November/December 1981
Volume II, No. 6

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Nematodes

by Dr. Don Blasingame, Mississippi State University

Although nematology is a fairly new field, it has seen rapid development in the past ten years. Nematodes, small eel worms, belong to a group of micro-organisms which scientists call obligate plant parasites. This term simply means that the organism lives and obtains its food only from living plants. This fact is both good and bad. On the good side it means that the nematodes very rarely kill the plants that they are feeding on. On the other hand, nematodes feed on the roots of the grass and take the nutrients that would normally be utilized by the grass. Also, this feeding activity destroys a portion of the root system and make them much more susceptible to other disease organisms. In many cases increased fertilization and water will offset some of the symptoms of a light infestation of nematodes. However, this is usually a simple postponement of the problem and eventually a point is reached where no amount of water or fertilizer will substitute for the lack of a root system and therefore, other steps must be taken to remedy the problem. Normally the conditions that are favorable for turf development are also favorable for nematode development. This is particularly true in areas where highly maintained turf has a long growing season.

We mentioned earlier that the nematodes do not kill the turf— well then, what are the symptoms of a heavy

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Figure 1: Nematodes are so small they can not be seen without the aid of a microscope.

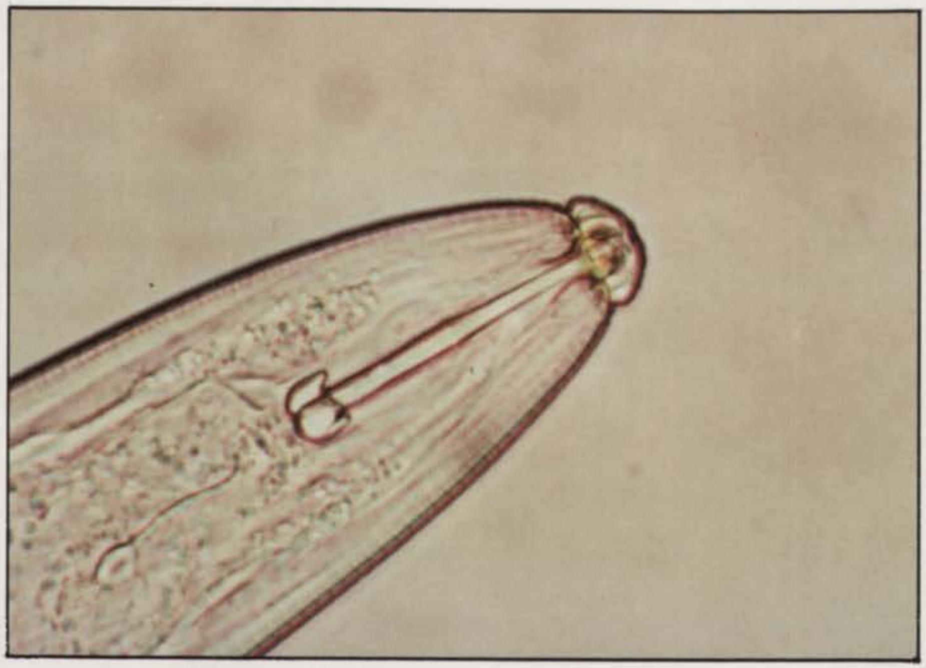


Figure 2: Nematodes feed on plants by injecting a needle-like stylet into the feeder roots.

