf is removed from a regular watering regime
4. A shredded and curled appearance of individual dead leaf blades—a ragged appearance that is distinctive from the intact blades associated with melting out or many other types of damage
5. Oftentimes, active disease symptoms under a tree or near a downspout, anywhere the microclimate is moderated with increased moisture and cooler temperatures—even though actual damage is most severe in sunny areas

Fusarium

This disease may be aggravated by a variety of limiting factors. However, thatch depth and density, mowing habits, inadequate or soil-saturating irrigation practices, and soil compaction, surface slope, and pH are especially relevant. Important criteria for field diagnosis of fusarium include:

1. Observation of similar symptoms on neighboring lawns
2. Frequently, lawn establishment by sodding 1 to 4 years prior to evidence of symptoms
3. Scars oriented in a south or west direction (indicating increased drought stress)
4. A sunken appearance with typically upright straw- or tan- to orange-colored turf at the outer perimeters of the scars. The bleached or straw coloration on the scar margins is common even during cooler periods on turf that has been subjected to abrupt temperature fluctuations, interrupting a period of fusarium activity.

Helminthosporium

Because Helminthosporium is prevalent in many home lawns, diagnosing the Helminth species as the dominant damaging factor is frequently dependent upon eliminating other causal agents. The damaged turf may have the withered, yellowed, but intact leaf blades typical of melting out. The turf may exhibit the lesions and crown rot that are characteristic of Helminthosporium. Information that is critical to the diagnosis of this disease often includes irrigation patterns, frequency, and timing.

Procedure

Adminstratively, certain background information is available to the diagnosticians concerning the lawns they service. A thorough visual analysis is made of each piece of property before it is accepted onto our program (Figure 1). Intensive data are subsequently recorded on an ongoing basis, including:

1. The technician responsible for the initial analysis
2. The type of fertilization program contracted for (when several options are available)
3. The dates of the initial and all subsequent applications of both fertilizer and pesticides
4. The technician(s) responsible for each application
5. Any special care intructions given by the lawnowner
6. Any previous diagnosis made, including the date(s) and technician(s) responsible

When a lawnowner notifies us of a problem, we ask him or her for background information for the diagnosing technician's use, including:

1. The date of problem occurrence
2. The exact location of the problem
3. The extent of the damage
4. The development of the problem
5. Its relation to previously observed symptoms

Although information from the homeowner is important, the final determinant in a successful diagnosis is the deductive analysis of the professional lawn-care technician. Thus, data obtained from both controlled research observation and field experience contribute to the expanding diagnostic science within the turf industry.

404 Mercantile Ct.
Wheeling,
Illinois 60090

TEMPO 21

PHONE:
541-1600

LawnBeautiful® ANALYSIS

Inquiry ____ / ____
Analysis ____ / ____
Approved ____ / ____
S.I. ____ Mail ____

This is a continuing program -- season to season -- If you find it necessary to discontinue the service, please notify us before your next application is due

Fac ____ Unit ____
Area ____
Prog ____ D $ ____
1 2 3 4

COMMENTS: **Referred by** ____

Name: ____
Address: ____
City: ____ Zip: ____
Phone: Home ____ Bus. ____

This Year **LawnBeautiful® Program Investment**

___ Spring $____
___ Early Summer $____
___ Late Summer $____
___ Fall $____

Total Grass Area (sq. ft.).......... ____

DESIRABLE GRASSES			WEED GRASSES		POTENTIAL
Type	**Population**	**Coloration**	**Controllable***	**No Control**	
___ Bluegrass	Dense	Dark	___ Crabgrass	___ Bentgrass	Excellent
			___ Foxtail	___ Coarse Fescue	
___ Fine Fescue	Average	Average	___ Goosegrass	___ Nimblewill	Good
			*Early Spring Only	___ Nutsedge	
___ Ryegrass	Thin	Pale		___ Quackgrass	Fair

CONTROLLABLE WEEDS

Faster Dying	Slower Dying		Most Difficult†		
___ Buckhorn	___ Black Medic	___ Red Sorrell	___ Bindweed	___ Ground Ivy	___ Violet
___ Chickweed	___ Knotweed	___ Smartweed	___ Chicory	___ Henbit	___ Wild Carrot
___ Dandelion	___ Plantain	___ Thistle	___ Clover	___ Oxalis	___ Yarrow
___ Shepherd's Purse	___ Purslane	___ Yellow Rocket	___ Curly Dock	___ Spurge	†Multiple Treatments Required

OTHER OBSERVATIONS

Disease Damage		Insect Damage		Miscellaneous Damage	
___ Brown Patch	___ Powdery Mildew	___ Army Worm	___ Earthworm	___ Cut too Low	___ Pet Damage
___ Dollar Spot	___ Rust	___ Billbug	___ Grub	___ Cut too High	___ Thatch Depth
___ Fairy Ring	___ Slime Mold	___ Chinch Bug	___ Leafhopper	___ Dull Blade	___ ____
___ Fusarium	___ Snow Mold	___ Cutworm	___ Sod Webworm	___ Too Dry	___ ____
___ Leafspot	___ Striped Smut				

If you feel your lawn's condition or size has been misjudged, we will be pleased to perform a reanalysis.

Turf Technician ____

Figure 1. Professional turf technician's visual analysis form.

Methods for Minimizing Winter Injury on the Golf Course

J.R. Watson

During late winter and early spring, fluctuating temperatures and waterlogged, partially frozen soil produce conditions that cause the loss of turf, either directly or indirectly. Direct damage or kill of the permanent grass may occur at any point of the freeze-frozen-thaw cycle so characteristic of this season. Indirect injury may result from attacks by disease-producing organisms (mostly snowmold and other low-temperature fungi) and by traffic on frozen and partially frozen turfgrass.

Causes Relating to Temperature Variations

Turfgrass may be destroyed at the time it freezes, during the time it is frozen, during the time it is thawing, or after it is thawed and growth has begun. Some killing probably occurs during each of these periods. This cycle of freezing, frozen, thawing may be repeated several times during each winter and early spring. When associated with intermittent growth in late winter and early spring, damage may be severe. Death as the plant freezes happens most often in the late fall and early winter but may occur after a period of growth (particularly rapid growth) in the spring when the temperature drops suddenly. This damage is worse when the grass plants are in a nonhardened condition. Ice crystals form within the cells, and this disruption of the protoplasm may cause death. Also, repeated cycles in the spring will exhaust the food reserves upon which the plants must draw to initiate growth. For this reason, *Poa annua* is especially vulnerable.

The plant is not likely to die during the time it is frozen unless it is subjected to traffic, which will seldom occur if a good snow cover exists, as is most often the case during the winter months. However, play during the time period under discussion may cause mechanical damage either by attrition or from pressure that forces the ice crystals through the cells, thereby puncturing them and causing death. Play when the grass is covered with frost has the same effect.

Death at the time of thawing depends upon the amount and the state of the "bound" water within the cell (intracellular water). Unless the plant has adequate bound water in the protoplasm, it may die if thawing is rapid or if intercellular water reenters the cell too rapidly. In the latter case, the cell wall is permeable, but the protoplasm is unable to absorb the water. Prolonged cold may be conducive to death because it contributes to brittleness of the protoplasm and, if contact (from traffic) is made, the plant is highly susceptible to damage.

Causes Relating to Traffic

Grass will initiate growth during the warmer periods of late winter and early spring. If the season is characterized by widely fluctuating temperatures, the

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grass is vulnerable to the freeze-frozen-thaw growth cycle with its attendant problems. Also, the environment that is produced is highly conducive to disease development. Thus, this phase may be the most critical part of the turf management program for the golf course superintendent. In addition, he often finds his turf management programs (and, therefore, himself) in direct conflict with the golfing membership, especially those desirous of playing a few early rounds.

Mechanical injury by traffic on partially frozen or wet soil may be immediately evident (visible) or delayed (invisible). Visible injuries (soil displacement) are the footprints and ruts caused by foot and vehicular traffic—sliding and slipping, walking or rolling—on partially frozen or saturated soil. Invisible injury stems from soil compaction. Although this type of mechanical damage is not confined to the winter months, soil compaction may be far more damaging during this period than is generally recognized. Traffic on partially frozen or wet soil, without the protection of living grass, will exert greater pressure (hence, more compacting force) than during the normal growing season. This compaction results, subsequently, in poor growth and may explain the "problem areas" that show up in spring and summer for no apparent reason. Cupping areas are particularly vulnerable in this respect.

Traffic on frosted turf causes the frost crystals to puncture the leaf cells and kill the grass. Removal of frost, or preventing play when the grass is frosted, is essential.

Control of traffic during vulnerable periods does not always contribute to harmony between early golfing members and the less enthusiastic golfing and non-golfing members. The responsibility for control rests with the club officials—the president, the greens chairman, the superintendent, and the golf professional.

Causes Relating to Ice Sheets and Ponded Water

Turfgrasses, although essentially dormant during the winter months, nevertheless carry on metabolic (growth) activity, particularly respiration. During late winter and early spring, as growth activity increases the grass may suffocate (1) if diffusion of atmospheric and soil gases is reduced or stopped, (2) if excess carbon dioxide accumulates, or (3) if oxygen supplies are reduced to a minimum. Such conditions exist under ice sheets in poorly drained areas where the soil remains saturated for extended periods and under flooded conditions when ponded or standing water persists. The higher the temperature, the shorter the period of time during which the grass can survive these adverse conditions.

Under limited (and rare) conditions, ice sheets and ponded water may act as a lens. The sun's rays are then magnified to the point where the excessive heat produced may cause a burning or scalding of the turfgrass.

Causes Related to Reduced Water Intake

Desiccation is a "wilting" phenomenon. Like wilt, which occurs during the normal growing season, desiccation occurs when evapotranspiration exceeds water intake. This inability of the roots to absorb water, or for the plant to transport it to or through its system, may result from a shallow, poorly branched root system, from a diseased vascular system, or from a reduced or restricted soil water supply. Limited soil moisture may be the result of a dry soil (not enough water) or of a frozen or partially frozen soil (water unavailable to the root because of its physical state). Thus, the roots simply cannot take in enough water to offset that being lost by the plant and it desiccates or dries up—it wilts.

Although more serious during periods when the soil is "on the dry side" or partially frozen, desiccation on high windswept sites may occur at any time. The increased air movement causes excessive transpiration, and under limited or reduced soil moisture conditions, the plants may die unless protected.

In late winter and early spring, before the irrigation system has been activated, damage from desiccation may be severe. Water hauled in spray tanks or by other means and applied to critical sites will preclude or minimize loss.

Review of Protective Measures

Techniques and procedures that protect from, avoid, and correct the damage that occurs in late winter and early spring are well known to and understood by the golf course superintendent. For the most part, protective measures relate to production of a healthy vigorous grass and to the control, to the extent possible, of the soil-plant environment. When these factors are adversely impacted by anomalous conditions of weather, poor construction, or inadequate equipment and supplies, the responsibility for loss of turfgrass must be shared.

Measures To Protect Against Temperature Variations

1. Apply sound cultural practices in the fall of the year, including properly timed applications of balanced fertilizer; cultivation of compacted areas and of areas where water infiltration is poor (such as slopes); controlled application of water to ensure satisfactory soil moisture; mowing in accordance with growth requirements, raising the height of the cut on areas known to be susceptible to desiccation; implementation of disease control programs at the proper times—fall and spring (programs to control or eliminate insects, weeds, and thatch would have been implemented at an earlier date).

2. Control traffic, especially during critical periods.

3. Use mulches or covers if warranted.

4. If late-winter and early-spring play is anticipated, cut cups in the fall and fill with newspaper.

5. Cut temporary greens if needed.

6. Work toward elimination of *Poa annua*.

7. Develop programs to introduce new, improved grasses as they become available. Seed greens lightly each fall to help eliminate *Poa annua*.

8. Avoid practices that stimulate excessive early growth or that produce soft, succulent growth in early spring.

9. Apply fungicides as needed.

Measures To Protect Against Traffic

1. Develop programs to control traffic during critical times and on critical sites.

2. Enlist the support of all golfers.

3. Take pictures of damage and make a presentation to the greens committee and membership.

Measures To Protect Against Ice Sheets and Ponded Water

1. Improve drainage—a key to many grass problems, not just to winterkill.

2. Redesign and rebuild if necessary.

3. Leave snow as an insulator as long as possible.

4. Apply dark material (milorganite, activated charcoal) to ice sheets to make them porous.

5. Mechanically break up solid (nonporous) ice sheets if temperatures range into the 50's or greater for extended periods.

6. Apply fungicides as needed.

Measures To Protect Against Limited Soil Water

1. Water in the fall as late as is needed to ensure good fall and winter supply of soil moisture.

2. Use covers and mulches to protect vulnerable sites.

3. Plant superior permanent grasses.

4. Apply those cultural practices needed to ensure adequate storage of food reserves and to develop deep-rooted, extensively branched grass plants.

5. Apply water to counteract desiccating conditions; haul if necessary.

6. Apply fungicides as needed.

7. Avoid all practices that stimulate early excessive growth or that produce soft, succulent growth.

Turfgrass Cultivation—Pros and Cons

Paul E. Rieke

Turf managers often overlook the fact that the roots of turfgrasses grow in pore spaces in the soil. Large pores (macropores or noncapillary pores) allow aeration, drainage, and easier root penetration. Small pores (micropores or capillary pores) hold the water available to the turf roots. Soils in which turfgrass grows are often compacted, which results in a decrease in macropores and an increase in micropores. This condition leads not only to reduced aeration and drainage but also to conditions that are less favorable for rooting. Further problems are lower infiltration, more susceptibility to certain diseases, reduced resilience, and overall, greater susceptibility to stresses.

Soil Compaction

When soil is compacted, its particles are pressed together into a denser mass (Beard, 1973). Where turfgrass is growing, the soil may have been compacted during construction and establishment. This type of compaction is difficult to correct because it often occurs so deep in the soil that the turf manager has no means of correcting the problem.

Turf maintenance practices and use of the turf compact the soil significantly. As also occurs on farm soils, each pass over the turf of the equipment (or user) causes a certain degree of compaction. The amount of compaction varies with the texture of the soil (silts and clays compact more than sands), soil moisture level (generally, soils higher in moisture compact more), vegetative cover (with more thatch there is more cushioning and less compaction), and the intensity and frequency of the pressure applied. The turf manager should therefore use low p.s.i. equipment, operate it carefully, keep off the soil when it is wet, correct drainage problems, change traffic patterns, and keep a healthy turf growing on the area.

Nature also provides some assistance in reducing compaction through freezing and thawing, wetting and drying, root activity, and the activity of other organisms, such as earthworms.

Cultivation

Turfgrass soil tends to compact in the surface inch or so. For this reason, the turf should be cultivated so as to limit the amount of surface disruption. Cultivation practices typically used on turf are core cultivation, spiking, slicing, grooving, forking, and subsoiling (Beard, 1973).

The turf manager should recognize that maintenance practices can contribute significantly to compaction. This fact has been most apparent with the wear and

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compaction that have resulted from the use of triplex greens mowers when the traffic pattern around the edge of the green has not been altered or when the mowing pattern has not been changed on fairways or other turf areas. The compacting effects of cultivation have not usually been considered, however, because a direct effect on the turf has not been readily apparent.

Recent research at Michigan State University (Petrovic, 1979) showed that core cultivation with Ryan's Greensaire tines in the laboratory results in compaction at both the edge of the coring hole and just below the bottom of the coring hole. Petrovic studied this effect by using a computerized axial tomography (CAT) scanner in cooperation with our Department of Medical Radiology.

In his studies, Petrovic found that the compaction at the edge of the coring holes dissipated with time because the sides of the coring walls sloughed into the opening in the sandy loam soil used in the research. We do not know if this sloughing will occur in finer textured soils, but on certain greens we have found coring holes that appear to be several years old. Further study is certainly needed on this aspect of the problem. When the tapered shape of the Greensaire tine is considered, it is not surprising that there would be compaction at the edge of the coring hole. Measurements taken from one tine revealed an inside bottom diameter of 0.28 inch. When the tine was forced into the soil to a depth of 1 inch, the outside diameter was found to be 0.44 inch. At 2 inches, the outside diameter was 0.48 inch, and if it was possible to reach a 3-inch depth, the opening was approximately 0.59 inch. Thus, the opening was increased 57, 71, and 111 percent when the tine penetrated to the 1-, 2-, and 3-inch depths, respectively. When a space is created in soil where there was none, it is obvious that compaction must occur on the sides of the coring holes.

In soil in which bentgrass is growing, the compaction at the bottom of the coring hole did not dissipate within 90 days after coring. Thus, when the turf is core cultivated to the same depth over a period of years, there is the potential that a compacted layer can develop just below the bottom of the coring hole. The turf manager can learn from the farmer, who has observed a plow pan (a compacted zone just below the plow layer) on certain soils when the soils were plowed to the same depth over several years. This plow pan can severely restrict root growth and water movement. Although we do not yet know if continued core cultivation is causing a "cultivation pan" in certain soils under turf, the turf manager should be aware of the potential.

In the research study, when soils with higher moisture content were cored, greater compaction occurred (Petrovic, 1979). This fact is not surprising because the effect of soil moisture on the compactibility of a soil has been known for many years (Beard, 1973). Still, to our knowledge, these data are the first reported on core cultivation effects, and they further support the importance of having the proper soil moisture content at the time of cultivation. In addition, the equipment may not penetrate the soil properly if the soil is too dry.

What should be done about the potential for creating a cultivation pan under turf with continued cultivation? First, it might be well to vary the depth of cultivation. Farmers have found this practice effective. It can be accomplished by varying the length (amount of wear) of the coring tines, changing the pattern of coring the greens (such as not always coring the number 1 green first), coring with different equipment, or coring at different moisture contents. Second, soil should be core cultivated at the proper soil moisture content. This practice is admittedly difficult because soil must be cultivated when the turf is not in use.

Common sense and the need for coring should be considered here. Third, the relative importance of the coring should be evaluated. If relief of surface compaction or some other problem is of greater importance than the potential for a limited amount of deeper compaction, then surely the core cultivation should be done. Fourth, it may be well to consider some deeper cultivation such as the deep core cultivation (this is very hard on the equipment available) or a subsoiling type of cultivation (such as with the Subaire or similar equipment). The latter practice should be done when the soil is relatively dry so that it will shatter.

On the basis of the results from Petrovic's studies and our general understanding of turf and soil management, our general recommendation is not to stop using core cultivation in the turf management program. Turf managers should be aware, however, that core cultivation will cause a certain amount of compaction and that they should rate the priorities on the importance of this practice. If they have a clear need, they should proceed.

Objectives of Cultivation

To evaluate any cultivation practice, the objectives should be considered. They may include one or more of the following: to improve water infiltration (less irrigation water needed and fewer localized dry spots); to improve aeration; to break up undesired layers near the surface; to control thatch; to reduce compaction in the surface layer; to improve rooting; to stimulate the turf; to improve resilience; to aid soil modification, renovation, or overseeding; and to improve the penetration of lime or fertilizer. The primary purpose of all of these objectives is to maintain a better, more stress-tolerant turf.

Disadvantages of Cultivation

On the negative side of the cultivation question, the turf manager must evaluate other factors: special equipment is required; trained labor to use that equipment is necessary; cultivation interferes with use of the turf and may disrupt the turf surface; cultivation causes injury to the turf, making the turf more susceptible to stresses; the soil is exposed for germination of annual bluegrass and other weed species; disruption of a preemergence herbicide barrier may be broken, making the herbicide less effective; and based on Petrovic's results, a certain amount of compaction occurs.

Conclusion

Each cultivation practice has a somewhat different objective and has different effects on the turf and soil. Cultivation practices may have disadvantages as well as significant objectives. As we weigh all the factors, however, the following conclusions may be helpful.

1. A given cultivation practice should not be considered to be a routine management tool.

2. The objective and need for the given cultivation tool on the turf and soil should be clear and established.

3. Soil should be cultivated during periods when the turf can grow and recover from the injury caused by the practice.

4. Soil should be cultivated at the proper soil moisture content.

5. Turf managers should be sure that the equipment is accomplishing what they think it is.

6. Turf managers should weigh all the factors, establish priorities on what the greatest need is, and then proceed.

Obviously, further study is needed regarding the effects of cultivation on turf and soil. Progress will be made as the scientist and the turf manager work together and keenly observe the results of these practices.

Literature Cited

Beard, J.B. 1973. *Turfgrass: Science and culture.* Englewood Cliffs, New Jersey: Prentice Hall, Inc.

Petrovic, A.M. 1979. The effects of vertical operating hollow tine (VOHT) cultivation on turfgrass soil structure. Ph.D. thesis, Michigan State University.

Care of the Golfer

Bill Lyons

Our care of the golfer at Lyons Den Golf Course begins in the parking lot. We have flowers planted in 1- x 2-foot drain tiles used as "bumper blocks." During 15 years of use, only 1 or 2 of these flower plantings have been upset or damaged. Flowers have a silent way of telling people "this is a nice place."

Because people hate to walk on concrete or asphalt when they are wearing golf shoes, we have reduced golf-shoe erosion on the edge of the asphalt by installing and sodding plastic Grass Cels. They have absorbed years of wear, and we have had no more hazard or lawsuits. In fact, everything at Lyons Den has to answer the question: "Is it lawyer proof?"

Next, the golfer sees a fleet of *clean* golf cars with two *clean* washable Chex towels attached with rubber bands. Our clubhouse gals put on the small grommets and rubber bands (in laundering we remove the bands). Stained towels that do not come clean at the laundry are recycled as grease rags in the turf equipment care center. Rental pull carts have "Keep America Clean" litter bags and Chex towels attached. What is the result? Very little trash is ever seen on Lyons Den.

Because we have many houses for purple martins (people love birds), we seldom have to fog for mosquito control until after the martins have left about August 15. Their friendly chirps and aerial dances are a delight to all. They are weather forecasters, too. If they feed so high that they are almost out of sight, look for an oncoming summer storm.

We take care of the golfer by doing the *little* things that capitalize on human interest, such as a post with a rain gauge and a Williams evaporator gauge with its colorful sponges and inch and metric gauge on the end. (We fill it and take a reading every morning.) One golfer commented, "You guys think of everything." Yes, we try to think of what we want the golfer to do without telling him. A diplomat can tell you to go to hell in such a way that you can hardly wait for the trip to start. Golfers have to be treated the same way.

Slow play is not a problem at Lyons Den. Why? We have no ranger insulting the customers. To tell golfers that they are too slow is an insult. Each score card tells the player his *reserved* starting time on the next nine. Money talks to slow players. If we see that they have left two holes open ahead of them, we politely give them their money back and tell them to find a course that will tolerate their slow play. We have protected ourselves legally by having printed on the score card, "Open to all good sports." We are the legal judges of sportmanship. Furthermore, we have a seven and four rule: Seven strokes in the tee to green and not more than four putts.

Bill Lyons is President and Owner, Lyons Den Golf Course, Canal Fulton, Ohio.

Those who do not know how to hold a golf club will slow down play, so we have Vardon grip clubs hanging on the first and tenth tees to help those who want to improve. Why? Because only one out of five going off our first tee knows how to hold a golf club. Thus we offer tips to better golf only in the interest of speeding play. Hundreds of our place mats with 20 golfing tips printed on them are carried home. Some are displayed on coffee tables. One lady said that she framed hers and it hangs on the wall in the bathroom so that when she is contemplating she can study her golf and plan her shots. We can only hope that she made that hole in one.

Traditions on the Course

Every course has little things that have become traditions: not just some poorly placed sand trap on the front of a green, but something natural like a gully or creek to cross, or a pine tree like Cypress Point in front of the eighteenth green. Or it could be a bell to tap or ring to signal following players to "come on" (or those slow players ahead that you are on their tails).

Neither golfers nor cows can read, so at our sixth hole we have a wooden fence to direct the play to the seventh tee. We have no signs on the whole course. If you are a diplomat, you can get the golfers to do what you want them to without their knowing that you are telling them. (They will enjoy the trip and will be back.)

Pets on the course are a tradition. Every golf course has to have a friendly dog, even if it is just a stray "mut." More people knew our dog Jasper than knew the course owner. Donald Duck on Lake 2 was the best-fed duck in the world—he knew those who offered him tidbits. Pets are a lot of fun on the course, even that mama cat in the turf equipment care center. One day she could have said, "Tee-hee, you thought we was fighting." Not long after we had her fightin' kittens to feed.

Sometimes we give homeowners tips about how they can care for their own lawns. We tell them how we eliminated disease on the fairways without using fungicides; how we inhibited Japanese beetles by applying 100 pounds of dolomite lime per 1,000 square feet; how thatch (enemy of all fine turf) can literally be dissolved without lifting a handful of it; and how to use fertilizer correctly. We take the attitude that the easier we can make it for the golfer's wife to take care of the home lawn, the more he will get to use our course. She has enough problems with painting the garage, hanging the storm windows, patching the roof, and curling her hair to waste time mowing overfertilized grass.

People love good grass—grass that has good color and is free of disease and weeds. You can't alibi insects; you have to control them. What does all this cost? Actually nothing; the small investment is the profit producer. Yet it takes about 5 percent of gross income to supply the tools of fertilizer, pesticides, soil amendments, and lime to produce that "come back again" type of turf. We at Lyons Den have the philosophy that if all turf can come up to the high standards we set for ourselves, more people will take up the game, and we will get our fair share of the business.

To take the guesswork out of growing grass and to simplify our turf management, we have packaged 40 years of experience into an agricultural and turf test kit. If you keep the daily records and follow the 11 steps of management, there is no need for failure. You will have a diary of performance. (It could save jobs, too).

The choice is yours. You can either keep abreast of progress or let it overtake you. For years we have relied on corn-farming soil test methods to grow turf, but soil tests and methods can be challenged. Do you ask the soil what it will give up to the turf? Or should you be asking the turf, through the clippings, what it is getting and what you need to supply it? Just remember that the corn farmer grows one plant to every 2 square feet, and you, the turf manager, grow hundreds of plants per square inch. He can turn it over, but you have to go with what you have, undisturbed, year after year.

The corn farmer will pull out a vertical core of soil 6 to 8 inches deep. Before he tests it, he will mix it thoroughly and throw away the trash or thatch. Turf has been tested the same way on a 2- to 4-inch sample (modified corn farming). If you want a false reading, go ahead on that basis, but if you want a real turf test so that you can improve the quality, follow these simple tests. First, test the thatch with a pH computer or the Purdue thatch test kit (we furnish both). If the pH is below 6.6, do not spread the grass seed until the pH is brought up to or above 6.6. Yes, you can have an acid thatch and a soil with a neutral ph of 7.0 or above. By the same methods, you should test chips of soil at the surface and then downward every 1/4 inch. From this testing you will soon learn that a mixed sample could give an erroneous reading.

The nitrate dew test in the morning will tell you how much nitrogen is guttating and will feed the yeasts that are the hosts for many disease organisms. Wash down the turf to recycle the nitrogen before you mow.

Test those clippings for phosphorus and potassium. Let the tests tell you the plants' needs, then correlate the plants' food needs with the temperature and moisture of both soil and air. According to Dr. Burt Musser, it matters not what kind of nitrogen is used, so long as the user knows the behavior of the product under all conditions. The controlled release of nitrogen to the turf has much to do with hot-weather diseases. Sandy soils can run out of all elements rather quickly, and "spoon" feeding may be required.

Lightning Protection

Your golfers would have more confidence in you if they knew that you were giving them all possible protection from lightning. How can you do this?

1. Install a weatheralert—a weather receiver that will be activated by the local weather bureau for the detectable weather fronts that carry lightning discharges.

2. Have two or more of your staff become Skywarners. The NOAA weather service, through your local weather bureau, would like to have an observer every 2 square miles and will train weather observers.

3. Make or install a warning system. Lyons Den has two sirens (bright red) mounted on a golf car. If it is parked at the first tee, it warns people that lightning storms are approaching or that we think the thermals are building and may be hazardous. We hope that we can give a five-minute warning to allow for those nickle and dime skins.

4. Provide lightning-proof shelters within 200 yards of all players. I will send you details on request.

To ignore the hazard of lightning on the golf course is to invite lawsuits for negligence. Can you afford that chance?

Summary

In conclusion: test, test, test, and then sell. You are selling yourself by the quality of turf you can produce. The best quality brings the best price. Good luck.

Wetting Agents on the Golf Course—A Superintendent's Experience

Bruce R. Williams

Wetting agents are nothing new and were probably in existence even before I was born. Today, however, wetting agents are often overlooked as a management tool on quality turfgrass stands—especially in areas with poor underlying soil structure.

I am sure that all of you have experienced seasons with infrequent precipitation and even, in some cases, actual severe drought. Well, try as we may to use our irrigation systems to compensate for a lack of rain, we find that irrigation water cannot take the place of natural rainfall but can only supplement it. Before too long, localized dry spots begin to appear, and the sprinklers' rotation pattern becomes highly evident.

When localized dry spots appear on our greens or tees, it is our standard practice to:

1. Aerate each individual dry spot

2. Apply a wetting agent

3. Water by hand

These measures are strictly curative. However, through the scheduled application of wetting agents on a preventive (rather than curative) basis, localized dry spots can be minimized. The preventive use of wetting agents on greens and tees provides a very uniform distribution of moisture in the soil.

Wetting agents are special chemicals that lower the tension of water. They are in the class of surfactants. Wetting agents change water yet have no visible effect on the soil structure. Since the wetting agent stays in the soil, however, the treated soil will accept water more rapidly, and excess water will drain freely, resulting in optimum growing conditions.

At Bob O'Link Golf Club, I apply a wetting agent on greens and tees in mid-May and then repeat the procedure in late June or early July. Applying one and one-half quarts of Aqua-Gro in 100 gallons of water (per 6,000-square-foot green) has given the best results. For such a high volume of water, a rose nozzle is the most efficient means of application. It is important to water the wetting agent into the soil immediately and thoroughly because permitting it to remain on the turf blade will cause a yellowing.

During the past two summers I have attempted to take my successful results with wetting agents on greens and tees another step further and incorporate

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preventive applications on 35 acres of fairways. The primary fairway application is made in mid-June, and a second application follows in mid-July. A third application may be necessary in August, but because of heavy precipitation in August, two applications proved to be sufficient last summer.

Through trial and error, the following rates have provided optimum results. Two gallons of Aqua-gro in 200 gallons of water covering 1 acre at a ground speed of 2 miles per hour is the recommended rate. We used test plots with varying volumes of water, different rates, and various brands of wetting agents as well as check plots; and we have made the following general observations.

1. Aqua-gro at the above-mentioned rate was the most effective wetting agent.

2. Good results were shown in test plots with All-wet and Hydro-wet.

3. Wetting agents not watered in are potentially phytotoxic.

4. All wetting agents were applied alone and not in combination with any pesticide.

In a comparison of wetting-agent-treated fairways and untreated check plots, the difference was like that between night and day. Treated fairways had the following qualities:

1. Dew was eliminated for a 6- to 7-day period following the application.

2. Localized dry spots in the wedge-shaped areas adjacent to our single row irrigation system required hand watering only once during the 1979 season. In prior years it took 80 to 100 man-hours to accomplish this task. Less hand watering means a lower labor cost and the freedom to use your staff on other projects. It means minimal or no interference with golfers. It means conservation of water and power.

3. Fairways had not only fewer dry spots but also fewer wet spots.

4. Overall, soil moisture continuity was increased.

5. Soils were able to absorb moisture more rapidly during the heavy precipitation that we had in August.

6. Less stress was evident on treated fairways, and wilting was not severe.

7. Prior to fairway applications, it was often difficult for irrigation water to penetrate a one-inch thatch layer unless fairways had been sliced or aerated in the spring.

The application of wetting agent on the fairways has proven as successful as the wetting-agent program on my greens and tees. The approximate cost of the materials for one application to 18 greens is $150. It would cost $700 to apply a wetting agent to 35 acres of fairways. Given the aforementioned results, however, I feel that this cost is offset by the savings in water and manpower and that it provides a better playing surface.

Each year the golf course superintendent sweats out the period from June to September, which is known to try men's souls, bring on ulcers, and cause sleepless nights. During this stress period we carry on a day-to-day battle in an effort to provide pleasurable playing conditions for our membership. In these modern times of turfgrass management, any loss of turf on our greens and tees is intolerable, and a loss of fairway turf is undesirable. More and more the trend in the Chicago area is that players who once compared golf courses by their fast and true greens are now judging them by the condition of their fairways. With this increased demand for fairway perfection, even a minimal loss of turf on our fairways is a problem.

With the incorporation of wetting agents into my fairway management program, maintenance of summertime *Poa* has certainly become more enjoyable. I am thankful for something that has made my job a little bit easier.

Fertilizer Programs for Bentgrass Putting Greens

Donald V. Waddington

Good turfgrass fertilization programs cover a wide range of practices. There is no "best" program for all situations. Even when similar fertilization programs are used by different superintendents, these programs may need slightly different "fine tuning" to obtain optimum results. When developing a fertilization program for putting greens, a superintendent should consider other maintenance practices, the kind of grass present, the soil type, the characteristics of various nutrient sources, and methods of determining fertilizer needs. Because considerable variation can occur among greens, the purpose of this paper is not to outline a specific program. Instead, some of the factors that will influence the choice of a program are presented and briefly discussed.

Fertilizer-Management Relationships

A turfgrass fertilization program should be considered as one part of a total management program. In developing a program, one should consider the interrelationships among fertilization practices and factors such as turfgrass diseases, weed encroachment, mowing, thatch, irrigation, and aerification. Some examples of these relationships follow:

Disease

High nitrogen (N) availability favors the development of brown patch, whereas rust and dollar spot are often associated with low N availability. Late-fall N fertilization has been shown to favor snow molds.

Weeds

Dense turf resists weed invasion. Thin turf, because of low fertility or other factors, favors weed encroachment. Timing of fertilization can affect weed populations. Dr. Ralph Engel recently reported that *Poa annua* infestation on greens was greater with fall than with winter (dormant) N fertilization. (See *Golf Course Mgt.*, Sept.-Oct. 1979.) Liberal phosphorus (P) and potassium (K) fertilization favor *Poa annua*, while sulfur (S) has suppressed it. High soil pH has been shown to encourage crabgrass in bentgrass.

Mowing

Clipping removal increases fertilizer requirements, and liberal fertilization increases the need for frequent mowing. On close-cut turf, fertilizer may be picked up by the mower, and mowing without catchers the first mowing or two after fertilization will reduce these losses.

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Irrigation

Adequate soil moisture favors efficient utilization of fertilizer nutrients, whereas excessive irrigation can increase losses by leaching or runoff. Irrigation following the application of soluble fertilizer salts reduces the chances for fertilizer burn.

Aerification

Fertilization after aerification aids in deeper placement of plant nutrients such as P and calcium (Ca), which move very slowly through the soil. Improved soil physical conditions from aerification or topdressing or both can increase the efficiency of N sources dependent on microbial breakdown for N release.

Thatch

Research at the University of Illinois at Urbana-Champaign has shown that thatch has a different effect on losses of N from different N sources. (See Dr. Turgeon's paper in these proceedings.) These few examples of fertilizer-management relationships illustrate the need for a superintendent to be familiar with all aspects of turfgrass management. The weed and the disease examples are not meant to endorse practices of fertilizing to control weeds and disease. Instead they are meant to point out the relationships between these management practices. When practical, use fertilizer practices that will minimize weeds or diseases. But do not starve the grass or make it too lush during stress periods while trying to control a disease or weed. We have fungicides and herbicides that are more effective controls.

Nutrient Retention and Availability

The two major soil properties that affect nutrient retention and availability are permeability and cation exchange capacity. Permeability refers to the ease with which water, air, or roots can penetrate or pass through soil. Soil texture and structure affect permeability, which increases as texture becomes coarser or as aggregation increases. On sand or the highly modified soils that are used on some greens, good to excessive permeability is associated with high air porosity (large pores), which contributes to rapid oxygen diffusion, infiltration, and percolation rates. High infiltration and percolation rates allow more rainfall and irrigation water to enter and percolate through the soil. Less runoff occurs. Greater water movement through the soil increases the probability of nutrient leaching. Another characteristic of sandy soils is their low water-holding capacity, and unless some provision such as the plastic liner used with Purr-Wick greens is used to increase water retention, more frequent irrigation increases the chances for excessive water applications that will leach nutrients.

Some plant nutrients are taken up by plants as cations (positively charged ions). Some examples are potassium (K^+), magnesium (Mg^{++}), calcium (Ca^{++}), and nitrogen as ammonium (NH_4^+), although most N is taken up in anion form as nitrate (NO_3^-). Cation exchange occurs between cations in solution and those held on the surface of negatively charged clay and organic colloids. Cation exchange (CEC) is the total amount of exchangeable cations that a soil can adsorb and is expressed using the unit of milliequivalents (meq.) per 100 grams of soil. The CEC increases with increases in clay or organic matter. As sand levels in modified soils are increased, clay content decreases and the ability of the soil to adsorb and retain cations also decreases. Addition of organic matter to sandy soils helps to overcome low CEC values. The CEC values for sand and soil mixes used in the Penn State soil modification study are shown in Table 1. The higher CEC of field samples was

Table 1. Soil Fertility of Original and Field Samples from Soil and Sand Plots on The Penn State Soil Modification Plots[a]

Soil test value	Plot[b]	Original sample[c]	Field sample[d]
Total N (percent)	Soil	0.24	0.33
	Sand	0.11	0.22
P (ppm)	Soil	38	63
	Sand	6	62
K (meq./100 grams)	Soil	0.5	0.4
	Sand	0.1	0.1
Ca (meq./100 grams)	Soil	10.4	12.4
	Sand	2.0	5.7
Mg (meq./100 grams)	Soil	1.0	2.1
	Sand	0.2	1.4
CEC (meq./100 grams)	Soil	15.9	16.9
	Sand	5.0	9.2
pH	Soil	5.9	6.7
	Sand	5.3	6.6

[a]Source: Zimmerman, T.L. 1969. Infiltration rates and fertility levels of physically amended Hagerstown soil. M.S. Thesis, The Pennsylvania State University.

[b]Soil plot was 80 percent soil (Hagerstown silt loam) + 20 percent peat, and sand plot was 80 percent sand + 20 percent peat (volume basis).

[c]Sampled at time of construction.

[d]Sampled at soil depth of 0 to 2 inches after 49-22-22 lb./1,000 ft^2 of N-P_2O_5-K_2O had been used over a 5-year period.

attributed to increased organic matter added by roots. Such organic additions and the presence of thatch or mat or both can be expected to be of prime importance in increasing nutrient retention in sandy soils.

Fertilizer Nutrients (N,P,K)

The fertilizer nutrients are normally added to turfgrass in the greatest quantity. The N requirement of turfgrass plants is highest and is followed by K and then P. The major forms of N in the soil are ammonium (NH_4^+), nitrate (NO_3^-), and organic. The NH_4^+ form can be adsorbed on soil colloids and is not leached to the extent of NO_3^-. Environmental conditions favorable for turfgrass growth also favor microbial conversion of NH_4^+ to the readily leached NO_3^- form. Thus, the leaching problem will exist with all soluble N sources, ammonium salts, and urea as well as nitrates, and the severity of the leaching problem will increase as soil texture becomes sandier. If soluble sources of N are used on sandy soils, using frequent, light applications of N becomes of particular importance. Using slow-release sources of N, such as natural organics, ureaform, IBDU, or coated soluble sources, will help to minimize the leaching problem. On the Penn State soil modification plots, soil N levels were increased over a 5-year period (Table 1) by using slow-release N fertilizers. Of the total N applied, 72 percent was from ureaform, 21 percent from activated sewage sludge, and 7 percent from soluble sources. The buildup of N in these soils was such that with only two N applications per year (spring plus fall) adequate N was being released to maintain good growth and color throughout the growing season.

Only about 1 to 2 percent of the total P in soils is available. Most of the inorganic P in soils is fixed in relatively unavailable forms in reactions with iron (Fe) aluminum (Al) in acid soils and with Ca in alkaline soils. Most of the Fe and Al is associated with the clay fraction, and in sand greens little clay exists. In acid sands, P may actually be leached; however, if sands are limed, leaching is not a problem because soluble P can be tied up with Ca. The P "fixed" by Fe and Al or Ca can become available at a slow rate. In our Penn State studies we found that, although wide differences existed in available P in the original mixes, the buildup of P in the sand was such that no difference between P in the sand and soil existed in the field after 5 years (Table 1).

Potassium exists in soils as (1) readily available K such as that in soil solution and that adsorbed on colloids (exchangeable); (2) slowly available K that is fixed within the structure of certain clays; and (3) unavailable or very slowly available K found in minerals such as micas or feldspars. Assuming that quartz (silica) sand is the primary component in sand greens, few or no K-containing minerals will be present, little fixed K will exist because of a low clay content, and a low CEC will allow little retention of K in the soil. Potassium is more susceptible to leaching in sandy soils, and lighter and more frequent applications would be in order for sandy soils. One or two applications per year are usually sufficient on finer textured soils having a higher CEC.

Fertilizer programs based on building large soil reserves of P and K and then using only N during the growing season to control growth and color are best left for the soil-containing greens. On sand greens a program using frequent applications of a complete fertilizer (containing N, P, and K) would be more appropriate. Soluble N sources and potash sources have high salt indexes—meaning that they have a high potential for burn. Low rates with frequent applications reduce the chance of burn from properly applied fertilizer. A disadvantage of frequent applications is the increased probability of fertilizer burn due to misapplication. Special care should be taken to see that spreaders are properly calibrated and that fertilizer is not spilled on turf. The probability and severity of burn can be reduced by using sulfate of potash rather than muriate of potash (which has about twice as much burning potential as sulfate of potash) and by using slow-release N sources alone or in combination with soluble N sources.

In the Penn State study, K did not increase in either the soil or sand mixture, and the sand contained only 20 to 25 percent as much exchangeable K as the soil (Table 1). The thatch on these plots held considerable exchangeable K, which could be taken up by roots in that layer.

Secondary Nutrients (Ca, Mg, S)

Plants use the secondary nutrients in relatively large amounts. Calcium and magnesium (Mg) exist as cations, and because they are adsorbed by soil colloids, their levels are higher in soil than in sand (Table 1). Liming materials are a major source of Ca and Mg. Calcium is also added in fertilizers such as superphosphate and calcium nitrate, and Mg may be added in sulfate of potash-magnesia and epsom salt (magnesium sulfate). Sulfur is taken up by plants in the sulfate form (SO_4^{--}). This anion is subject to leaching, and leaching would be greatest in sandy soils. If levels of S are low, it can be added by using elemental S or S in combination with other essential elements in fertilizer materials such as sulfate of potash, iron sulfate, and normal superphosphate. Gypsum contains both Ca and S, and epsom salt contains Mg and S.

Micronutrients (Fe, Mn, Cu, Zn, B, Mo, Cl)

Micronutrients are used in small quantities by plants, and adequate amounts occur in most soils. Sandiness increases the possibility of micronutrient deficiency; nevertheless, sufficient amounts are usually present and are often supplied as components or impurities of commonly used fertilizers and liming materials. Iron is the only micronutrient commonly used on putting greens: the purpose being to obtain a darker green color. If deficiencies of other micronutrients are suspected, it would be best to document the deficiency with soil or plant tissue analyses or both before applying micronutrient fertilizers.