Figure 3: Nematodes damage plants by reducing the amount of root system available for food and water uptake.

nematode infestation? The answer to this is that nematodes will cause almost any sort of symptom that can be caused by an inadequate root system. Generally a yellowing or off-color of the foliage is the first symptom. This is followed by a general stunting and thinning out of the grass. Also, the turf frequently will wilt during the hot periods of the day and will respond little to fertilizer or water. The only positive way to

Usually several different types of plant parasitic nematodes may be present

diagnose a nematode problem is to assay the soil around the root system of a plant for the presence of nematodes. Laboratory techniques and assay procedures have been developed over the years to accurately detect not only the number of nematodes present but also the types of nematodes that are causing the problems. There are a large number of different nematodes that damage turfgrasses. Of course, some are more damaging than others and at different population levels. Usually in a random soil sample from a golf course or home lawn, several different types of plant parasitic nematodes may be present. For example, the single most damaging type of nematode found on bermuda grass is a nematode known as the sting nematode *(Belonolaimus)*. This very

Nematodes

large nematode causes a great deal of mechanical damage to the root system making it more susceptible to other types of problems. The lance nematode *(Hoplolaimus)* is also very potent in its damage of turfgrass. The root-knot nematode *(Meloidogyne)* causes considerable damage to turfgrass. This nematode is probably best known on field crops, vegetables and on ornamentals. It causes galls and swelling of the root system making it very easy to recognize. The lesion nematode and stubby root nematodes are also found frequently parasitizing grasses. Ring

Mixed combinations of nematodes compound the problem

nematodes have been found in well over 50 percent of the turf samples from the southeast assayed by our labortory. Other nematodes that are found in association with the unhealthy turf samples include stunt, dagger, and spiral nematodes. All of these are forms of parasitic nematodes that feed on turfgrass and probably cause some type of damage to the turf. However, they are not as economically damaging as are the first five mentioned. Nematodes very seldom occur in an area as a single species but rather appear as mixed population. Mixed populations normally compound the problem since each type contributes its share toward weakening the plant. Some guidelines can be set as to the amount of individual damage by nematode species, however, it is difficult to say how much damage

Figure 4: In the lawn nematode damage appears as thin yellow areas.

occurs in these populations. This then becomes a matter of judgment.

What can be done to combat the high nematode population in turf? There are several things we can do, first of all, grass should not be planted in areas where high nematode populations are already present. In other words, if high nematode populations are present in an area where you plan to plant grass, then they must be eradicated prior to seeding or sodding. This can be done by application of a soil fumigant or a nematicide. Also, turfgrass management personnel should insist upon nematode free planting material.

Nematode populations must be eradicated prior to seeding or sodding

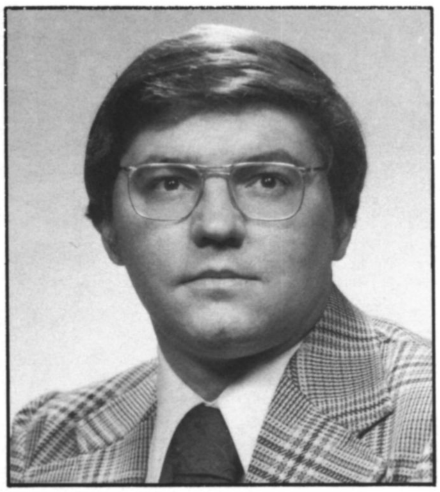
As with any other type disease, prevention is much better than cure. However, there are measures that can be taken if nematodes are present in established turf. This involves the application of a nematicide. A number of nematicides once used in turf are no longer available. All remaining nematicides have been placed on the "restricted pesticide" list and must be applied by a licensed applicator. These materials may be applied in a liquid or granular form. These chemicals are normally applied either in late spring or early fall. Be sure to have soil analyzed for nematodes and get professional help before using a soil sterilant or nematicide.

xxx

Figure 5: Nematodes can be a severe problem for the golf course superintendent.

Nitrogen Fertilizers

by Dr. John R. Street, Ohio State University



John R. Street is an Assoc. Professor of Agronomy/Turfgrass Science at the Ohio State University. He received his B.S. degree from Calif. State College in plant physiology and his M.S. and PhD degrees from the Ohio State University in Agronomy. Dr. Street's chief research interests are in turfgrass nutrition, nitrogen fertilizers, and weed control.