Determination of Fertilizer Needs

Various methods and combinations of methods can be used to determine the fertilizer needs of turfgrass. Visual observations of turf color, deficiency symptoms, density, or growth can be utilized. Soil tests are very valuable for obtaining information on limestone and fertilizer needs. Plant tissue testing can be used to determine whether adequate levels of a nutrient are in the plant. Tissue testing includes those quick tests that can be made in the field as well as the more complicated and time-consuming laboratory methods. Infrequent soil testing (every 3 or 4 years) may be sufficient on soils having a relatively high CEC, which increases nutrient retention and also acts to buffer the soil from rapid pH changes.

It should be apparent that more rapid changes in soil fertility status will occur in sandy soils. Annual soil testing would therefore be appropriate on sand greens, especially on newly constructed greens. After monitoring soil fertility for several years, less frequent soil testing would be in order if a fertilization program has been developed to meet the needs of the turf. The quick tests for tissue analyses would be a valuable tool for monitoring the nutrient levels in the turf grown on the sandy soils that have low nutrient-holding capabilities.

Developing a fertilizer program within a sound management program is not all science. It is also art, and the art of fertilization comes with experience, practice, some basic knowledge, and a lot of common sense. Having the art allows for the fine tuning mentioned in the opening paragraph.

An All-Out Approach to Fairway Renovation

James W. Brandt

The Danville Country Club fairways were seeded to common Kentucky bluegrass in 1929. The fairways remained a relatively pure stand of bluegrass until a fairway watering system was installed in 1966. With moderate watering and applications of approximately 3 pounds of nitrogen and 2 pounds of potash per 1,000 square feet per year, there was a gradual invasion of *Poa annua*. In recent years there has been an increased incidence of *Fusarium roseum*. Each time bluegrass was lost to disease, *Poa annua* was its ready replacement. An overseeding program of improved ryegrasses and a mixture of improved bluegrasses had been attempted with very limited success, the ryegrass being the sole survivor of the introduced species.

In 1973 Dr. Bill Meyer, who was with the Warren Turfgrass Nursery, approached me with the idea of experimentally planting some new cultivars of Kentucky bluegrass into the existing turf at a selected site at the Danville Country Club. Number 16 fairway was chosen because of its high incidence of disease and the greater infestation of *Poa annua*. Three replications of nine cultivars were planted with 8-inch plugs on 3-foot centers. These cultivars included Baron and Fylking Kentucky bluegrasses as checks as well as seven cultivars being developed by Warren's. The plots were observed by a representative from Warren's as well as being evaluated by the author.

The 1976, 1977, and 1978 seasons were excellent for the development of disease and stress on a mixed population of common Kentucky bluegrass and *Poa annua*. As a result of turf loss in August of 1978, the membership demanded that something be done to prevent the "annual August loss of fairway turf." In evaluating the cultivars established on the 16th fairway, those designated as H-7 and I-13 were outstanding in their ability to withstand disease and in their ability to spread into the existing fairway turf. Both Fylking and Baron were gone from the 1973 planting by August of 1978.

In the fall of 1978 we decided to try a pilot program of fairway renovation. Sites were selected on fairways number 1, 6, 14, and 16. Those areas represented both the best, average, and poorest turf on the fairways. At the selected sites, a swath 16 feet in length and running the entire width of the fairways was sprayed with Roundup at the rate of 2 quarts per acre. After 1 week, 4-foot strips of four different grasses or mixture of grasses were seeded the width of the fairways. The following diagram gives the plot layouts.

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Width of fairway

↕ 4 ft.	Warren's cultivar H-7
↕ 4 ft.	Warren's cultivar I-13
↕ 4 ft.	Mixture of equal parts of Adelphi, Baron, Glade, Nugget, Pennstar, and Sypsport
↕ 4 ft.	Equal parts of Derby, Manhattan, and Pennfine improved ryegrasses

Germination in all four replicates was excellent. In the spring the ryegrasses, as expected, looked excellent. One cultivar designated as I-13 seemed to have outstanding seedling vigor. Very little growth past the seedling stage occurred in the fall of 1978. By mid-spring all but the ryegrass plots seemed to have a predominance of *Poa annua*. By mid-summer the I-13 started to predominate over the *Poa*. By mid-August the I-13 was an outstanding plot of improved bluegrass. The H-7 fared somewhat better than the mixture of six improved bluegrasses. By August 10, 1978, we experienced our usual loss of fairway turf in spite of what was considered to be an adequate spray program for disease prevention. We had 9 inches of rain in July and were well on the way to our 10 inches for August. With the accompanying heat and humidity of August, *Poa annua* was GONE.

As a result of the pilot program, we decided to embark on a complete fairway renovation program to be accomplished in 2 years. The front nine was selected as the first to undergo the complete renovation.

We sent the membership a detailed letter explaining when and how the renovation was to be accomplished. We were on schedule with our spraying with Roundup, but the office was not on schedule in sending out the mailing, so my members saw the dead grass before the letter of explanation. We were the talk of the town for having lost our turf.

The following is the renovation timetable:

August 27	Sprayed all fairways with 2 quarts of Roundup per acre.
August 30	Fairways off color and showing cart tracks.
August 31	Fairway grass black. Applied 375 pounds per acre of 13-25-12.
September 3	Fairways completely brown.
September 4	Started seeding equal parts of H-7 and I-13 using Rogers Seeder at 10 pounds per acre. Seeded on diagonal at same rate making total of 20 pounds seeded per acre.

September 7 Started watering first areas seeded.

September 11 Finished seeding last fairways.

September 13 Seed germination started.

September 20 Germination started in all areas.

September 21 Closed front nine to all play.

October 9 Mowed all new seeded fairways. Fairways have been mowed five times this fall.

October 15 Adequate stands in all fairways.

November 19 Applied 1.25 pounds of potash per 1,000 square feet. Applied 3 pounds of nitrogen as Ureaform per 1,000 square feet.

Currently, all new grass on the fairways is much ahead of the grass in the pilot program in 1978 at the same period in time. The cost was approximately $265 per acre for material and a little less than $44.00 per acre for labor. We are to renovate the back nine in the fall of 1980 using the same mixtures and procedures that were used in 1979.

Some Current Ideas on Sand Topdressing

Carl H. Schwartzkopf

In May of 1974, a rather controversial article appeared in the *U.S.G.A. Green Section Record*. The article, "Consider a New Management Program for Greens" by John H. Madison, Jack L. Paul, and William B. Davis, dealt with the practice of applying light and frequent applications of sand topdressing to putting greens. The educational policy for topdressing of greens has been to use the same or very similar material as was used during construction to avoid the possibility of developing a soil layer or strata. At the time that their article was published, the conclusions of Madison, Paul, and Davis were contrary to many of the soil science teachings in turfgrass management curriculums throughout the United States.

Historically, the procedure of topdressing greens with sand is not that new or revolutionary. Many greens have been sanded, especially putting surfaces in Scotland, for approximately 100 years. Many of the courses (especially the links land type such as St. Andrews and the honorable Company of Edinboro Golfers, better known as Muirfield, along with Carnoustie, Troon, and Turnbury) were built on sand areas so that a soil layer or strata is not very likely to develop. However, on inland courses that are built on mineral and organic soil, such as Gleneagles, sand topdressing has been practiced for several decades without any adverse effects. Although it is important to realize that the climatic conditions in Scotland differ greatly from those in Carbondale, Champaign, and Chicago, the principles of soil chemistry and physics, water infiltration, and nutrient availability are the same. As a result, the Madison, Paul, and Davis article is an update and describes the reinitiation of a practice that has been successful in the past.

Since it is difficult to obtain acceptable topsoil and the organic amendments needed for preparing a topdressing material, applying a light sand topdressing is desirable from a golf course superintendent's point of view. Also, during my tenure as assistant superintendent for a golf course, it became apparent to me that the quality of the topdressing material varied with just about every truckload that was delivered. Fortunately, when you use a sand topdressing material, it is possible to monitor the quality, thereby providing a uniform application of a similar material each time. You should use a sand in the range of 0.05 to 1.0 millimeters because it will drop out of sight and the golfer will never know that the green has been topdressed. Apply just enough sand to mingle with the stolons and prevent a thatch layer from forming. Coring can be eliminated since compaction is reduced. Initially, some golf course superintendents have aerified the green a time or two, removing the cores and then topdressing with sand. After the initial aerification, they have discontinued coring. However, if you should initiate such a program, remember that when the greens are aerified the cores are removed. Occasionally, when the sand is not applied evenly, it does not drop from sight as

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soon as it dries or is washed in by the irrigation system. In these particular instances, use a steel dragmat to work the sand into the thatch and mat layer. Frequently, the steel dragmat can be abrasive to the turf. If it is, use a piece of synthetic turf or cut pile carpeting in the inverted position instead of a steel dragmat. Also, some golf course superintendents have reported favorable results when they manufactured a series of street brooms to a riding Triplex unit.

In Dr. Madison's research at the University of California—Davis, 1/28 of an inch of sand was applied at each treatment with a power topdressing machine. He also found out that the topdressing machines, which roll material out on a belt, can handle both damp and dry sand, whereas the vibrating type of machine handles only the damp sand if it is going fast and vibrating rapidly. Also, several golf course superintendents have reported favorable results when they applied sand with a fertilizer spreader. Occasionally, some fertilizer spreaders have to be equipped with a special agitator to function properly.

As mentioned earlier, in many instances you can eliminate coring—a maintenance procedure that involves much time and labor as well as inconvenience to golfers. Also, light and frequent sand topdressing applications will bury many weed seeds, especially *Poa annua*. Several golf courses that have initiated sand topdressing programs in the past have reported favorable results and *Poa annua* reduction on the putting surface. Coring or aerification will continue to dig up buried *Poa annua* seeds.

Since water infiltration is increased, you will have a drier media and environment with fewer disease-control problems. Because the sand creates an easier environment for the caterpillars and worms to burrow in, these pests may become somewhat more troublesome than in the past. With a regular insecticide program, however, these damaging insect larvae can be eliminated very easily.

Since the actively growing bentgrass creates organic matter that adds to the cation exchange of the soil, you do not need to add any amendments to the sand. As old layers of thatch become buried, they slowly decay unless they remain saturated with water.

The infiltration rates into the new sand surface are very acceptable, but if the old buried surface was impermeable, it may limit the green's ability to absorb water. As mentioned earlier, initially you should aerify or cultivate the old interface with an aerification or two. Once 2 or 3 inches of thatch-free sand are built up, the grass appears to perform well in spite of the buried layers.

From the point of view of the golfer, sand topdressing is desirable because it can be completed with minimal interference, irritation, and annoyance to the players. In the past, after greens have been topdressed they have been muddy for two or three days and sometimes for as long as a week, which has been annoying to both the golfers and the superintendent. The superintendent found it difficult on reels and bed knives. Also, when a light sand topdressing has been applied to them frequently, the greens appear to have a somewhat faster putting surface as well as one that is smooth and true. Also, the resiliency, or the ability of the green to hold a shot, improves with the sand topdressing program.

Although many of you, especially after you have talked to superintendents who have been topdressing with sand, may feel that this method is ideal for maintaining a putting green, you might have some problems with the sand topdressing program. Possible problems include:

1. Excessive water infiltration
2. Excessive nutrient leaching
3. Lower microbial activity
4. Hydrophobic drying
5. Lack of moisture reservoir
6. Susceptibility to layering

Excessive water infiltration is likely after a 2- or 3-inch layer of sand is finally achieved after several years of sand topdressing. The water then can build up at the interface between the newly applied sand and the old soil surface. Consequently, you should irrigate judiciously when you use the sand topdressing program. This saturated soil profile can become anaerobic, thereby causing extensive turf loss in the middle of the summer. On greens with adequate surface drainage, this problem is minimized. Consequently, you should realize that where surface drainage is inadequate sand topdressing is not going to correct the built-in problem.

Increased nutrient leaching in high sand content greens or those topdressed frequently with sand occurs until the decomposed stems, leaves, and stolons provide the necessary cation exchange sites.

Lower microbial activity may be undesirable when you use synthetic, organic fertilizer materials such as urea-formaldehyde.

Hydrophobic drying or localized dry spots have been a problem on some high sand content greens as well as other areas of the golf course. Fortunately, coring and applying a surfactant followed by saturating the area thoroughly can minimize or eliminate the hydrophobic soil condition or localized dry spots.

The lack of an adequate moisture reservoir in the upper portion of the soil profile has been of some concern to superintendents during the hot summer months when breeze is prevalent. During this particular time, especially with increased *Poa annua*, irrigate or syringe more frequently.

Susceptibility to layering is another problem that can develop because of a change of golf course superintendent or because a superintendent decides to change the topdressing mixtures. Consequently, you should realize that once a sand topdressing program has been initiated it must continue for the life of the green regardless of the superintendent, the chairman of the green committee, or the president of the golf club.

Developing a topdressing mixture that has the correct capillary and noncapillary pore space, infiltration rate, moisture retention, pH, and bulk density is not easy. To achieve these parameters, you must have laboratory tests. The price for a laboratory analysis is small when you consider the need to reconstruct a green or maintain a green that has been abused with poor topdressing materials and practices. Be aware of commercially prepared topdressing mixtures that state "Meet U.S.G.A. specifications" or that they meet the approval of a local university or superintendents' association.

The U.S.G.A. Green Section's position is that materials applied as topdressing must be as carefully prepared as soil mixtures for putting green construction. This preparation will require extensive laboratory tests by trained soil scientists. Such facilities and services are available at nominal costs through universities and state experiment stations. Why not take more frequent advantage of the scientific approach? It is the safest way to ensure progress in converting a problem green into one that performs satisfactorily. If a putting green is poor because of its soil, a good program of topdressing can greatly improve it. One rule of thumb (mentioned earlier) that has been handed down through the years is that to maintain a uniform profile you must use a topdressing mixture that is similar to the soil presently under the green. Although this rule is generally good, it is not without exception. If the original soil is unsatisfactory, there is no advantage in perpetuating its use. If it is too heavy and drains poorly to begin with, there is little chance that permanent improvement can be made by adding a topdressing mixture of the same poor quality.

If your greens have a quality root zone and the currently existing cultural and maintenance program does not involve any extensive topdressing, and if good putting surfaces are being maintained, you would not be justified in initiating a light, frequent topdressing program. However, if your greens have an existing soil compaction or thatch problem that is recurrent, regardless of the particular cultural and maintenance practices used, you should seek an alternative solution. Light, frequent topdressing using the proper size sand particle is promising if financial funds are not available for complete root zone renovation (rebuilding). As time continues, this approach will be evaluated at additional turfgrass experimental sites and golf courses to determine in how wide an area this approach to turf management can be used.

Nitrogen and the Turfgrass Plant

John R. Street

Turfgrass growth is dependent upon an adequate supply of all essential plant nutrients, as well as a multiplicity of other cultural and edaphic factors. At least 16 elements are considered necessary for plant growth and development. Nitrogen receives the most attention in turfgrass fertilization programs because it is the essential element to which turfgrass is most responsive. The turfgrass plant contains more nitrogen (3 to 6 percent on a dry-weight basis) than any other essential element. Nitrogen is very dynamic, however; its concentration in the soil system is constantly changing. It may be depleted from soils by 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 to maintain a soil level that is sufficient 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 added nitrogen is nitrogenous fertilizers, which are initially added to the turfgrass system as ammonium (NH_4^+), nitrate (NO_3^-), or both or as some nitrogen carrier that eventually breaks down into ammonium. Although the turfgrass plant absorbs nitrogen from the soil as either ammonium or nitrate, the latter is the predominant form absorbed by the plant because ammonium is rapidly converted to nitrate by soil bacteria. This biological oxidation of ammonium to nitrate is nitrification, 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° to 95° F.

Once absorbed into the plant, nitrate can be stored in the cell or reduced back into 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 use of nitrogen is probably inefficient, especially if the 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

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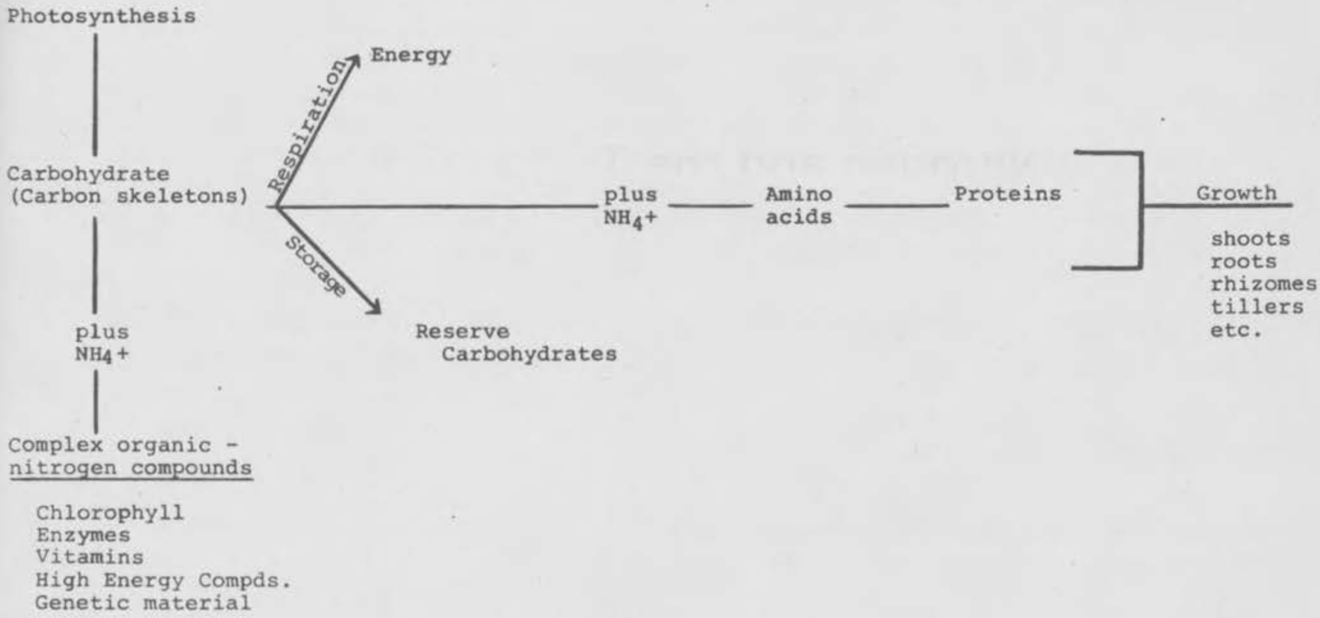

Figure 1. A brief outline of carbohydrate utilization and nitrogen assimilation.

organic compounds containing nitrogen (Figure 1). 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 the growth processes (Figure 1). The more the turfgrass grows, the greater its demand for carbohydrate. This source of energy is also the key to maintaining all the various growth and physiological processes within the plant. Carbohydrates are broken down into carbon dioxide and water through 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, which are usually stored in the crowns, rhizomes, and stolons of cool-season grasses. Carbohydrate reserves are desirable because 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, growth is rapid, or both. 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 its energy status.

Nitrogen fertilization has a definite effect upon 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 of root growth and other growth processes.

These effects are well illustrated by a fertilization study evaluating the response of a Merion Kentucky bluegrass sod to incremental rates of nitrogen (Table 1) (Rieke, 1975). Higher nitrogen rates resulted in an increase in clipping yield (topgrowth) and the nitrogen content of the 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 recognize that a grass plant is no better than the root system that supports it.

Table 1. Nitrogen Treatment Effects on a Merion Kentucky Bluegrass Sod[a]

Nitrogen rate (lb./acre/month)	Annual clipping yield (lb./acre dry wt.)	Nitrogen content in clippings (percent)	Sod strength (lb. to tear)	Rhizomes (grams)
0	463	3.0	146	99
15	1,807	3.3	188	89
30	2,555	3.6	130	120
60	5,676	4.5	97	43
120	8,447	5.4	67	14

[a]Source: Rieke, 1975.

Research has shown that a considerable amount of root initiation and root growth of cool-season grasses occurs in the spring (Beard and Daniel, 1966.) Liberal nitrogen fertilization in the spring will tend to restrict root growth. The turfgrass plant will go into the summer with a shorter root system than if moderate rates of nitrogen fertilizer were used. Furthermore, high amounts of nitrogen will increase topgrowth and 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 turfgrass root system as it goes 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 likely the result of more rapid plant growth and the production of fewer structural carbohydrates (Figure 1). This type of growth 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, which 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 increase the severity of Pythium, brown patch, Fusarium blight, stripe smut, snow mold, and Helminthosporium (leafspot) diseases (Vargas, 1975). 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 at Urbana-Champaign (Turgeon and Meyer, 1974) has shown that the incidence of Fusarium blight in the summer is greater with increasing nitrogen application rates in the spring (Table 2). Nugget, Merion, Fylking, and Pennstar were highly susceptible to the disease when more than a total of 2 pounds of soluble nitrogen per 1,000 square feet was applied in the spring. Kenblue was affected by the disease at all the fertility levels. This information lends support to the practice of using moderate levels of nitrogen fertilizer in the spring. It more specifically suggests a critical limit of using no more than 2 pounds of total soluble nitrogen per 1,000 square feet in the spring.

Table 2. Effects of Various Spring Fertilization Rates and Mowing Heights on the Incidence of Fusarium Blight on Several Kentucky Bluegrass Cultivars[a]

Fertilizer rate[b] ($lb.\ N/1{,}000\ ft^2$)		Mowing height	Kentucky bluegrass varieties[c]				
May	June	(inches)	Nugget	Merion	Fylking	Pennstar	Kenblue
1	0	0.75	1.0	1.3	2.3	1.7	4.7
1	0	1.5	1.0	1.3	2.3	1.0	4.0
1	1	0.75	1.0	2.0	1.7	2.7	4.0
1	1	1.5	1.7	3.0	2.0	2.0	4.0
2	1	0.75	1.0	2.3	3.7	4.3	4.0
2	1	1.5	3.0	3.7	4.0	4.0	4.0
2	2	0.75	2.3	3.0	5.7	5.3	4.7
2	2	1.5	3.7	5.3	6.0	3.7	4.3

[a]Source: Turgeon and Meyer, 1974.
[b]A water-soluble nitrogen fertilizer was used.
[c]Visual ratings of disease were made using a scale of 1 through 9, with 1 representing no apparent disease and 9 representing complete blighting of the turf.

Liberal nitrogen fertilization is also critical during the summer (Beard, 1973). 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 because of 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 applications of nitrogen. Nitrogen, however, is frequently referred to as the "TNT" of turfgrass fertilization programs. It can be just as detrimental as beneficial if it is 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 reached between agronomics and aesthetics.

Literature Cited

Beard, J.B. 1973. *Turfgrass: Science and culture.* Englewood Cliffs, New Jersey: Prentice-Hall, Inc.

Beard, J.B., and W.H. Daniel. 1966. Relationship of creeping bentgrass (*Agrostis palustris* Huds.) root growth to environmental factors in the field. *Agronomy Journal* 58:337-39.

Rieke, P.E. 1975. Turfgrass fertilization—Nitrogen. In *Proceedings of the 16th Illinois Turfgrass Conference*, pp. 81-85. Urbana, Illinois: University of Illinois.

Turgeon, A.J., and W.A. Meyer. 1974. Effects of mowing and fertilization level on disease incidence in five Kentucky bluegrasses. *Plant Disease Reporter* 58:514-16.

Vargas, J.M. 1975. Turfgrass disease—Nitrogen relationships. In *Proceedings of the 16th Illinois Turfgrass Conference*, pp. 90-102. Urbana, Illinois: University of Illinois.

Nitrogen Fertilizers—How They Work in the Turf Ecosystem

Paul E. Rieke

Good turfgrass management involves the proper manipulation of each of the required maintenance practices: mowing, irrigation, pest control, fertilization and cultivation, and other auxiliary practices. Improper use of any one of the above could result in a poor-quality turf or worse. Thus, fertilization is just one of the keys to good turf management.

Proper planning of the nitrogen (N) component is the heart of a good fertilization program, although all of the essential elements must be provided to the plant from either the soil or supplemental fertilization. Greater attention is being focused today on proper rates of potassium, sulfur, and micronutrients for healthy, stress-tolerant turf, but the key is still with the wise use of N fertilizers.

Nitrogen Effects on Turf

Nitrogen has so many important effects on the turf that it deserves special emphasis. The N content of turf clippings ranges from about 3 to 6 percent, which is higher than that for any other fertilizer nutrient.

The specific effects of N on the turf are reported in great detail (Beard, 1973; Madison, 1971; Hanson and Juska, 1969). Their reports include the effects on: (1) color (as a component of the chlorophyll molecule); (2) shoot growth rate (which determines the mowing frequency that is needed; (3) shoot density (the higher the N, the more the density increases); (4) recovery of turf (that has been thinned by disease, insects, nematodes, weed control, traffic, and other stress injury); (5) root growth (both roots and rhizomes may be reduced with too high N); (6) wear tolerance (a highly succulent turf will normally be more susceptible to all stresses, including traffic); (7) high and low temperature stress; (8) moisture stress; (9) susceptibility to diseases (this topic deserves significantly more attention); (10) susceptibility to seedhead formation; (11) tendency to form a thatch layer; and (12) plant composition of the turf (competition among species such as annual bluegrass, bentgrass, Kentucky bluegrass, red fescue, crabgrass, dandelions, and other weed species). Many of these effects are intimately involved with the physiology of the turf plant, and we admittedly need to learn much more about them. Considering all of the potential positive and negative effects of N on the turf, it becomes apparent that the turf manager needs to know as much as possible about how a given N fertilizer should be expected to respond. To understand how a specific N fertilizer works, it is helpful to understand what can happen to N in the turf root zone—to understand the N cycle (Figure 1).

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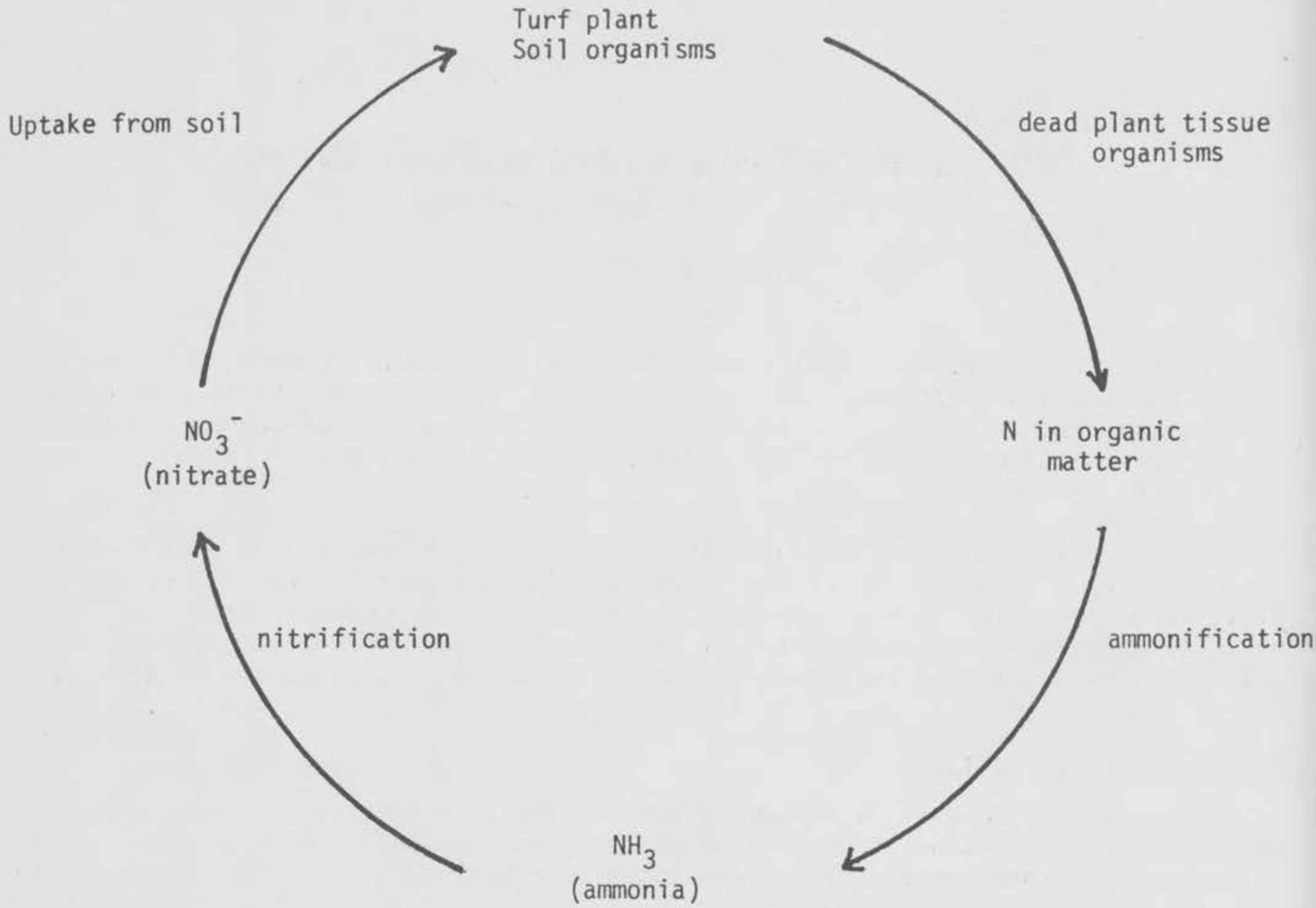

Figure 1. The nitrogen cycle.

Nitrogen Cycle

Most soils on which turfs are being grown contain at least some organic matter. One of the components of organic matter is N. A general rule of thumb is that the more organic matter in the soil, the more N, but this form of N is complex and is not available to plants. Certain soil organisms must attack the organic matter, and eventually the complex N is converted to ammonia (NH_3). This conversion is called "ammonification." The rate at which these soil organisms convert the N to NH_3 is affected by many of the same factors that affect plant growth, such as nutrient levels, soil acidity, moisture, aeration, and soil temperature. The last of these, soil temperature, is the most important factor in how fast the microorganisms normally convert the complex N in organic matter into NH_3. Thus, when soils are cold (soil temperature below 40° to 45° F), the rate of conversion to NH_3 is very limited. Likewise, when the soil temperature is warm (above 60° to 65° F), the rate of organism activity is quite high. In between these temperatures, the rate of ammonification is intermediate. Therefore, these activities are called "temperature dependent."

Ammonia is really a gas and has little practical attraction to soil particles. This characteristic makes ammonia highly susceptible to loss to the atmosphere as a gas through ammonia volatilization. Fortunately, most soils have many hydrogen (H^+) ions that, when combined with ammonia (NH_3), form the ammonium (NH_4^+) cation. This cation can be held in the soil by attraction to the cation exchange capacity of the clays and humus particles.

When urea is applied to warm soils, it is rapidly converted to ammonia. If high quantities of ammonia are present, especially in the thatch layer, the potential for volatilization losses is high. It is therefore best to water urea applications into the soil.

Although the turf plant can utilize small quantities of ammonium, it prefers to take up N in the nitrate (NO_2^-) form. The conversion of ammonia to nitrate is accomplished by specific soil microorganisms. This process is called "nitrification" and is also soil temperature dependent.

Once the nitrate is available, the plant root can take it up and utilize the N in the plant. Some soil organisms also use nitrate and infrequently compete with plants for it.

As clippings are returned to the soil and plants or other soil organisms die, they become part of the soil organic-matter pool. Thus, the N returns to its organic form. The next steps are ammonification to nitrification to plant uptake, and so forth. Thus, the N is cycled around.

Nitrogen Losses

Unfortunately, losses from the N cycle can occur under the turf. These losses include: (1) leaching of nitrate with excess rainfall, irrigation, or both (some ammonium and even urea can be leached from sands); (2) clipping removal; (3) volatilization of ammonia; (4) denitrification (nitrate is converted by certain microorganisms to a gas that is lost from the turf); and (5) erosion of topsoil.

Nitrogen Additions

Nitrogen can be added to the turf environment: (1) primarily by fertilization; (2) by organic-matter additions (as with topdressing); (3) by rainfall (from pollution and lightning); and (4) by N fixation (conversion of N gas to organic-matter N) by several different microorganisms. Most of the N contained in clippings, stems, and roots will ultimately be recycled and is not considered to be a gain or a loss from the turf ecosystem.

Nitrogen Fertilizers

That background sets the stage for understanding where the various N fertilizers fit into the N cycle and what environmental factors may limit the rate of response from each. Several N fertilizers are listed below, and the variables that affect their release are discussed briefly. The turf must be physiologically active enough for the roots to take up the nitrate.

Ammonium nitrate (33-0-0)—Highly water soluble with half ammonium and half nitrate. Quick response. High burn potential. Absorbs moisture from the air. Acidity effect upon soil.

Ammonium sulfate (21-0-0)—Water soluble containing 24 percent sulfur. Quick response. High burn potential. Very strongly acidifying effect upon soil. Quite soluble in water.

Ammonium phosphate (varies from 11-48-0 to 21-53-0)—Moderately water soluble with high P_2O_5. Quick response. Moderately high burn potential. Strong acidifying effect upon soil. Often present in complete fertilizers, but not often used alone on turf because of high P_2O_5.

IBDU-isobutylidene diurea (31-0-0)—Very low water solubility. Slow-release N source. Smaller particles give faster response. Soil moisture necessary for release of N. Somewhat more rapid response on acid soils. Slightly slower response under cold soil conditions.

Methylene urea—Contains some free urea, giving quick response, and methylene ureas of low molecular weight, giving somewhat longer response periods. Nitrogen response to longer-chain methylene ureas is dependent upon soil organism activity (soil temperature dependent). Low burn potential. Slight acidifying effect upon soil.

Methylol urea—Contains unpolymerized methylol urea and free urea. Supposedly has lower burn potential than other soluble carriers. The degree to which slow release occurs when applied to turf needs to be studied further. Should provide relatively quick response. Slight acidifying effect upon soil.

Nitrification inhibitors—Used on ammonium, urea, or both to slow the rate of nitrification to nitrate, giving a somewhat slower, longer response. Burn potential is the same as the N carrier. More data needed to determine efficacy and best means of application. Acidifying effect depends upon N carrier.

Potassium nitrate (13-0-44)—Water-soluble carrier with high K_2O. High burn potential. Quick response. Should be applied primarily as a K_2O source. May have a slight basic effect upon soil.

Sewage sludge—Most commonly used is milorganite (6-2-0), which gives slow (temperature dependent) response. Contains considerable P_2O_5 and iron. Iron frequently contributes to "green" response of turf. No significant burn potential. Other treated sludges vary considerably in nutrient content.

Sulfur-coated urea (32 to 37 percent N)—A molten sulfur (and other materials) coating of urea granules prevents ready availability of the N in urea. Water diffuses through cracks into the particle and urea diffuses out. Breaking the coatings mechanically, by organism activity and by water, allows the urea to enter the soil solution. If many coatings are broken, burn potential is higher.

Urea (46-0-0)—Highly water soluble. Moderately high burn potential. Quick response. Acidifying effect on soil. Cheapest N source for turf.

Ureaformaldehyde (38-0-0)—Contains some free urea, water-soluble methylene ureas, and water-insoluble methylene ureas. The more water-insoluble methylene urea, the slower the N release. Nitrogen release is temperature dependent. Essentially no burn potential. Usually combined with other N sources in complete fertilizers or mixed with soluble N sources. Available in both powder (quicker response) and chip form.

There is a wide range in cost per pound of N from these N sources. Generally, the water-soluble carriers are cheapest (urea, ammonium nitrate, and ammonium sulfate). Methylol ureas, ureaformaldehyde, IBDU, and milorganite are higher in cost per pound of N. This difference in cost must be weighed against other factors, such as cost of application, safety, use of the turf, labor, equipment, irrigation, weather conditions, leaching, volatilization, and uniformity of the fertilizer.

Summary

As energy costs continue to rise, the cost of manufacturing fertilizers will also rise. This fact, coupled with increased maintenance costs, will focus greater attention on using N fertilizers most efficiently while maintaining functional turf. The turf manager will need to have a good grasp of the concepts discussed in this report to help him make good decisions about fertilization.

Literature Cited

Beard, J.B. 1973. *Turfgrass: Science and culture.* Englewood, Cliffs, New Jersey: Prentice-Hall, Inc.

Madison, J.H. 1971. *Principles of turfgrass culture.* New York: Van Nostrand Reinhold Co.

Hanson, A.A., and F.V. Juska. 1969. *Turfgrass science.* Madison, Wisconsin: Agronomy Monograph 14. Amer. Soc. Agron.

Characteristics of Soluble Nitrogen Fertilizers

Roger Funk

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.

Soluble nitrogen fertilizers may be used at any time of the year with minimal injury to the turf and with minimal loss of nitrogen by considering the characteristics of the fertilizers and the interactions with environmental and soil factors.

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 on the total nutrient content.

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Table 1. Solubility and Salt Indexes of Soluble Nitrogen Fertilizers

Fertilizer	Formula	Primary analysis (percent) N	P_2O_5	K_2O	Total plant food[a]	Salt index[b]	Adjusted salt index[c]	Solubility[d]
ammonia	NH_3	82.0	-	-	82.0	47.1	57.4	90
urea	H_2NCONH_2	46.0	-	-	46.0	75.4	163.9	67
ammonium nitrate	NH_4NO_3	33.5	-	-	33.5	104.7	312.5	118
ammonium sulfate	$(NH_4)_2SO_4$	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	$NH_4H_2PO_4$	11.0	48.0	-	59.0	29.9	50.7	43
diammonium phosphate	$(NH_4)_2HPO_4$	18.0	46.0	-	64.0	34.2	53.4	25
ammonium polyphosphate (liquid form)	NH_4PO_3	10.0	34.0	-	44.0	29.9[e]	67.9	-

[a]Percent N + percent P_2O_5 + percent K_2O (primary analysis).
[b]Rader, L.F., Jr., et al. 1943. *Soil Science* 55(3):201-18.
[c]Salt index per unit of plant food = (2) x 100/(1).
[d]Parts in 100 parts pure water at 32° F.
[e]TVA.

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 requirement for plants, the level of soluble salts in soil solution that is "safe" during 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 [$CO\ (NH_2)_2$].

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 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 and leachable 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. Table 2 lists the relative leaching potential of some of the more common soluble nitrogen fertilizers.

Table 2. Leaching of Soluble Nitrogen Fertilizers

Fertilizers	Leaching potential
sodium nitrate	High
calcium nitrate	↓
ammonium nitrate	↓
ammonium sulfate	↓
urea	↓
ammonium phosphate	↓
ammonium carbonate	Low

Reference: Benson, Nels, and R.M. Barnette. 1939. Leaching studies with various sources of nitrogen. *Journal of The American Society of Agronomy* 31:44-530.

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 ammonic fertilizers and urea are placed in the soil, the ammonia gas that they release is held by the soil particles. However, when urea or ammonic 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.

A comparison of the nitrogen lost through volatilization from surface-applied soluble nitrogen fertilizers is given in Table 3.

Table 3. Volatilization of Surface-Applied Soluble Nitrogen Fertilizers

Fertilizers	Volatilization potential
urea	High
urea ammonium phosphate	↓
diammonium phosphate	↓
ammonium sulfate	↓
ammonium nitrate	↓
ammonium phosphate nitrate	↓
ammonium phosphate	↓
monoammonium phosphate	Low

Reference: Terman, G.L., and C.M. Hunt. 1964. Volatilization losses of nitrogen from surface-applied fertilizers, as measured by crop response. *Soil Science Society Proceedings* 28:667-72.

All of the characteristics of nitrogen fertilizers should be considered when a turf fertilization progam is planned. If the materials are applied properly for 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.

The Oldest Synthetic Source of Slowly Available Nitrogen—Ureaformaldehyde

John T. Hays

The title of my paper was assigned to me; although it may not be just what I would have chosen, it is quite appropriate. Fertilizers based on the reaction of urea with formaldehyde have indeed 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 the name "ureaform" for this product, and this name seems to us to be far preferable to "ureaformaldehyde" to distinguish the odorless, stable fertilizer from the noxious ureaformaldehyde 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 Company and the Nitroform Corporation in the mid-1950's. Hercules purchased the Nitroform Corporation 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. As Dr. McVey will undoubtedly tell us, O.M. Scott utilizes ureaformaldehyde solutions in the manufacture of mixed fertilizers, 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). The standard nitrogen fertilizers such as urea, ammonium nitrate and sulfate, and diammonium phosphate are all extremely soluble in water. This solubility makes their nitrogen very quickly available but also makes it possible for them to damage growing plants or be lost by leaching. The soluble forms are also susceptible to losses by denitrification and by immobilization in the soil. Fertilizers are made slowly available by decreasing this solubility. In coated fertilizers such as sulfur-coated urea, solubility is decreased by actually creating a physical barrier through which the nitrogen must pass. In other types, the solubility is reduced because the nitrogen is chemically combined—in IBDU, urea is reacted with isobutyraldehyde; in ureaforms and other ureaformaldehyde compositions, urea is reacted with formaldehyde to form a polymer; in natural organics, nature provides the nitrogen combined in proteins or other complex organic structures. These various types of fertilizers are released by different mechanisms that in turn cause different responses to changes in soil conditions such as moisture, temperature, and pH and also in fertilizer properties such as particle size and coating thickness.

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The rate of the diffusion-dissolution process of release from coated fertilizers is decreased at low temperatures but is little affected by pH or soil moisture. It is most dependent on variations in the thickness and continuity of the applied coating.

IBDU is hydrolyzed chemically by moisture in the soil; it is released just as rapidly in sterilized soil as in soil containing active microorganisms. Its release is thus greatly dependent on soil moisture, particle size, and pH but is not greatly affected by temperature. Therefore, it is an effective fertilizer at low temperatures.

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.

These points are summarized as follows:

Fertilizer	Release type	Critical variables
Coated	Diffusion	Temperature Coating properties
IBDU	Chemical hydrolysis	Moisture Particle size pH
Ureaform Natural organics	Microbial	Temperature pH Aeration

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, long lasting* or similar terms, the guaranteed analysis must indicate the percentage of water-insoluble nitrogen in the material." This requirement to specify minimum values for water-insoluble nitrogen (WIN) protects the customer from being sold a "slowly available" fertilizer that in fact does not contain sufficient WIN to affect its availability in a practical manner. 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. The WIN value obviously needs to be supplemented by a measurement indicating agronomic availability. Either measurements of effects on plant growth are needed or, alternatively, measurement of fertilizer changes in soil (such as nitrification). Such tests require weeks to give significant results, however. 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, microorganisms 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.

Figure 1 compares a generalized nitrification curve for Nitroform with that for ammonium sulfate. It illustrates in a striking fashion the difference between the rapid release from the soluble ammonium salt and the gradual release from the ureaform. Figure 2 shows a nitrification curve for Nitroform ureaform (this time at a somewhat more rapid rate than in the generalized curve of Figure 1) compared with published USDA data on various natural organics. The natural organics appear to be a little more rapid initially but level off at a value indicating incomplete release.

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.