Turfgrass growth is dependent on maintaining an adequate supply of all essential plant nutrients as well as properly maintaining a multiplicity of other cultural and edaphic factors. There are at least sixteen elements considered essential for plant growth and development. Elements used by plants in relatively large quantities (percentage levels in the plant on a dry weight basis) are commonly referred to as macronutrients. Nitrogen, phosphorus, and potassium fall into the macronutrient category. Those elements required by the plant in relatively small quantities (ppm levels on a dry weight basis) are referred to as micronutrients. Iron, manganese and zinc are included in this category. Nitrogen is the essential element that receives the most attention in turfgrass fertilization programs. There are several reasons for its key position in fertility programs. First, the nitrogen content of turfgrass tissue is usually higher than any other element supplied by the soil. Generally, the nitrogen concentration in turfgrass tissue ranges from three to six percent on a dry weight basis. Second, nitrogen is frequently referred to as the "TNT" of turfgrass fertilization programs. Turfgrass growth usually increases with increasing application rates of nitrogen fertilizer. Overapplication or mismanagement of nitrogen can result in many detrimental effects. Thus, proper fertilizer selection, seasonal timing, and application rate are all important in successful long-term programs. Third, nitrogen is a very dynamic element in the soil system. The concentration of soil nitrogen is in a constant state of change. Nitrogen depletion in soils may result from leaching, clipping removal, volatilization, denitrification, immobilization, or nitrogen fixation in the lattice structure of certain clays. Thus, nitrogen must be added to turfgrass sites

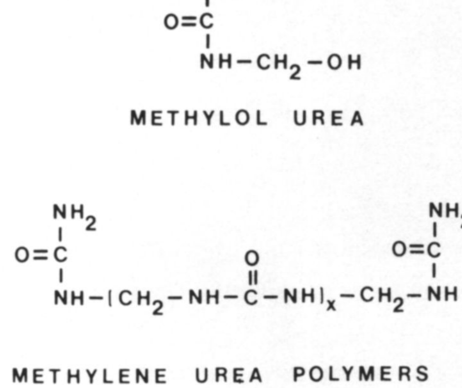


Figure 1: The chemical structures of urea, menthylol urea, and methylene urea polymers. The longer the methylene urea polymer the slower is the nitrogen release rate.

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Table 1. Several Characteristics of Quickly-Available Nitrogen Sources.

ADVANTAGES

* Rapid initial plant response
* Ease of application in liquid delivery systems
* Minimum temperature dependence for nitrogen availability to the plant
* Low cost per unit of nitrogen

DISADVANTAGES

* High foliar burn potential
* Potential for undesirable growth surges at anything above moderate rates
* Short residual plant response
* Greater nitrogen loss potential due to leaching, volatility, and surface run-off
* Lower and more frequent applications relative to slowly-available sources

Table 2. Commonly Used Quickly-Available Nitrogen Sources*

FERTILIZER	ANALYSIS
Urea	46-0-0
Ammonium Nitrate	33.5-0-0
Ammonium Sulfate	21-0-0
Potassium Nitrate	13-0-46
Diammonium Phosphate	18-46-0
Ammonium Polyphosphate (liquid form)	10-34-0

*The quickly-available nitrogen sources are readily available under numerous turf and agricultural names.

on a routine basis in order to maintain a sufficient soil level for turfgrass growth.

Generally, nitrogen additions to the turfgrass system from clipping return, decomposition of organic matter, topdressing, nitrogen fixation, and rainfall are not sufficient to supply the needs of high quality turf. The main source of nitrogen is added by the application of nitrogenous fertilizers. Turfgrass managers have many alternatives when it comes to choosing a source of nitrogen for turfgrass fertilization. Nitrogen sources can be divided into two general groups: (1) quickly-available and (2) slowly-available. The choice of a nitrogen source is not simply limited to the above categories. Various combinations are available in many mixed fertilizers which may vary widely in the source and amount of quickly- and slowly-available nitrogen.