Time	Conversion to NO_3^- (cumulative) (percent)
4 weeks	30 to 40
8 weeks	45 to 60
12 weeks	50 to 65
24 weeks	60 to 75

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, has the following screen analysis (U.S. Standard):

Through 10-mesh	100 percent
Through 20-mesh	8 percent
Through 40-mesh	> 2 percent

It is designed for direct application in mechanical spreaders and is well known to golf course superintendents and other professionals concerned with quality turfgrass and to nurserymen who specialize in high-quality stock. It is also used in balanced fertilizers (N, P, K). The Blue Chip tag indicates that at least 50 percent of the nitrogen in such a fertilizer is derived from Nitroform ureaform.

Powder Blue™ nitrogen fertilizer is the powder form made so that 100 percent will pass a U.S. Standard 60-mesh screen. 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. Powder Blue is particularly suited for use on close-knit areas such as golf greens; the small particles move readily into deep turf and are not picked up by mowers or lawn sweepers. It is used by nurserymen as the plant food to protect stock through the retail sales period. 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. TVA workers (J.D. Dement, C.M. Hunt, and G. Stanford, *J. Agr. Food Chem.* *9*:453-56, 1961) in their original study on the effect of particle size on the rate of release from oxamide, also studied ureaform. They used nitrogen uptake by corn forage (three crops over 26 weeks) rather than nitrification to determine the effect of particle size. They arrived at the following comparison of various fertilizers:

Granule size	Oxamide	Ureaform	NH_4NO_3
- 4+ 6	0.22	0.29	0.92
- 6+ 9	0.38	0.38	-
-14+ 20	0.65	0.38	-
-28+ 35	0.89	-	-
-60+100	1.00	0.56	0.97

They make the statement from these data: "Nitrogen uptake from ureaform was approximately doubled as the granule size was decreased from -4+6 to -60+100 mesh." Fitting these data to the particle sizes of the granular and powder forms of Nitroform, we get an increase of about 1.5 in going from the granular to the powder form. Thus the powder form will give a significantly faster release but without changing the basic nature of the release pattern.

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 2/3 in the fall and 1/3 in the spring. For warm-season grasses (Bermuda, zoysia, centipede, and St. Augustine) apply 2/3 in the spring and 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 is 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.

For greenhouses, foliage crops, and bedding plants (trees, shrubs, and evergreens) use:

Soil surface—1/4 pound per inch of plant diameter
1 teaspoon per 6-inch pot

Soil mix—6 to 7 ounces per bushel or 2 to 3 pounds per cubic yard

Bedding plants—2 to 3 pounds per 100 square feet

These recommendations should be useful guides, but the turfgrass manager or nurseryman will adapt them to his own conditions.

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.

Summary

Nitroform ureaform fertilizer has the following characteristics:

1. It consists essentially of chemically combined urea with greatly reduced solubility.
2. Nitrogen is released through the action of soil microorganisms. Biological reactions are dependent on temperature; they require the same conditions as growing plants.
3. Quality is indicated by a combination of WIN and AI. Other slowly available fertilizers require data such as on coating thickness, particle size, soil moisture, and permanganate values to indicate quality.
4. Nitrification studies in soil indicate a 30 to 40 percent release in 4 weeks and a 60 to 75 percent release in 24 weeks, with a portion being carried over for utilization in the following season.

5. It is available in granular and powder form. The powder form can be sprayed in a water suspension and is somewhat more rapidly released than the granular form.
6. Recommendations for turfgrass and nursery stock call for relatively large single applications (4 to 8 pounds of nitrogen per 1,000 square feet). Soluble fertilizers generally cannot be applied in these quantities.

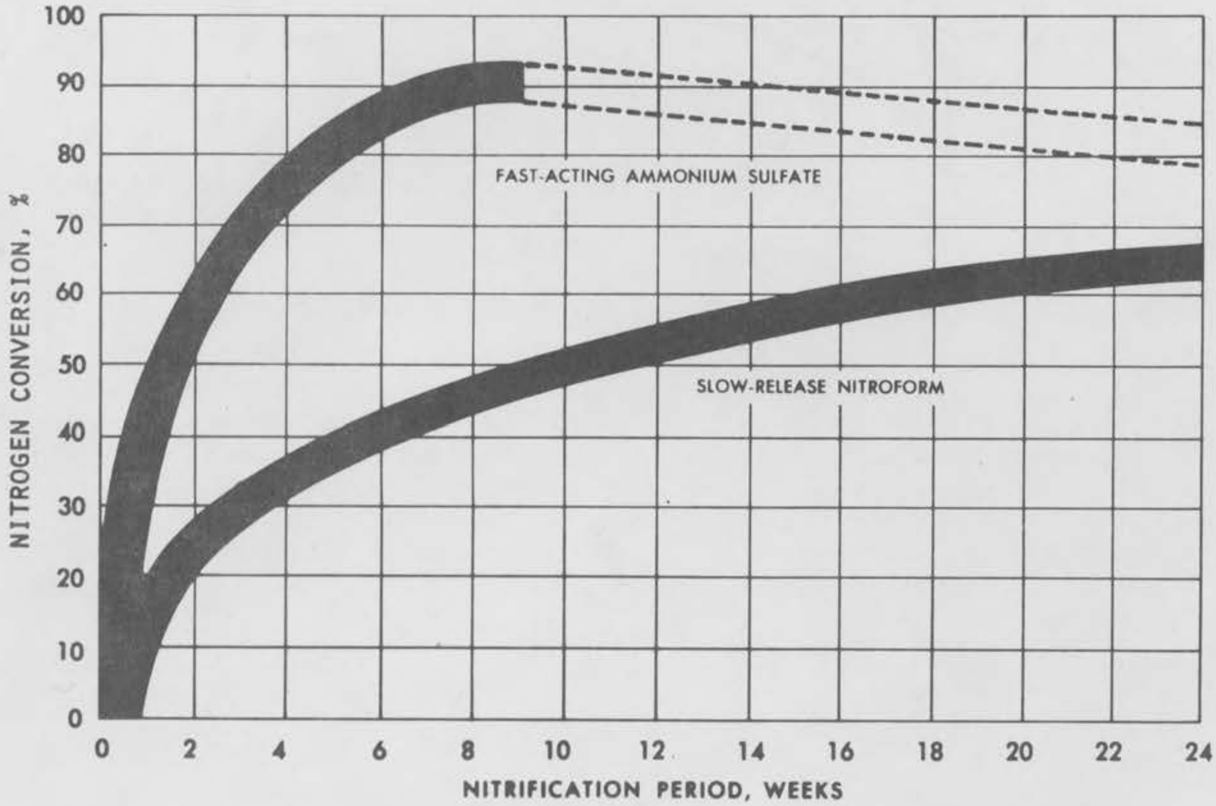
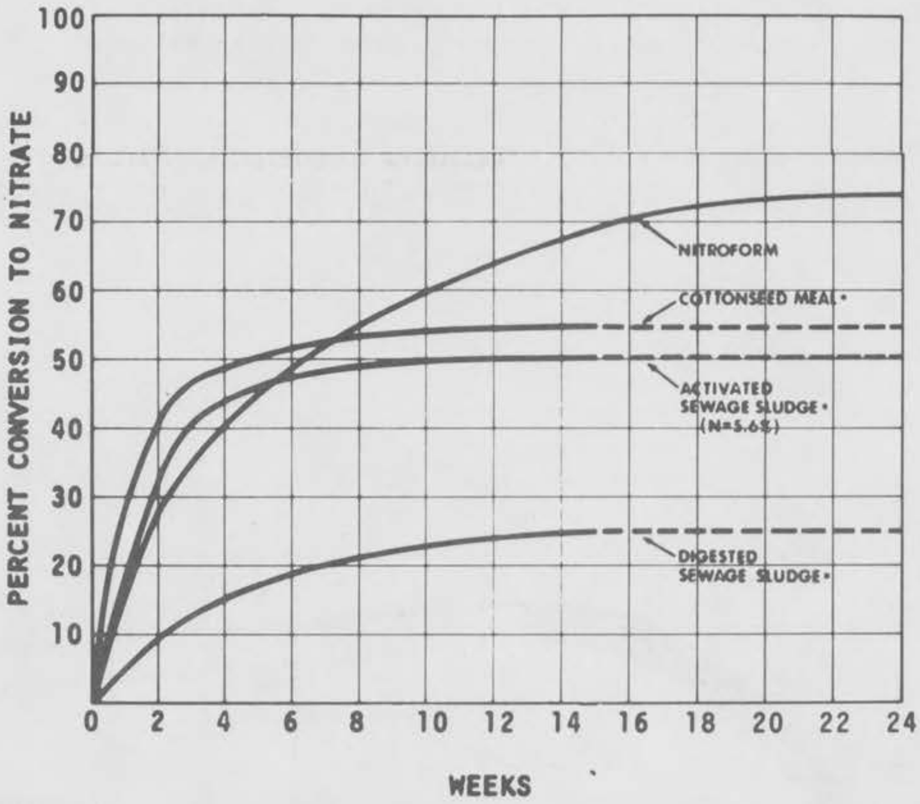


Figure 1. Comparative nitrification for ammonium sulfate and Nitroform® under laboratory conditions.



*The nitrification rates used are based on published USDA data.

Figure 2. Comparative nitrification for Nitroform® and other organic nitrogens.

Methylene Urea—A Controlled Release Nitrogen Source for Turfgrasses and Woody Ornamentals

George R. McVey

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 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.

According to a report in Marketing Research Report on Controlled Release Fertilizers by Jeanie H. Ayers, *Chemical Economics Handbook*, Menlo Park, California (October 1978), nitrogen derived from urea formaldehyde condensation products accounted for 90 percent of all the controlled release nitrogen consumed in the United States.

Although the generic name "ureaform" and ureaformaldehyde have been used for a number of years to describe the condensation products of urea and formaldehyde, it has been suggested (O'Donnell, 1976, personal communication) that methylene urea (MU) would be technically more accurate. This name will be used in the discussion to follow.

The early pioneering research carried out at the U.S. Department of Agriculture and reported in 1946 by Yee and Love (*Proc. Soil Science Soc. Amer.* 11:389) showed that a nitrogen product with controlled availability could be made by condensing urea with formaldehyde under specific reaction conditions. Following this initial research, two distinct categories of MU products were commercialized. These two categories differed primarily in their solubility characteristics as affected by the distribution of the mixture of MU polymers in the final product plus the level of unreacted urea.

Manufacturing

Production of MU requires exact control of temperature, pH, reaction time, and reaction components. The release characteristics can be controlled by modifying the reaction variables. As shown in Table 1, six basic components are required for production of MU. Urea and formaldehyde are the major components, and sulfuric acid, sodium hydroxide, and surfactant are only required in molecular quantities.

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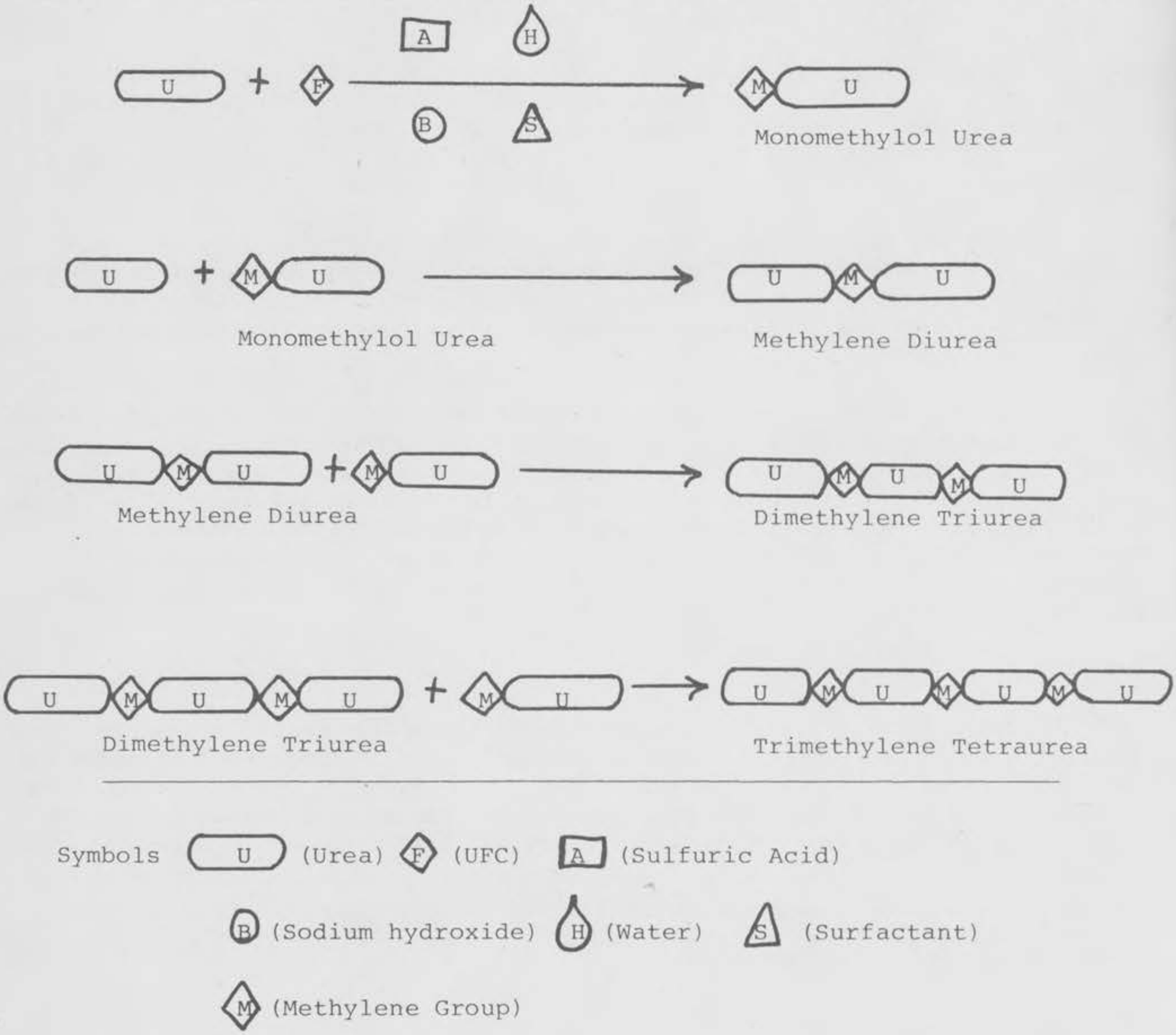
Table 1. Materials Used in the Production of Methylene Ureas

Compound	Function
Urea	Nitrogen source
UFC (60 percent urea)	Formaldehyde source (25 percent)
Sulfuric acid	Catalyst
Sodium hydroxide	Stabilizer
Water	Diluent
Surfactant	Foaming agent

In the reaction process, urea reacts with formaldehyde to produce monomethylol urea, which further reacts with urea to produce MU varying in chain length (2 to 5 urea molecules, or possibly even higher, attached together with methylene groups)(see Table 2).

Table 2. Symbolic Representation of the Methylene Urea Condensation Reaction



The manufacturing of these products differs relative to the ratio of urea to formaldehyde and the reaction conditions. I will discuss the products more common to Category 2 (MU) with minimal discussion of products common to Category 1 (ureaform)(see Table 3).

Chemical Properties

To give you some background on the two major categories of MU products, typical chemical characteristics are shown in Table 3. A further breakdown on the distribution of nitrogen components within the solubility fractions will also help to characterize differences in these two categories (see Table 4).

Table 3. Nitrogen Characteristics of Typical Methylene Urea Products Commercially Available

	Use		
Nitrogen characteristics	Turf & woody ornamentals	Turf (percent)	Woody ornamentals
	Category 1[a]	*Category 2*[b]	
Total nitrogen percent	38	38	38
Nitrogen active index (NAI)	33	60	33
Cold water soluble nitrogen (CWSN)	25	64	45
Cold water insoluble nitrogen (CWIN)	75	36	55

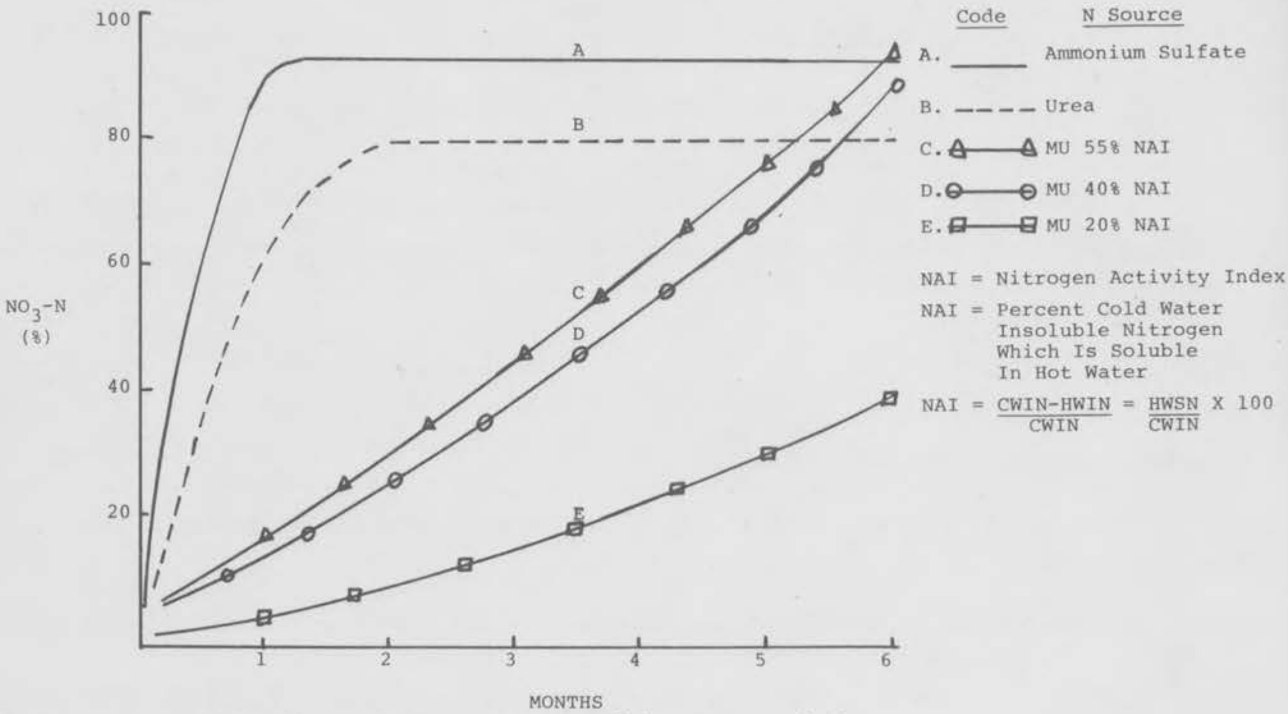
[a]Ureaform (Hercules Incorporated and E.I. du Pont de Nemours & Company, Inc.).
[b]Methylene ureas (O.M. Scott & Sons).

Table 4. Approximate Distribution of Methylene Urea Fractions and Urea in Commercially Available Products

	Use		
Nitrogen characteristics	Turf & woody ornamentals	Turf (percent)	Woody ornamentals
	Category 1[a]	*Category 2*[b]	
Total nitrogen	38	38	38
Nitrogen active index (NAI)	33	60	33
Cold water soluble nitrogen	25	64	45
Urea	(8)	(28)	(15)
Methylene diurea	(7)	(27)	(20)
Dimethylene triurea	(10)	(9)	(10)
Cold water insoluble nitrogen	75	36	55
Trimethylene tetraurea	(21)	(22)	(15)
Pentamethylene hexaurea	(54)	(14)	(40)

[a]Ureaforms (Hercules Incorporated and E.I. du Pont de Nemours & Company, Inc.).
[b]Methylene ureas (O.M. Scott & Sons Co.).

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 shown in Figure 1, 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.



Source: R.B. Church. 1968. *New Fertilizer Materials.*

Figure 1. Nitrification rate of ammonium sulfate, urea, and methylene urea as affected by time.

One of the primary benefits of MU is attributed to its low salt index. As shown in Table 5, 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. As shown in Figures 2 and 3, 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 nitrogen level decreases. This increase was only evident if the nitrogen source was MU (Figure 3). 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 in greater pollution potential than with MU.

Table 5. Salt Index of Various Nitrogen Sources

Nitrogen source	Percent N	Salt index[a,b] Equal weights	Equal N levels
Sodium nitrate	16	100	6.25
Ammonium nitrate	33	105	3.18
Urea	46	75	1.63
Ammonium sulfate	21	69	3.29
Methylene urea	38	4	0.11

[a]Concentration of ions in the soil solution based on sodium nitrate at 100.

[b]Nitrogen is mixed with air-dried soil that is brought to 75 percent of field capacity and stored for 5 days at 5° C.

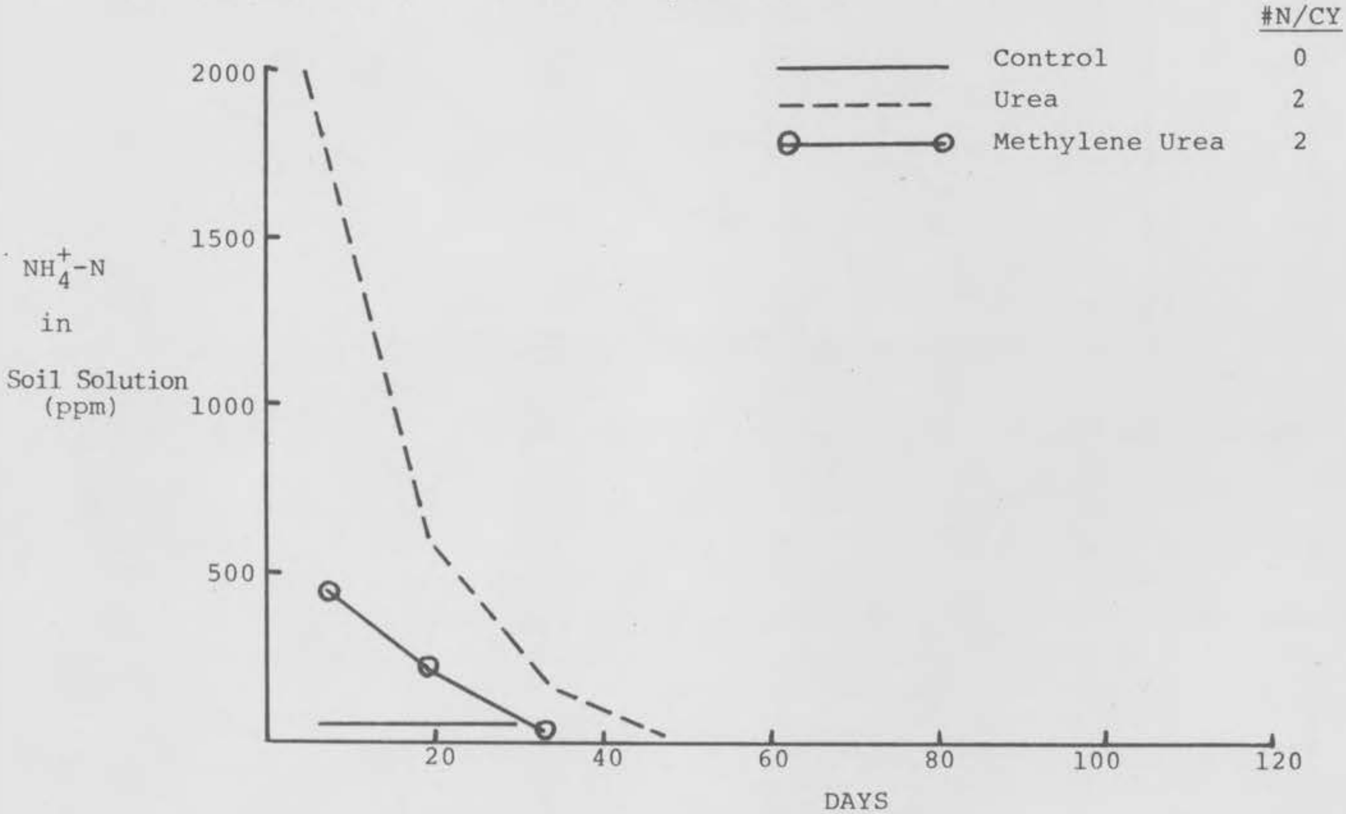


Figure 2. Ammoniacal-N analysis of the soil solution as affected by urea and methylene urea applied at 2 pounds of nitrogen per cubic yard.

Biological Properties

Turf

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 shown in Table 6, 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

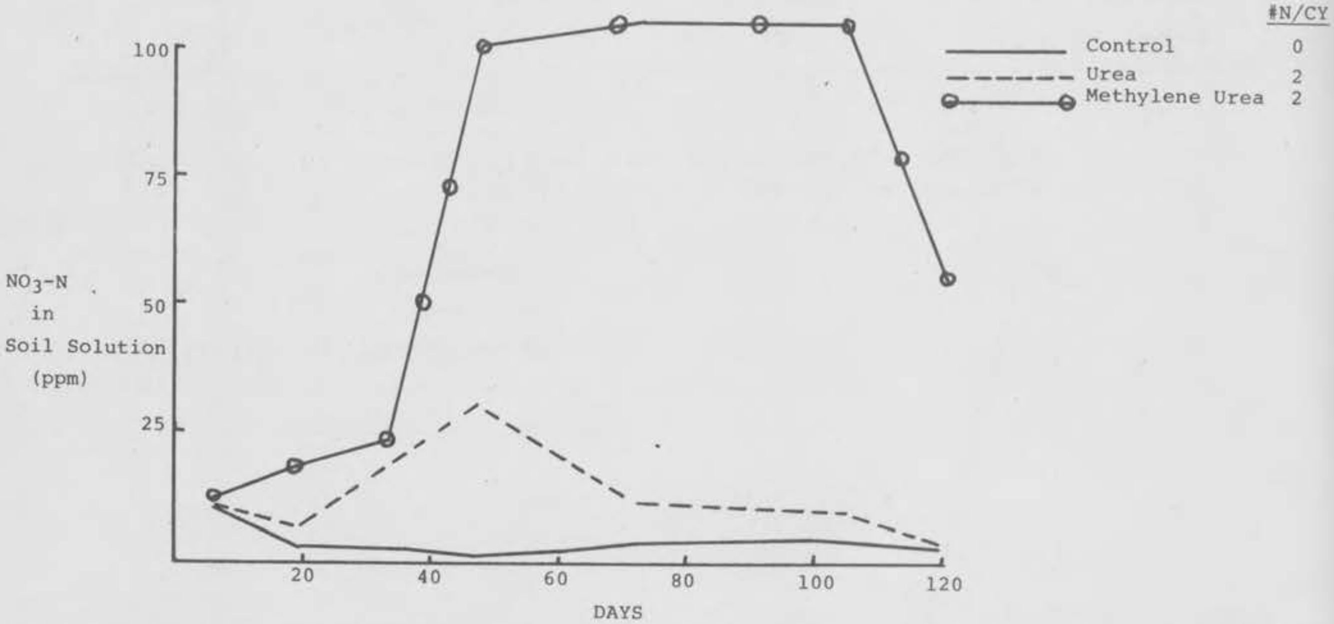


Figure 3. Nitrate-N analysis of the soil solution as affected by urea and methylene urea applied at 2 pounds of nitrogen per cubic yard.

Table 6. Percentage Injury of Merion Kentucky Bluegrass As Affected by Soluble and Partially Soluble Nitrogen Sources Applied to Wet or Dry Foliage[a, b, c]

		Lb. N/1000 square feet							
		1		2		4		Average	
		Foliage condition when applied							
Analysis	Percent CWIN	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
		(percent)							
10-6-4	2	70	0	70	15	100	20	80	12
16-8-8	38	15	0	35	0	80	5	43	2
23-7-7	42	0	0	5	5	0	5	2	3

[a]Waddington, Duich, and Moberg. 1969. Lawn fertilizer test progress report 296. University Park, Pennsylvania: The Pennsylvania State University.
[b]Recorded 2 days after application (August 26, 1966).
[c]Temperature 73, 84, 90° F maximum and 52, 59, and 53° F minimum on 0, 1, and 2 days after treating, respectively. Relative humidity 39 to 49 percent.

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 temperature conditions).

When we compared MU from Category 1 with that from Category 2 relative to turf response, a substantial difference in turf color was noted. As shown in Table 7, 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 (see Table 7).

Spring applications of IBDU and MU (Category 2) were compared (see Table 8). 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. As shown in Figure 4, 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

Table 7. Initial and Residual Color Response of Kentucky Bluegrass As Affected by Various Nitrogen Sources Applied in Late Fall (11/22/77) (Color 10>1)

N source	Category	Percent CWIN	Lb.N /1,000 square feet	Date of observation 12/1	4/7	4/19	5/10
				Initial response			*Residual response*
Methylene urea	2	38	0.9	6.0	5.0*	5.0*	5.7*
Ureaform	1	75	0.9	6.0	3.7	4.0	6.0*
IBDU (coarse)	-	78	0.9	6.0	3.5	4.0	4.3*
Control	-	-	0	6.0	2.5	2.7	2.0
LSD 0.05				NS	1.6	1.3	1.5

*Significant improvement in color as compared with the check (no fertilizer).

Table 8. Initial and Residual Color Response of Kentucky Bluegrass As Affected by Various Nitrogen Sources Applied in Mid-Spring (5-18-77) (Color 10>1)

N source	Percent CWIN	Lb.N /1,000 square feet	Date of observation 5/31	6/14	7/29
			Initial response		*Residual response*
Methylene urea	38	2.0	10.0	9.3	8.3
IBDU (coarse)	78	2.0	4.3	6.3	7.0
Control	-	0	2.3	3.7	4.3

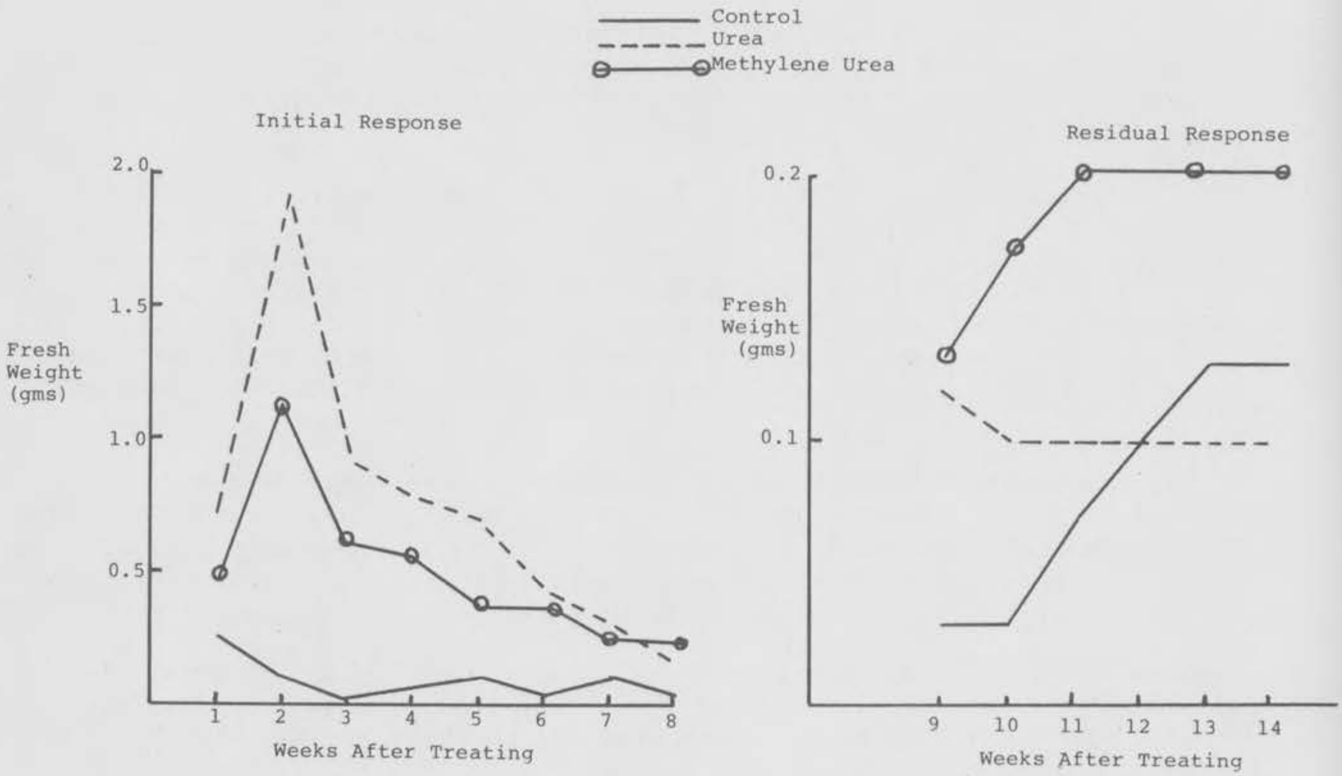
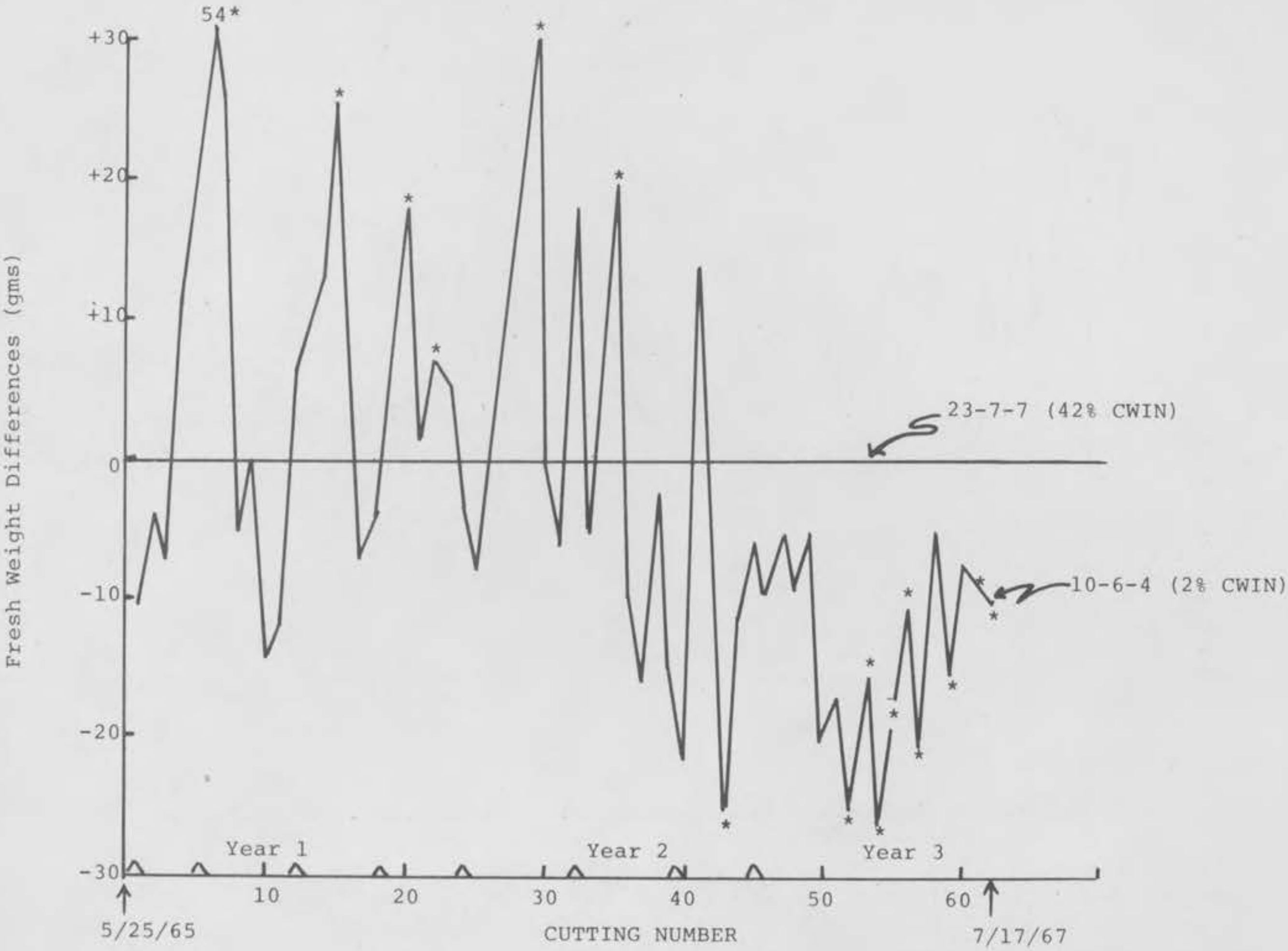


Figure 4. Fresh weight of Kentucky bluegrass as affected by urea and methylene urea applied at 1.8 pounds of nitrogen per 1,000 square feet.

percent reduction in fresh weight). 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, as shown in Figure 5. 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 (see Figure 6).

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. As shown in Table 9, 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.

In another experiment, we compared two kinds of MU sources from Category 2 (see Table 10). Two products varying in percent CWIN were applied in early October to Kentucky bluegrass. Although it is often reported that MU products will not provide a good color and growth response under cool soil conditions, our results were the contrary. The product containing 36 percent CWIN induced better turf color than products containing 50 percent CWIN, suggesting that greening



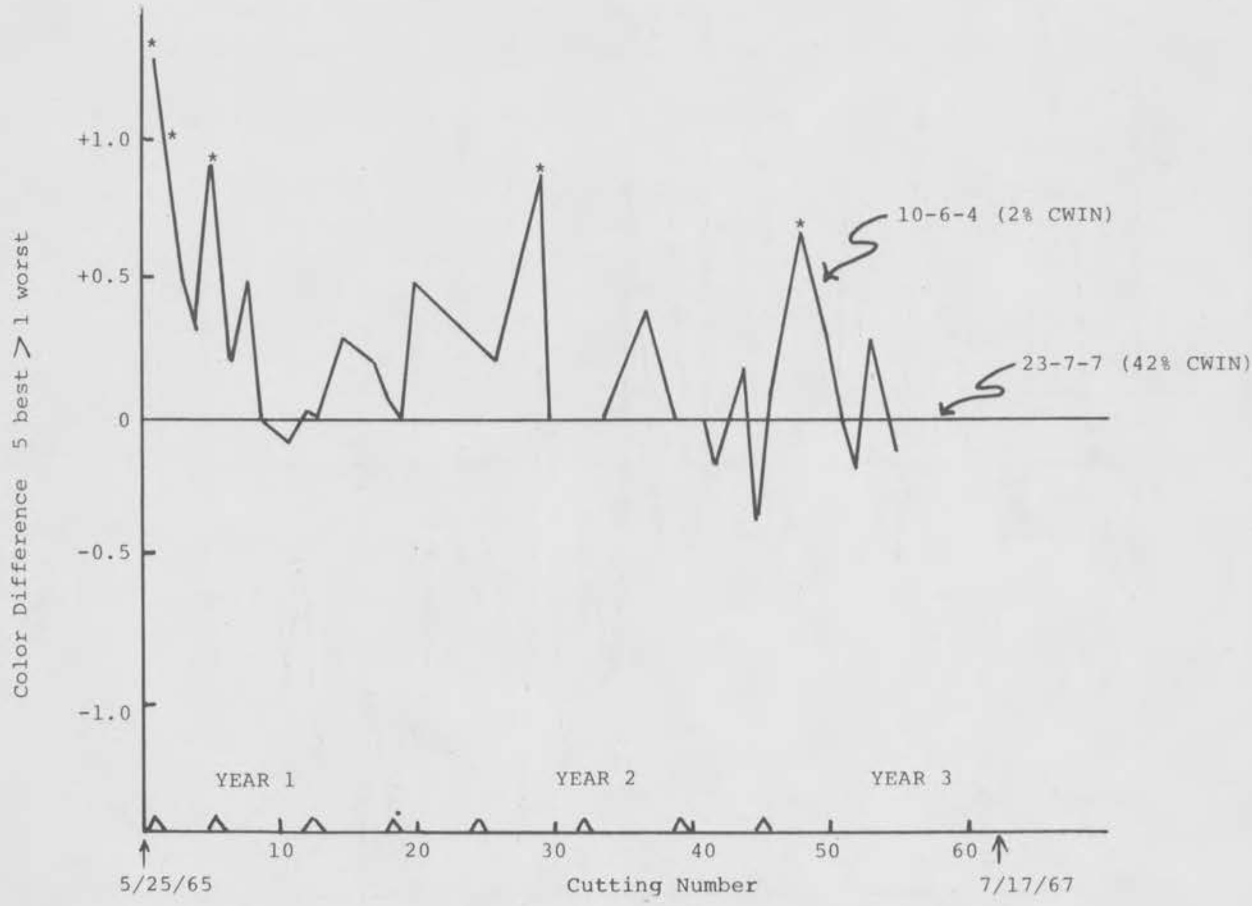
△ Fertilizer Applied at 1 lb nitrogen/1000 sq. ft.
* Significantly different from 23-7-7 at the 5% level.
Source: Waddington, Duich and Moberg. June 1969. Lawn fertilizer test progress report 296. University Park, Pennsylvania: The Pennsylvania State University.

Figure 5. Clipping fresh weight of Poa pratensis treated with a 2 percent CWIN source (10-6-4) expressed as differences from turf treated with a 42 percent CWIN source (23-7-7).

Table 9. Fresh Weight of Kentucky Bluegrass Clippings Removed from a 10,000 Square Foot Area As Affected by Methylene Urea of Urea

Product	Lb.N /1,000 square feet	Weeks after application 1	2	4	6	Total	%
		(Lb. of clipping/10,000 sq. ft.)					
Methylene urea	0.9	1908	1372	2120	64	5464	68[a]
Urea	0.9	2872	2241	2840	84	8037	100

[a]Approximately 1/3 fewer clippings when turf is treated with methylene urea when compared with urea.



△ Fertilizer applied at 1 lb N/1000 sq. ft.
* Significantly different from 23-7-7 at the 5% level.
Source: Waddington, Duich and Moberg. 1969. Lawn fertilizer test progress report 296. University Park, Pennsylvania: The Pennsylvania State University.

Figure 6. Color of Poa pratensis treated with a 2 percent CWIN source (10-6-4) expressed as differences from turf treated with 42 percent CWIN source (23-7-7).