QUICKLY-AVAILABLE NITROGEN SOURCES

The major characteristics of quickly-available nitrogen sources are summarized in Table 1. Quickly-available nitrogen sources are also commonly referred to as quick-release, fast-acting, readily-available, water-soluble and other terminology that denotes rapid or quick availability of nitrogen to the turfgrass plant after fertilizer application. Examples of several quickly-available nitrogen sources are listed in Table 2. A major agronomic advantage to the quickly-available sources is a rapid initial plant response (i.e. color and growth) following fertilizer application. Their rapid availability does, however, cause an undesirable flush or surge of topgrowth when applied at anything greater than moderate rates and a short residual response. In Ohio studies, Urea has provided a residual response of 7-8 weeks on fine-textured soil and during normal rainfall periods. This past Spring urea residual lasted only 5-6 weeks due to the large amount of rain (Table 5). Thus, these sources are applied more frequently and at lower rates than slowly-available sources to minimize over stimulation of growth and in combination with slowly-available sources to lengthen the residual response.

Rapid initial plant response to quickly-available sources

Quickly-available nitrogen sources have a high potential for foliar burn. They have salt-like characteristics dissolving readily in water to form cations (positive ions) and anions (negative ions). For example, ammonium nitrate (NH_4NO_3) dissolves or dissociates readily into the cation ammonium (NH_4^+) and anion nitrate (NO_3^-). The more free cations and anions in soil solution or on the plant surface the greater is the potential for fertilizer burn. The salt index value is used to differentiate the relative burn potential among various fertilizers. The higher the salt index value, the greater the tendency for fertilizer burn (Table 3). The relative burn potential of various commercially available nitrogen sources in Ohio studies is provided in Table 4. Many factors are considered to influence fertilizer burn. Lower soil moisture and higher temperature increase the potential for fertilizer burn. This necessitates a reduction in the nitrogen application rate for quickly-available sources during the warmer periods of the growing season.

Nitrogen Fertilizers

Table 3. Salt Indexes of Various Nitrogen Fertilizer Sources*

FERTILIZER	SALT INDEX VALUE
Urea	75
Ammonium Nitrate	105
Sodium Nitrate	100
Potassium Nitrate	74
Ammonium Sulfate	69
Nitroform	10
IBDU	5
Methylene Urea	4

*Concentration of ions in soil solution based on nitrate at 100°.

Table 4. Foliar burn rating for various nitrogen fertilizers on Kentucky bluegrass

FERTILIZER	BURN RATING[1]
Urea, liquid	5.5
Folian	5.4
UF & Urea	4.3
Formolene	1.5
UF	1.0
Fluf	1.0
Urea, granular	1.0

1. Burn ratings were made on a scale of 1 through 9 with one representing no burn and nine representing severe burn.
2. Fertilizer was applied at one pound of actual nitrogen per 1,000 square feet in July. The midday temperature was approximately 88-90°F.

SLOWLY-AVAILABLE NITROGEN SOURCES

The major characteristics of slowly-available nitrogen sources are summarized in Table 6. These nitrogen sources are also commonly referred to as controlled-release, slow-release, slow-acting, water-insoluble, and other terminology that denotes gradual release or availability of nitrogen to the turfgrass plant after fertilizer application. The gradual release characteristic provides for a more uniform turf growth response and a longer period of nitrogen release as compared to quickly-available sources. Safety is another major agronomic advantage due to their low foliar burn potential (Table 3). The potential for producing turf injury from overapplication or overlapping is minimized due to the slow rate of nitrogen release. This is a very desirable characteristic especially during warm weather. These latter characteristics also enable these sources to be applied at higher nitrogen rates and less frequently than quickly-available sources. Some sources do provide a slow initial plant response, especially at low rates, and some are dependent on warm soil temperatures for maximum nitrogen release. The cool-weather response is minimal from many of these sources. Many commercial fertilizer formulations will include a certain percentage of quickly-available nitrogen to compensate for these disadvantages.

Slowly-available nitrogen sources can be classified according to the mechanism controlling the release of nitrogen. The three major groups and fertilizer sources included in each are:

Group I. Organic (carbon) compounds dependent on microbial decomposition for nitrogen release.
1. Nitroform (UF)
2. Methylene ureas
3. Methylol ureas
4. Natural organics

Group II. Organic compounds of low water solubility that release nitrogen by slow dissolution of the fertilizer particle.
1. IBDU

Group III. Soluble sources that are coated forming physical barrier or shell that delays dissolution or release of nitrogen.
1. Sulfer-coated urea

UREAFORM (UF)-TYPE FERTILIZERS

UF-type fertilizers are formed by reacting urea with formaldehyde under specific reaction conditions. In the reaction process, urea initially reacts with formaldehyde to form an organic (carbon) compound called monomethylol urea (Figure 1). Monomethylol urea is the primary organic compound in Formolene (Hawkeye Chem. Co.). This compound further reacts with urea to produce methylene ureas (Figure 1) that vary in chain length from short chain water-soluble molecules to the long chain highly water-insoluble molecules. The longer the methylene urea chain length, the less soluble the nitrogen product. Some free or unreacted urea also remains as a part of the final product. Thus, the UF-type fertilizers do not consist of a single compound, but they are composed of a mixture of various chain length methylene ureas and free urea. The relative percentage of the latter components in the final product will depend on reaction conditions such as temperature, pH, reaction time, and the ratio of reaction components (i.e. urea to formaldelhyde). Nitroform, Scott's ProTurf methylene urea, and Fluf are UF-types that fit into this catagory. The relative

Table 5. Kentucky bluegrass quality ratings as affected by nitrogen fertilizers during the 1981 Spring Season.

Fertilizer[1]	Quality rating[2]							
	5/7	5/17	5/26	6/5	6/15	6/28	7/8	7/16
Urea, liquid	7.0	7.0	7.0	7.0	7.0	6.0	5.7	5.1
Urea, granular	7.0	7.0	7.0	7.2	7.0	6.7	5.8	5.3
Nitroform (UF) Powder Blue	4.7	5.0	5.3	6.0	6.0	6.5	6.0	5.5
Formolene	6.0	6.3	7.0	7.0	7.0	6.0	6.0	5.5
Fluf	6.0	6.0	6.2	7.2	7.0	6.3	6.2	5.7
Folian	7.0	7.0	7.0	7.2	7.0	6.0	5.8	5.3
SCU Canadian Indus., Ltd.	5.0	7.0	7.0	7.5	7.5	7.5	7.0	6.5
SCU Lakeshore	5.0	7.0	7.0	7.5	7.5	7.5	7.0	6.5
Scotts Methylene Urea	6.3	7.0	7.0	7.0	7.0	7.0	6.8	6.3
IBDU	4.0	6.0	6.7	7.5	7.8	7.3	7.0	6.5

1. Nitrogen sources were applied on April 30 at 1 pound of nitrogen per 1,000 ft^2.
2. Quality ratings are based on a scale of 1 through 9 with 9 representing best and 1 representing poorest.

percentages of free urea and short and long chain methylene ureas give each product its own unique fertilizer characteristics. (Table 7)

The nitrogen release or availability characteristics of the UF-types are classified by the solubility of the products in water. Two water temperatures are used: (1) room temperature– cold water (22°C) and (2) boiling water– hot water (100°C). Three water soluable fractions are designed from this test:

Fraction I. Cold water soluble nitrogen (CWSN)
- consists of free urea and short chain methylene urea polymers
- methylene diurea and dimethylene triurea
- nitrogen release is rapid and similar to quickly-available sources

Fraction II. Cold water insoluble nitrogen (CWIN)
- consists of slowly-available nitrogen and intermediate length methylene urea polymers
- trimethylene tetraurea and tetramethylene pentaurea
- nitrogen release is slow and over a period of several weeks

Fraction III. Hot water insoluble nitrogen (HWIN)
- consists of slowly-available nitrogen and long chain methylene urea polymers
- pentamethylene hexaurea and longer chain polymers
- nitrogen release is very slow and over a period of several years

The amount of water-insoluble nitrogen (WIN) that makes up a fertilizer product is designated on the fertilizer label. The WIN value indicates the percentage of Fraction II (CWIN) plus Fraction III (HWIN) in the fertilizer. The WIN value however, does not define the relative percentage of these two fractions. Thus, two fertilizers with identical WIN values could produce significantly different agronomic responses.