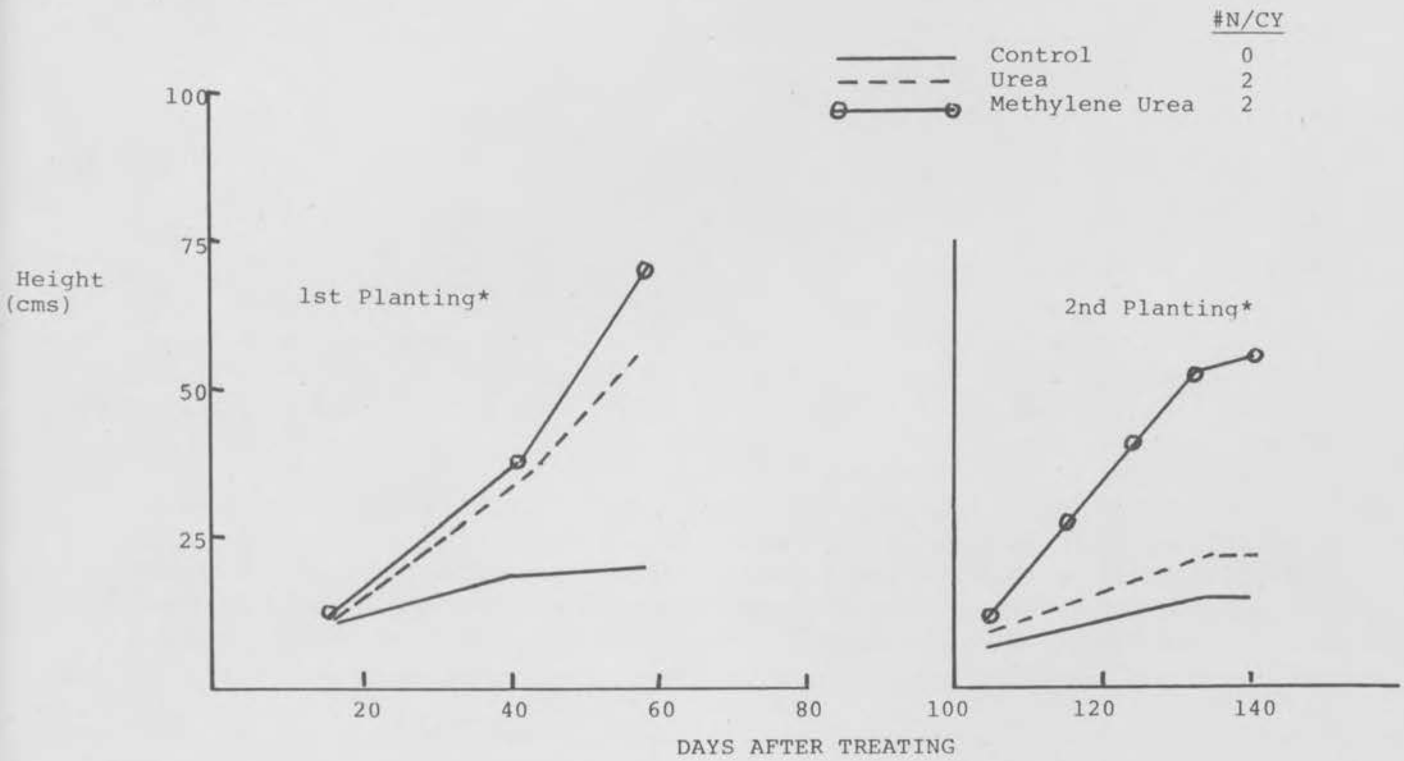
Table 10. Fall Greening Response of Kentucky Bluegrass As Affected by Two Methylene Urea Sources. (Category 2) Applied in Early October (10/2/78) (Color 10>1)

N source	Percent CWIN	Lb.N /1,000 square feet	Date of observation 10/17	10/27	11/14	11/20	Average
Methylene urea	36	0.9	8.0	9.0	7.8	6.7	7.9
Methylene urea	50	0.9	7.3	8.0	6.3	5.3	6.7
Control	-	0	3.0	4.7	3.0	2.0	3.2

response is associated with the percent CWIN in the product. This result again illustrates the flexibility in formulating MU products to meet the biological demands of turf.

Woody Ornamentals

Nitrogen product residual and safety are also very important for woody ornamentals—in particular, plants grown in containers containing a modified potting media (bark, peat, and sand mixes). As shown in Figure 7, when MU was incorporated in a modified potting media, the residual of nitrogen was reflected in the growth of *Catalpa speciosa*, which was planted in the media 100 days after fertilizing (second planting). In contrast, plants grown in soil containing urea grew in a manner very similar to that of plants not fertilized.



*Harvested on the 58th day
& replanted on the 100th day.

Figure 7. Height growth response of Catalpa speciosa as affected by urea and methylene urea applied at 2 pounds of nitrogen per cubic yard.

The tolerance and response of container-grown woody ornamentals was also studied using Juniper and Cotoneaster as the indicator plants. As shown in Table 11, when 3 pounds of nitrogen per cubic yard were incorporated in the potting media, urea caused dramatic injury. In contrast, plants treated with MU exhibited no injury; however, the optimum growth varied with the release characteristics of the product. Maximum growth was realized when the CWIN ranged from 33 to 50 percent. A CWIN above or below this range resulted in too fast or too slow a release of the nitrogen, respectively.

The tolerance of bare root liners of Juniper and Cotoneaster followed a similar pattern. As shown in Table 12, using 1 pound of nitrogen per cubic yard as urea caused extreme injury to Cotoneaster (90 percent) and moderate injury to Juniper (25 percent). The subsequent development of these plants was also very poor. Plants treated with MU exhibited excellent growth when the CWIN ranged from 33 to 50 percent. Growth from a single application at potting time was comparable with the grower's standard, which was applied four times to obtain a nitrogen level comparable with that for plants treated with a single application of MU.

Table 11. Tolerance of Juniperus chinensis pfitzeriana to Urea and Methylene Ureas Incorporated into the Potting Media Using 3 Pounds of Nitrogen per Cubic Yard.[a]

Nitrogen source	Percent CWIN[b]	Category	Fresh weight (gms) Root	Top	Total
Urea	0	-	5	5	10
MU	25	2	33	56	89
MU	33	2	46*	114*	160*
MU	50	2	56*	113*	169*
MU	70	1	42	75	117
L.S.D. 0.05			13	24	37

[a]Incorporated into the potting media (60/40 bark/sand) just prior to planting potted liners in one gallon cans May 1, 1974. Recorded 17 months after treating.

[b]Percent nitrogen insoluble in water at 22° C.

*Significantly larger than all other roots or tops at the 5 percent level.

Table 12. Tolerance of Bare Root Liners of Juniperus chinensis pfitzeriana and Cotoneaster apiculata to Urea and Methylene Urea Incorporated into the Potting Media

Nutrient source[a]	Percent CWIN[c]	Category	Juniper Injury (%)	Juniper Top fresh weight (gms)	Cotoneaster Injury (%)	Cotoneaster Top fresh weight (gms)
Urea	0	-	25	1.7	90	1.2
MU	25	2	0	5.1	0	4.8
MU	33	2	0	6.8	0	8.3
MU	50	2	0	7.1	0	9.6
Growers standard[b]			0	7.0	0	10.7
None			0	4.4	0	2.9

[a]Fertilizer incorporated into the potting media using 1 lb. of N/cubic yard just prior to potting on 7/21/73 (equal to 12 lb. N/1,000 sq. ft.). No additional fertilizer was applied.

[b]A total of 12 lb. of nitrogen/1,000 sq. ft. applied in split applications of 3 lb. of N/1,000 sq. ft. on 8/21, 10/28, 4/1, and 6/1.

[c]Percent nitrogen insoluble in water at 22° C.

Summary

1. The properties of two groups of MU, other slow release nitrogen sources, and soluble nitrogen sources vary widely relative to chemical and biological properties.

2. Varying the water soluble and insoluble characteristics of MU of Category 2 (see Table 4) provides substantial flexibility in manufacturing products to meet varied use conditions for turf and woody ornamental plants.

3. The MU nitrogen sources offer advantages over conventional fast release nitrogen sources relative to improved plant tolerance, increased nitrogen efficiency (which is reflected in a reduction in volatilization and leaching), reduced application frequency, and improved regulation of nitrogen nutrition to the plant.

This technology has additional benefits that have been overlooked through the years. The pollution potential of nitrogen can be reduced by this technology. These advantages have created a renewed interest in MU in many areas of agriculture.

Characteristics of Sulfur-Coated Urea and Natural Organic Nitrogen Fertilizers

S.E. Allen

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

Preparation

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

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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

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 interpret 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 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 H_2O) > alternating moist/dry > continuously moist (20 percent H_2O). 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. In a field experiment, a bare soil study was conducted adjacent to turf plots. In this case, dissolution was in the order: surface-placed on bare soil > surface-placed on turf > band-placed at 2-inch depth in bare soil.

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. In a greenhouse experiment, fescue was grown in 6-inch by 48-inch cylinders filled with coarse-textured soil. Once each month, 4 inches of drainage water were passed through the columns and collected for analysis. Under this extreme leaching regime, 30 percent of applied NH_4NO_3 was leached, as compared with 5 percent of SCU.

7. 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.

Natural Organic Nitrogen Fertilizers

Natural organic N fertilizers may be defined as any natural product containing N in forms available to plants, either directly or following biodegradation by soil organisms. The most common materials include animal and poultry manures, sewage sludge, industrial by-products (meatpacking and leather processing residues), and composted municipal wastes. The latter contain large amounts of paper residues and may be relatively low in N content, unless fortified with sewage sludge or soluble N fertilizers. Detailed discussion of the widely varying products is not possible within the limits of this paper. Fortunately, natural products have in common many properties, which are summarized below:

1. Most processed products contain relatively little water-soluble N and supply crop-available N only following biodegradation by soil organisms.

2. Since biodegradation is a dominant factor, release of crop-available N is accelerated in warm soil. Therefore, natural products are most effective in summer when soil temperature and moisture favor growth of soil microorganisms.

3. Most natural fertilizers contain large amounts of complex organic molecules that do not biodegrade readily. For this reason, crop recovery of applied N may be low in the season of application. However, there is evidence that most of the carry-over eventually becomes available to crops.

4. Because of the low content of water-soluble N, plants are rarely damaged by natural fertilizers (poultry manures at high rates may be an exception).

5. Most natural fertilizers contain other plant nutrients, particularly phosphorus and micronutrients, in biodegradable forms.

Conclusions

There is ample evidence that controlled-release fertilizers have a place in crop production, especially for forage and turfgrasses. Since controlled-release fertilizers are entirely different from conventional water-soluble fertilizers, users need to understand the factors controlling N release and uptake by crop plants. With this information in hand, it should be possible to use controlled-release fertilizers effectively and thereby do a better job of crop management.

Understanding Isobutylidene Diurea (IBDU)

Bob Rehberg

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

Preparation

The manufacture of IBDU involves a simple mixing of isobutyraldehyde (IBA), which is a liquid, with solid urea. The product is then screened and bagged into two size ranges, 0.5 to 1.0 millimeter fine and 0.7 to 2.5 millimeters coarse. The finished IBDU product is a small white granule that is not hydroscopic and will store indefinitely.

Nitrogen Release Mechanism

IBDU particles dissolve slowly, and the molecule splits to give:

1. Isobutyraldehyde, which volatilizes or is used as a food source by microorganisms.

2. Urea, which would undergo normal conversions to ammonium and nitrate forms. See the complete schematic Figure 1.

The hydrolysis of urea to ammonium carbonate occurs quickly in soils. The process is described in the following equation:

$$\underset{\text{urea}}{CO\,(NH_2)_2} + \underset{\text{water}}{2\,H_2O} = \underset{\text{ammonium carbonate}}{(NH_4)_2\,CO_3}$$

Nitrobacteria can then convert the ammonium nitrogen to nitrate if temperatures are about 40° F or above and other environmental factors are favorable. However, turf can utilize nitrogen in either form. Although the urea conversion would be the same regardless of the parent material—urea-formaldehyde (UF), sulfur-coated urea (SCU), or IBDU—it is solubility that determines the rate at which IBDU converts to plant-available forms, and solubility is independent of bacterial activity. This fact 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.

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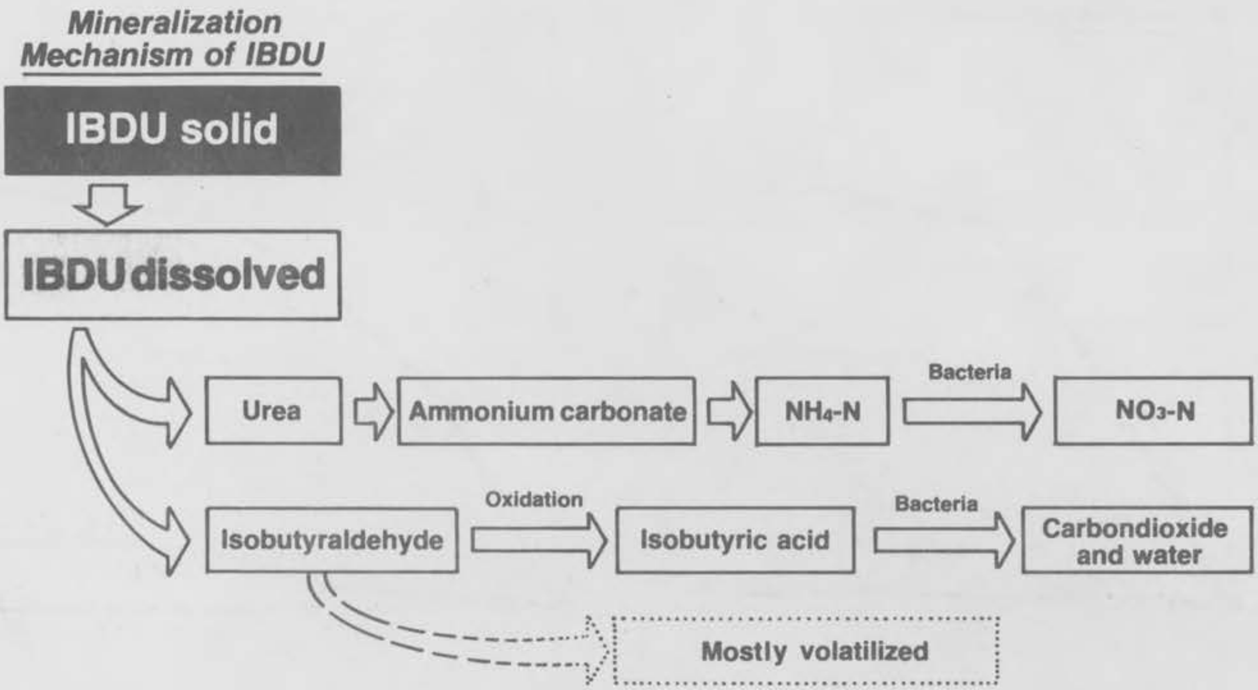

Figure 1. Mineralization mechanism of IBDU.

IBDU release is temperature dependent only as temperature affects solubility, so at constant temperatures of 40° and 80° F, approximately 50 and 75 percent, respectively, of the nitrogen would be released over a 3-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 if we get a heavy rain?" The answer is that some IBDU will dissolve. Continuous leaching tests in glass cylinders show that 36 inches of water are needed to dissolve powdered IBDU, and about 80 inches of water are required to dissolve a 1.4 to 1.6 millimeter size granule. Therefore, a 5-inch deluge of rain would release about 6 percent of the N from coarse IBDU or about 0.1 pound of N from an application of 1.5 pounds of N per 1,000 square feet.

Efficiency

A source of N is efficient if most of the applied N is absorbed by the plant and not lost in the environment by leaching past the root system, volatilization, or other factors. The following two graphs (Figure 2) are a result of the work of Falkenstrom and Turgeon at the University of Illinois at Urbana-Champaign. They compare the leaching and volatilization of IBDU with that of urea.

The first graph demonstrates the amount of N lost by volatilization from turf cores over an 8-day period. During this time 23.4 percent of the N in the urea was lost as gaseous ammonia versus only an 0.5 percent loss of N from IBDU. The second graph shows N leaching losses of 43.9 percent from soluble urea and only 6.3 percent from the slow-release IBDU over a period of 14 days. These studies were conducted in a laboratory microecosystem apparatus that monitored all gases and liquids entering and leaving the system.

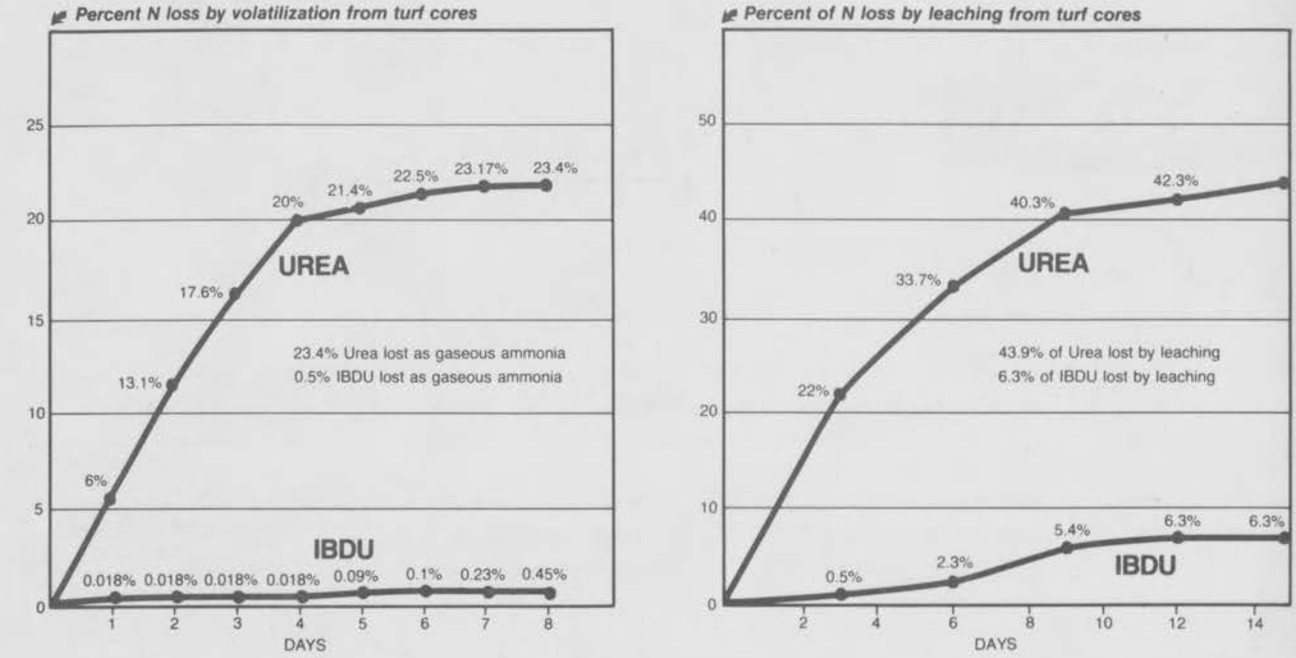

Figure 2. Urea and IBDU comparison of nitrogen loss through volatilization and leaching.

The results of field studies by Brown, Duble, and Thomas of Texas A&M were published in the January 1977 *USGA Green Section Record.* The authors found that on sand greens as much as 22 percent of the N from soluble sources was lost by leaching in the first 3 weeks, giving high nitrate contamination of the leachate water. Less than 2 percent of the N applied as IBDU was lost.

It is obvious from these studies that, compared with soluble N sources, N from IBDU trickles slowly past the root system, increasing the total uptake over time and resulting in better nutrient efficiency and less N pollution of water. Another efficiency factor of IBDU is that it is a single compound and not composed of polymers, as is the case with UF materials. All the N from IDBU is available in a single growing season. Some UF polymers may require several years to break down and become available. Lawn-care specialists have been especially pleased with this property of IBDU because with UF they may be investing 15 to 25 percent of their fertilizer cost for a competitor's benefit if they lose the customer.

Dormant Fertilization

The results from research at 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 is outlined in Figure 3 and will vary somewhat depending upon the location. The last application (November or December) should be applied when vertical growth has stopped or approximately 30 to 40 days before the ground is expected to freeze.
IBDU also works well on overseeded Bermudagrass in southern areas.

IBDU/SCU Combinations

Turf managers have always wanted a source of N that will provide an even growth pattern with minimum flush-and-deficiency cycles. We are now testing IBDU/SCU combinations that appear promising. SCU starts sooner but does not have the residual properties of IBDU, so by combining the two materials we should be able

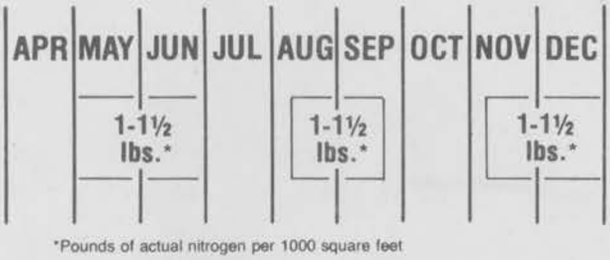

Figure 3. Dormant nitrogen fertility schedule with IBDU for Kentucky bluegrass, creeping bentgrass, and annual bluegrass.

to obtain an excellent release pattern that may be more consistent than either material alone. Also, IBDU is smaller than SCU and gives more particles per unit area, which we hope will reduce or eliminate the mottling effect often seen with SCU during cool weather or at the end of a fertilization cycle.

Slow-release nitrogen materials are an important tool in turfgrass culture. A complete understanding of the nature and properties of the source utilized in a program, with adaptation to a particular soil, turf type, and environment, will contribute greatly to the success of a turf manager.

The New Solution Nitrogen Fertilizer

John H. Detrick and Robert H. Doberneck

So what is new? *Nitrogen* fertilizers have been around for a long time. *Solution* fertilizers have been around for a long time. But a fertilizer that is a *true solution*—not a suspension—and that exhibits the low burn characteristics of an organic fertilizer, making it highly suited for commercial spray application to turfgrass by lawn-care companies—that is what is *new*!

Let us look at some of the aspects of these new organic fertilizers, such as Formolene™ controlled-release solution nitrogen fertilizer, manufactured by Ashland Chemical Company. We will discuss briefly how Formolene is made, its chemistry, and its properties both as a solution and after application, particularly with respect to economics—both from the point of view of nitrogen utilization and of materials handling and operation. Finally, we will look at the wide range of markets for which these new solution nitrogen fertilizers are applicable or potentially applicable.

First let us look at how these new products are made and how they compare chemically and physically with other commonly used nitrogen fertilizers. Formolene fertilizer nitrogen is contained in a water solution of "short-chain" urea-formaldehyde (UF) compounds, principally methylol-urea along with urea (Figure 1).