The activity index (AI) value provides a more specific indication of the relative amount of CWIN and HWIN. AI is represented by the equation:

$$AI = \frac{\%\,CWIN - \%\,HWIN}{\%\,CWIN}$$

The higher the AI value, the lower the amount of HWIN in the product. Nitrogen release will be more rapid from products having a lower HWIN content.

Nitrogen Fertilizers

Table 6. Several Characteristics of Slowly-Available Nitrogen Sources

ADVANTAGES

* Low burn potential due to low salt index values
* More uniform growth response
* Longer residual plant response
* Higher application rates allowing for less frequent applications and reduced labor costs
* Less potential for nitrogen loss compared to quickly-available nitrogen sources

DISADVANTAGES

* High cost per unit of nitrogen
* Slow initial plant response with some sources
* Nitrogen carryover into the following growing season
* Some sources not adaptable to liquid application systems

UF-type fertilizers should have an AI value of 40 or greater for satisfactory agronomic performance. In other words, 40% of the WIN must be soluble in hot water.

Nitroform has a 38-0-0 analysis and approximately 70% of the nitrogen is WIN. It consists of equal fractions of CWSN, CWIN, and HWIN. In soil incubation studies, 4% of Fraction I, 25% of Fraction II, and 84% of Fraction III remained in the soil and after 26 weeks (4). The low efficiency or recovery of Nitroform nitrogen during the initial years of use is attributed to the slow mineralization or breakdown of Fraction's II and III. It was predicted that mineralization proceeds at about 15% per week in the first two weeks and drops to about 1.5% per week in the fourth to sixth month for Fraction II and at a rate of about 10% per year for Fraction III. Low recovery from Fraction's II and III make it necessary to use higher nitrogen rates or supplement Nitroform with soluble sources during the initial years of use. Nitroform is available in granular (Blue Chip) and powder (Powder Blue) forms. The Powder Blue form is adaptable to liquid applications systems.

Scott's ProTurf methylene urea has a 41-0-0 analysis and approximately 36% of the nitrogen is WIN. Approximately 55% of the CWSN fraction consists of short chain methylene ureas. Only about 40% of the WIN is HWIN. The high percentage of CWSN provides for a rapid initial plant response but still good safety characteristics and residual due to the varying degrees of solubility of the methylene urea polymers.

Fluf has an 18-0-0 analysis and approximately 20% of the nitrogen is WIN. It is described as a UF-type liquid suspension. Free urea and methylene ureas constitute the CWSN fraction. In Ohio tests, burn potential has been low and initial response has been slightly slower than quickly-available sources (Table 5).

Formolene has a 30-0-2 analysis and is described as a true solution (clear liquid) with zero WIN. Short chain methylol urea constitue the major organic portion of the product. It has ranked low in burn potential in Ohio tests and the initial plant response has been comparable to quickly-available sources. (Tables 4 & 5) A comparison of Kentucky bluegrass quality among several nitrogen sources from Ohio studies is provided in Table 5.

SULFUR COATED UREA

Sulfur-coated urea (SCU) is formed in a continuous-flow process by spraying preheated urea pellets with molten sulfur. A sealant coat of polyethylene oil or microcrystalline wax is then applied. Finally, a conditioner, consisting of diatomaceous earth or vermiculite, is added to reduce the stickiness of the sealant. Pinholes and cracks do develop in the sulfur coating of certain particles as they cool. The purpose of the sealant is to plug these defects, strengthen the sulfur shell, and decrease the initial rate of urea release. Nitrogen content of commercially-available products is in the range of 32 to 37%. These products usually contain a nitrogen:sulfur ratio of approximately 2:1. In Ohio tests, initial turf response has been slower than quickly-available sources but residual response has been excellent (Table 5).

Release of urea from SCU granules occurs through defects in the coating such as pinholes and cracks and through openings as the sealant and sulfur coat deteriorate. A certain percentage of granules contains major defects (i.e. pinholes and cracks) which are not covered by sealant coating. The granules empty rapidly when placed in water. This nitrogen fraction acts as quickly-available or water-soluble nitrogen. The 7-day dissolution rate in water is commonly used to characterize the initial release rate (quickly-available fraction) of different SCU formulations. Under laboratory conditions, 50 grams of SCU is immersed in 250 ml of water at 38°C and the amount of urea which enters the solution after 7 days is measured. This amount, expressed as a percentage of the total urea content, characterizes each SCU product. For example, SCU-30 is a product from which 30% of the urea is released under the 7-day dissolution test. A 7-day dissolution rate of 20-30% has proven to be acceptable for initial turf response when applied at rates of greater than 1 pound of nitrogen per 1,000 square feet.

Three general solubility classes of SCU are described within a produce (2):

CLASS I. Granules with holes or cracks through the coating.
CLASS II. Granules with holes or cracks in the coating which are plugged with sealant.
CLASS III. Granules which have no holes through the sulfur coating.

Class I granules act like quickly-available nitrogen and release urea as soon as they contact moisture. Class II granules begin to release nitrogen as soon as the sealant is broken down or removed. Class III granules begin to release nitrogen as soon as the sulfur coating is penetrated. Temperature, soil moisture, and microbial activity are all considered to play a role in the release of nitrogen from Class II and III granules.

The release of nitrogen from individual granules of SCU is described as "catastrophic release". Release of urea from granules is rapid once water gains access into the sulfur shell. Thus, slow availability of nitrogen from SCU results from many granules that release nitrogen at different times. Nitrogen is not released from all granules uniformly.

Temperature, soil moisture, and microbal activity affects release of nitrogen

The UF-type fertilizers are dependent on microbial activity for release of nitrogen from the organic structure. The breakdown of the organic compound and the subsequent release of nitrogen as ammonium (NH_4+) is termed mineralization. The process is favored by adequate supplies of oxygen and water, soil pH near neutral, and warm soil temperatures. Microbial activity occurs slowly at soil temperatures below 50-55°F and increases with soil temperature up to an optimum range at or near 100°F. Thus, the UF-type fertilizers, like Nitroform, that contain appreciable quantities of WIN will not perform well during the cooler periods of the season when soil temperatures are low. Quickly-available sources are usually applied alone or in combination with these UF-types during cool periods.

NATURAL ORGANICS

The nitrogen in natural organic sources is contained in complex organic (carbon) compounds that are not readily soluble in water. The materials are predominantly by-products of the plant and animal processing industry or waste products. Dried manures, seed meals, process tankage, bone meal, and cocoa shell meal are examples of natural organics, but these materials have only received very limited use for turf fertilization. The natural organic source used most readily for turf fertilization today is activated sewage sludge. It is sold under the tradename of Milorganite. It is made from sewage freed from grit and coarse solids by aerating in tanks with microorganisms. The resultant organic matter is then filtered, dried, ground and screened. The material is steam sterilized to kill weed seeds and harmful organisms. In addition to nitrogen, Milorganite also contains significant amounts of phosphorus, potassium and many micronutrients. The commercially available product has an approximate 6-2-0 analysis and a WIN value of 5.5. Nitrogen release from natural organics is dependent on microbial activity for breakdown of the complex organic compounds. Initial plant response and residual response is considered intermediate between quickly-available nitrogen sources and Nitroform.