The manufacturing process for producing these and other UF products is relatively simple, as are the ingredients. However, a preciseness in processing procedure and catalyst control is imperative to achieve the desired solution stability and clarity. Basically, 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 to form a number of UF compounds that, as short-chain methylol ureas, methylene diureas, and dimethylol ureas, will remain in water solution when kept alkaline at around 9 to 10 pH (see Figure 2).

Some manufacturers elect to continue the polymerization process, converting these soluble short-chain compounds into longer-chain UF water-insoluble polymers. that are subsequently chipped or powdered and bagged for distribution to the marketplace.

It is not these water-*in*soluble powdered UF materials we are discussing but the short-chain water-*soluble* UF materials (methylol ureas) which, as we will see later, in some respects behave similarly to organic *in*soluble nitrogen *after* application to the turf (see Figure 3).

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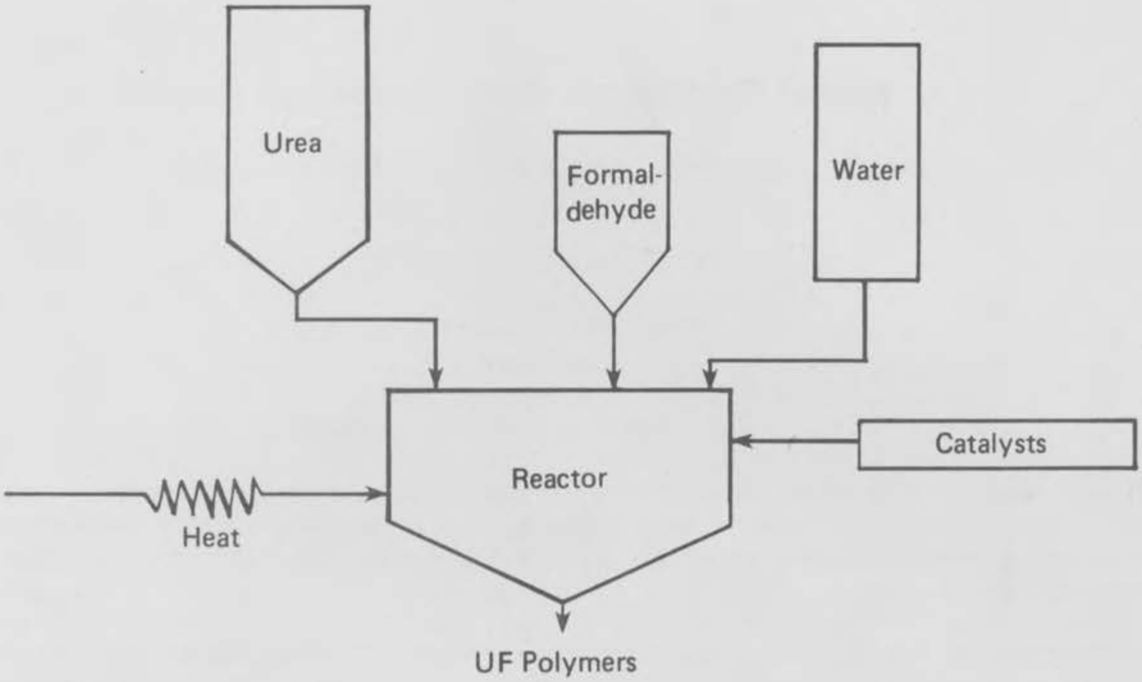

Figure 1. Production of urea-formaldehyde compounds.

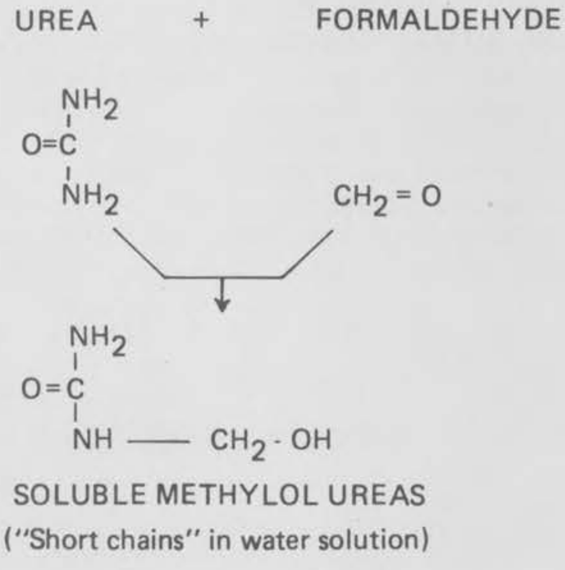

Figure 2. The chemistry of UF synthesis.

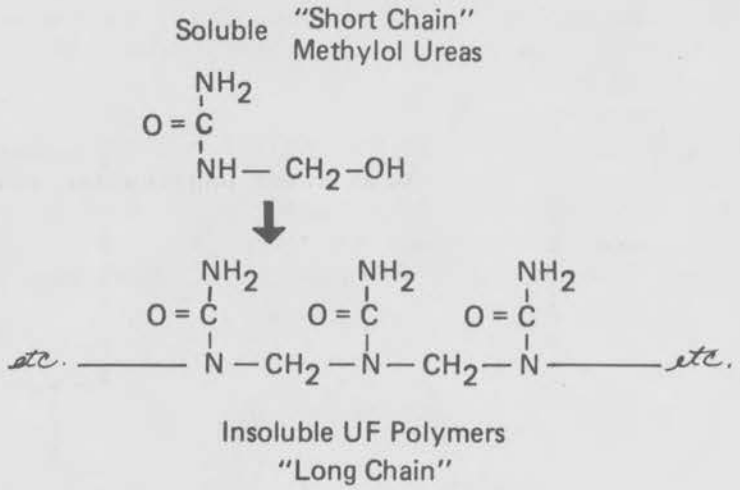

Figure 3. The formation of UF polymers.

Since these new fertilizers, such as Formolene, are shipped as bulk or drummed liquid concentrates, it might be more instructive to compare their properties with a concentrated straight urea solution and to focus our attention on the significant differences (see Table 1).

Both are water solutions, and they have a simliar appearance—very clear and very fluid. But that is where the similarity stops. Urea dissolved in water reaches a concentration maximum of about 20 percent N. To go above this concentration requires heating. This urea solution contains 57 percent water and 43 percent urea and has a *plus* 40° F salt-out temperature.

On the other hand, Formolene fertilizer, a methylol-urea solution, is an entirely different product. It contains only 15 percent water, yet the short-chain polymers in that water solution remain very fluid, permitting a much higher nitrogen concentration of 30 percent, and the salt-out temperature is *minus* 20° F. These two solutions are obviously not the same.

What does that mean to a lawn-care company? It means an economical shipment of liquid nitrogen in concentrated form without the use of heated or insulated tank trucks or rail cars. And Formolene fertilizer can be stored outdoors in low-cost uninsulated carbon steel or poly tanks.

Table 1. Formolene™ Fertilizer Comparative Solution Properties

Property	Formolene 30 solution	Urea 20 solution
N content (percent)	30	20[a]
Water content (percent)	15	57
pH	9 to 10	7+
Salt-out temperature	-20° F	+40° F
Appearance	Clear light amber	Clear colorless

[a]Maximum concentration at ambient temperature.

Also note that urea solutions are a neutral pH, but Formolene methylol-urea solutions must be kept at a pH above 8 (usually around 9 or 10) for it to remain in a stable water solution.

Now that we have examined the characteristics of the Formolene fertilizer solution, let us look at how it performs after application to the turf and the economics of its use. Formolene fertilizer solution is both a foliar and root feeding liquid nitrogen (Figure 4). This fact increases the turfgrasses' opportunity for nitrogen uptake, resulting in improved performance characteristics, as shown in Table 2.

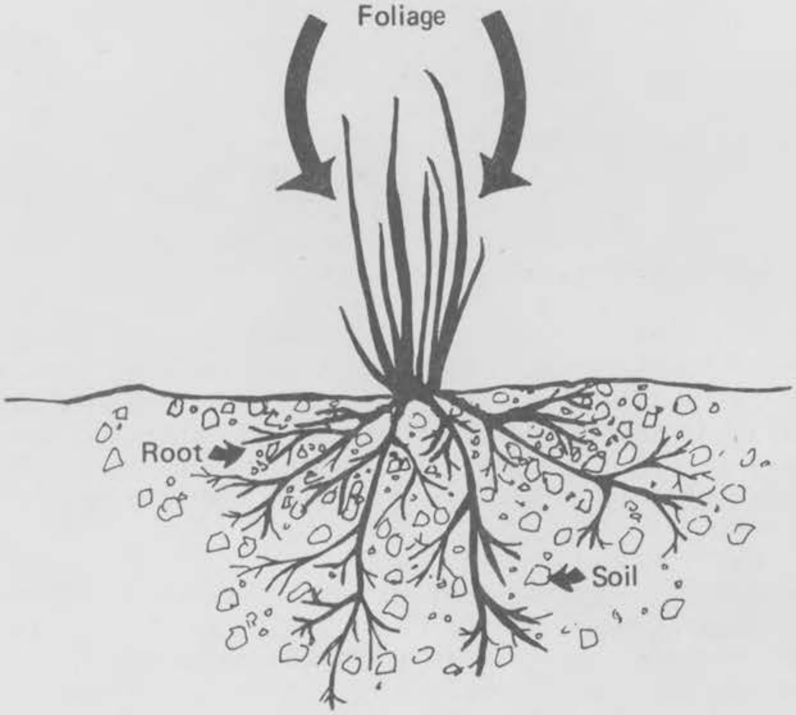

Figure 4. UF solution foliar and root feeding system.

Table 2. Formolene Fertilizer Comparative Performance Properties (after application)

Property	Formolene solution	UF powder suspension	Urea solution
Burn potential	Low	None	Medium to high
Initital response	Moderate	None to low	High
N-release period[a]	8 to 12 weeks	2 to 3 years	4 to 8 weeks
N-utilization by the plant[a] (percent)	85 to 95	70 to 80	50 to 85

[a]Estimates pending verification in continuing university and field tests.

The performance properties of these short-chain methylol ureas, such as Formolene, are compared with urea solutions and UF powder suspension after spray application to the turf.

Although it is possible to burn grass with Formolene fertilizer, its nitrogen phytotoxicity potential is significantly lower than with a urea solution; and when it is applied at rates of 1 to 2 pounds of nitrogen per 1,000 square feet, even in the hot, dry summer or early fall months, burn has not been a factor when it was used with normal water dilutions.

The moderate initial response of Formolene fertilizer reduces the tendency for disease problems that are associated with the excessive burst of growth frequently experienced with urea applications, particularly in the spring.

The nitrogen release period is 8 to 12 weeks. Also, based on some limited experiences of our first commercial year, it appears that there is a higher degree of nitrogen utilization when Formolene fertilizer is used. If so, the desired results could be achieved with a reduction in total applied nitrogen.

This consideration is where you, the lawn-care businessman, must address the real economics of your materials.

Urea is lower priced. However, if you could use half the amount of nitrogen per 1,000 square feet when using Formolene fertilizer than when you used the nitrogen in urea, the costs come close to a standoff. Although it does not seem possible that one-half the rate would get the same performance, companies who were using 4 pounds per year per 1,000 square feet might now use perhaps 3 pounds per year per 1,000 square feet for a similar or even better result in terms of green-up and color retention.

For example, in four applications during the year, the following schedule might be used: 1/2 to 1 pound per 1,000 square feet. With this rate of nitrogen, what are the economics of Formolene compared with a urea application of 1 1/4 to 1 1/2 pounds per 1,000 square feet? This comparison represents 3 pounds of Formolene fertilizer nitrogen versus 4 pounds of urea nitrogen and—on top of it—the elimination of burn complaints.

In addition to the agronomic economics of the materials used, there are materials-handling economics (see Table 3).

Table 3. Economic Comparisons of Cost of Nitrogen Used (dollars per pound)[a]

Fertilizer product	Cost contained nitrogen	Cost plant utilized nitrogen
Urea solution	0.25	0.29 to 0.50
UF powder	0.68	0.75 to 0.97
UF solution	0.58	0.61 to 0.68

[a]Estimates based on variable university and field test data.

Let us focus on the material-handling aspect of your nitrogen fertilizer requirements prior to the time the truck or spray rig departs for its first job. Some quantity of material must be received at your shop, stored, and then loaded into trucks. Each of these procedures will require some combination of labor, equipment, and warehousing cost.

The question of material handling is really the classic controversy over liquid versus dry materials for use in a lawn-spray applied system. A truckload of bagged material could require as many as five people (spray applicators) working one-half day to unload and stock 400 100-pound bags. For one man using a fork lift it could require only 1 hour to unload 20 pallets, but for three men with a pallet jack it could require 2 hours. In all cases the dry fertilizer requires more man hours and more equipment than are needed to pump off a 20-ton delivery of liquid nitrogen that can be unloaded by the transport driver in about 20 minutes and with no labor cost to you.

The most important advantages of a liquid-fill system over a bag-breaking, back-breaking fill system include: the reduced labor requirement saves money and improves morale; instead of dumping 5 to 10 bags, in less than 1 minute 60 gallons of liquid fertilizer can be pumped into the truck; by using a meter, a high degree of measured accuracy can be achieved with liquid fertilizer. These points are illustrated in more detail in Tables 4 and 5.

Table 4. Material Handling System for Lawn-Care Nitrogen Fertilizer

Receiving	Warehousing	Blending
Equipment investment Labor involved	Space required	Labor Accuracy Morale

A final, but certainly not unimportant reason for using liquid nitrogen is that the broad range of turf markets for Formolene solution nitrogen are exciting and challenging. Let us look at some of the markets that can use an organic type of solution nitrogen. The midwestern lawn-service business is an active and dramatically growing market, and the South and West are becoming increasingly active. The golf-course market, both for packaged goods for greens and tees and for volume spray or fertigation fairway applications, is scheduled for test marketing in 1980. Low-maintenance industrial, institutional, and governmental turfs are areas where the properties of Formolene fertilizer will be well accepted. Developments are currently under way for treating manure and other organic products with Formolene fertilizer to supplement and increase their nitrogen content.

Currently, Formolene has proven to be a very good turf fertilizer for lawn-service operation and application, and it has the promise of being used for many other turf applications.

A tank, pump, and piping system to handle solution fertilizers is relatively simple. Ashland Oil or its dealers can assist a lawn-care company in installing the equipment necessary for proper operation. Figure 5 shows a basic design. A storage tank system for liquid fertilizer should include the capability of using a pump to unload bulk deliveries. The best way is to build in a recirculation

Table 5. Comparison of Requirements for Handling Dry and Liquid Fertilizers

Standard package	Equipment needed	Receiving process	Receiving time	Storage space required
Urea (prill)				
50-, 80-, 100-lb. bag	Pallet jack $500	Remove 20 pallets	4 man hr.	500 sq. ft. inside
Palletized, ton	Fork lifts $12,000 to $20,000		2 man hr.	250 sq. ft. inside
Non-palletized	None	Remove 200 to 400 bags	10 man hr.	400 sq. ft. inside
UF powder				
50-lb. bag	Pallet jack $500	Remove & stock 20 pallets	4 man hr.	500 sq. ft.
Palletized, ton	Fork lift $12,000 to $20,000	Remove & stock	2 man hr.	250 sq. ft Double stock
Non-palletized	None	400 bags	10 man hr.	400 sq. ft. Half-stocked
UF solutions				
Bulk tank truck 4,000 gal.	6,000 gal. tank Pump & meter $4,000	Pump off 4,000 gal.	1 man hr.	None inside 100 sq. ft. outside

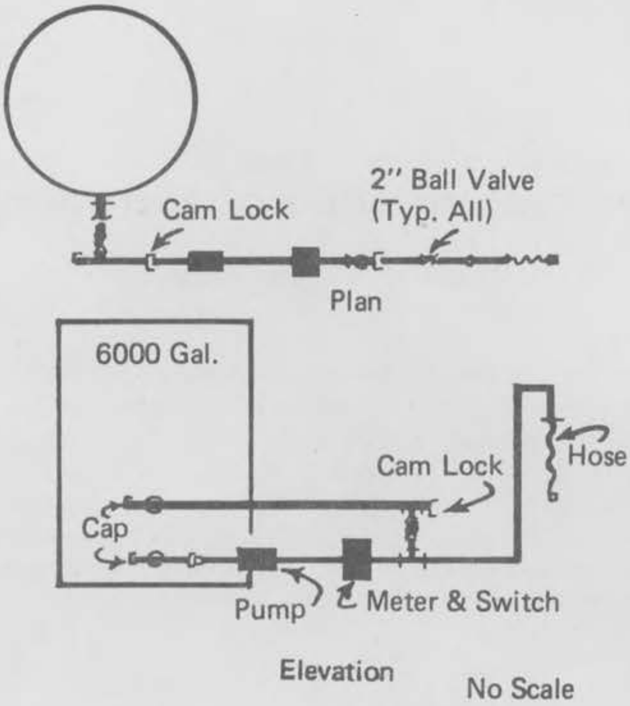

Figure 5. A basic design for a UF solution system.

capability with a quick couple filtering in front of the pump. More detailed information is available in technical data sheets from Ashland or from Formolene™ fertilizer dealers.

In summary, controlled-release nitrogen solution fertilizers are short-chain UF polymer (methylol ureas) in water solution. The solution nitrogen converts to controlled-release nitrogen after it is applied to the turf.

Nitrogen solution fertilizers are easier to handle because they are pumpable, the handling cost is low, they blend readily, they do not require much storage space, no agitation is necessary, and they are nonabrasive. These fertilizers also perform well. The initial response is quick; their burn potential is low; most of the N is used; and all the N is released in one season.

Long-Term Performance of Nitrogen Fertilizers

Donald V. Waddington

More complete information can be obtained to characterize nitrogen (N) sources or N fertilization programs if long-term studies are used. The residual effects of slow-release N sources are of particular importance in such studies. "Long-term" is not defined in this presentation because assigning an exact time or minimum time would be difficult. Certainly, making observations or collecting results from a single application or during a single season could be considered short-term. Depending on the type of information desired, various lengths of time would be needed to obtain meaningful data from long-term studies.

Field Observations

Continued use of an N source or N fertilizer program has produced satisfactory turf for many turf managers. Although individuals may not agree on a "best" N source or N program, many have stuck with practices that work for them. It should be common knowledge that long-term use of activated sewage sludge (in particular, Milorganite) has proven successful. Also, continued use of ureaform or IBDU has given good results. Sulfur-coated urea, a relative newcomer to the family of slow-release N sources, has not been available long enough to have had years of use on turfgrass like these other sources, but I am confident that long-term use of this product will also be favorable. Use of soluble N sources and various combinations of soluble and slow-release sources in mixed fertilizers have also given good long-term results. This is not to say that all materials will work in all situations, but instead that many people have selected a program that works under their conditions. We also have turf managers who are continually changing their fertilizer program for one reason or another. Their reasons are varied: N sources may not do what they expected, salesmen may sell them on the merits of another fertilizer, cost may be a deciding factor, or they may be searching for that panacea that will cure all their turf's ills.

Now, back to those who have stuck with one program, perhaps making minor adjustments as needed. How do they know that a different program or N-source would not have worked better? Usually they do not know for sure. However, if a person has a program that works, he is best advised to stick with it. Most turf managers are not in a position to evaluate several N sources or programs at one time. Comparisons among N treatments are usually left to the turf researcher.

Long-Term Research

In research studies several N sources or fertilizer programs can be observed at one time. The longer a study is conducted, the more can be learned concerning the effects of a treatment. Long-term studies enable the researcher to determine the residual effects of slow-release N sources, which are often inefficient in the

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first years of use. Even if residual effects are not of major importance, it is a good idea to obtain data from several growing seasons, which can provide different weather patterns or disease pressure. Long-term studies are also valuable for providing information on responses such as turfgrass species competition, weed encroachment, disease incidence, and thatch development when these responses are desired. However, in studies designed with N-source evaluation as the prime objective, it is best to minimize the effects of things such as species changes, weeds, and diseases. The researcher likes to know for sure that responses such as slow growth, poor color, and thin turf are related directly to the availability of N from an N 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.

Material	Treatment (lb. N/1,000 ft^2)	Appl.*	Nitrogen recovery (percent) First season	Second season
IBDU	5	2	25	55
Ureaform	5	2	9	25
Urex	5	2	48	56
ADM	5	2	45	63
Milorganite	5	3	20	33
Urea	3	9	41	63

*Number of equal applications to obtain annual rate of N shown.

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.

Material	Treatment (lb. N/1,000 ft^2)	Appl.*	Average clipping yields 1966	1967	1968	1969	1970	1971	1972
						(grams)			
IBDU	5	2	72	121	116	108	122	94	98
Ureaform	5	2	46	68	82	90	120	75	103
Urex	5	2	102	109	103	106	124	85	100
ADM	5	2	103	129	116	125	135	105	118
Milorganite	5	3	69	87	89	88	106	67	96
Urea	3	9	76	96	80	74	91	67	82

*Number of equal applications to obtain annual rate of N shown.

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. A summary of the results follows:

Fertilizer	Total clipping yields (fresh wt.)			Applied SCU remaining		Estimate of N released
	1974	1975	1976	11/76	11/78	11/76 to 11/78
		(g/m^2)		(percent)		(lb./1,000 ft^2)
SCU-16w*	370	402	346	17	0	2.0
SCU-17	247	296	242	37	13	2.9
SCU-26w	570	576	475	3	0	0.4
SCU-26	323	401	299	23	9	1.7
SCU-35	430	444	349	14	4	1.2
Gold-N	522	525	370	10	1	1.1

*Numbers refer to 7-day dissolution rate and "w" indicates sulfur plus wax coating.

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. Other 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.