IBDU

IBDU (isobutyledene diurea) is formed by reacting isobutyraldehyde and urea in acid solution. The resulting product contains 31% nitrogen and 90% is water insoluble (WIN). The WIN portion of IBDU has a uniform composition, whereas, UF-type fertilizers consist

Nitrogen Fertilizers

Table 7. Approximate amounts of various nitrogen fractions for several nitrogen fertilizers. (2)

PRODUCT	TOTAL N	UREA	Soluble Methylene Ureas	WIN	HWIN	AI
	--- % ---	------------ % of the total N				
Urea	46	100	–	–	–	
Formolene	30	45-50	50-60	–	–	
Methylene Urea	41	35	30	36	13	60
Fluf	18	28	52-54	18-20	6	65-75
Nitroform (UF)	38	11	17	72	40	40

of various chain length methylene ureas and free urea. The finished reaction product is screened into two sizes, 0.5-1.0 mm fine and 0.7-2.5 mm coarse.

IBDU has a low solubility in water. The conversion of IBDU to plant-available nitrogen is dependent on dissolution of IBDU molecules from the granule. This is considered the rate-limiting step in breakdown of IBDU. Following dissolution from the particle, the IBDU molecule is hydrolyzed (split) to urea and aldehyde. Urea is then converted to ammonium (NH_4^+) by enzymatic hydrolysis.

The nitrogen-release rate is predominantly affected by soil moisture and particle size. Higher soil moisture and smaller particle size result in a more rapid release rate. Nitrogen release from IBDU is somewhat depressed at alkaline pH values, especially those near pH 8. Nitrogen release is independent of microbial activity. Thus, IBDU will release nitrogen much more readily than Nitroform and natural organics during cool weather. Nitrogen release is increased to some degree by higher soil temperatures.

Fall-applied IBDU provides an excellent turf quality response during the late fall and early spring. It has proven to be an excellent nitrogen source for use in late-season fertilization programs. Initial turf response from IBDU applications is usually slow due to low solubility and too high WIN content. Once a threshold concentration of soil nitrogen is reached, turf response is usually excellent. Commercial formulations are available (e.g. Par Ex 24-4-12) that provide a certain percentage of free urea to enhance early turf green-up. With liquid applications, initial turf response and pumping. The addition of ½ pound of nitrogen per 1,000 square feet as IBDU was found to be a lower limit for extending the residual response of quickly-available sources in liquid programs (5). Two applications (spring and fall) of granular IBDU have given good results on both bentgrass and Kentucky bluegrass during the growing season at nitrogen rates of 2-3 pounds per 1,000 square feet (7).

IBDU is an excellent nitrogen source for late-season fertilization

"Controlled-release soluble urea nitrogen" (CRSUN) is a term used on certain SCU fertilizer labels. The CRSUN value simply refers to the total percentage of nitrogen as SCU in the product. Another term "controlled-release nitrogen" (CRN) refers to the amount or percentage of Class II and III nitrogen in the product. The CRN value excludes the Class I or water-soluble (7-day dissolution) nitrogen fraction.

Nitrogen fertilizers available for turfgrass fertilization vary considerably in their chemical and physical properties. Fertilizer use should be based on the properties of the nitrogen source and on factors that affect release and availability of nitrogen from the source. Quickly-available nitrogen sources release nitrogen rapidly to the plant and best agronomic responses occur at low to moderate nitrogen application rates. Many of the slowly-available nitrogen sources that have a high WIN content, like Nitroform, can be applied at higher rates and less frequently than quickly-available sources. In fact, nitrogen sources that have a high WIN content usually provide best overall turf quality at higher rates per application than are traditionally used for quickly-available sources. Generally, at lease two applications per year are considered necessary for maintaining an acceptable level of turf quality. Many commercial formulations consist of both quickly-available and slowly-available sources. These fertilizer products attempt to include the advantages of both types. It is important to understand the differences in nitrogen sources and fertilizer products before making decisions on product, application timing, and application rates.

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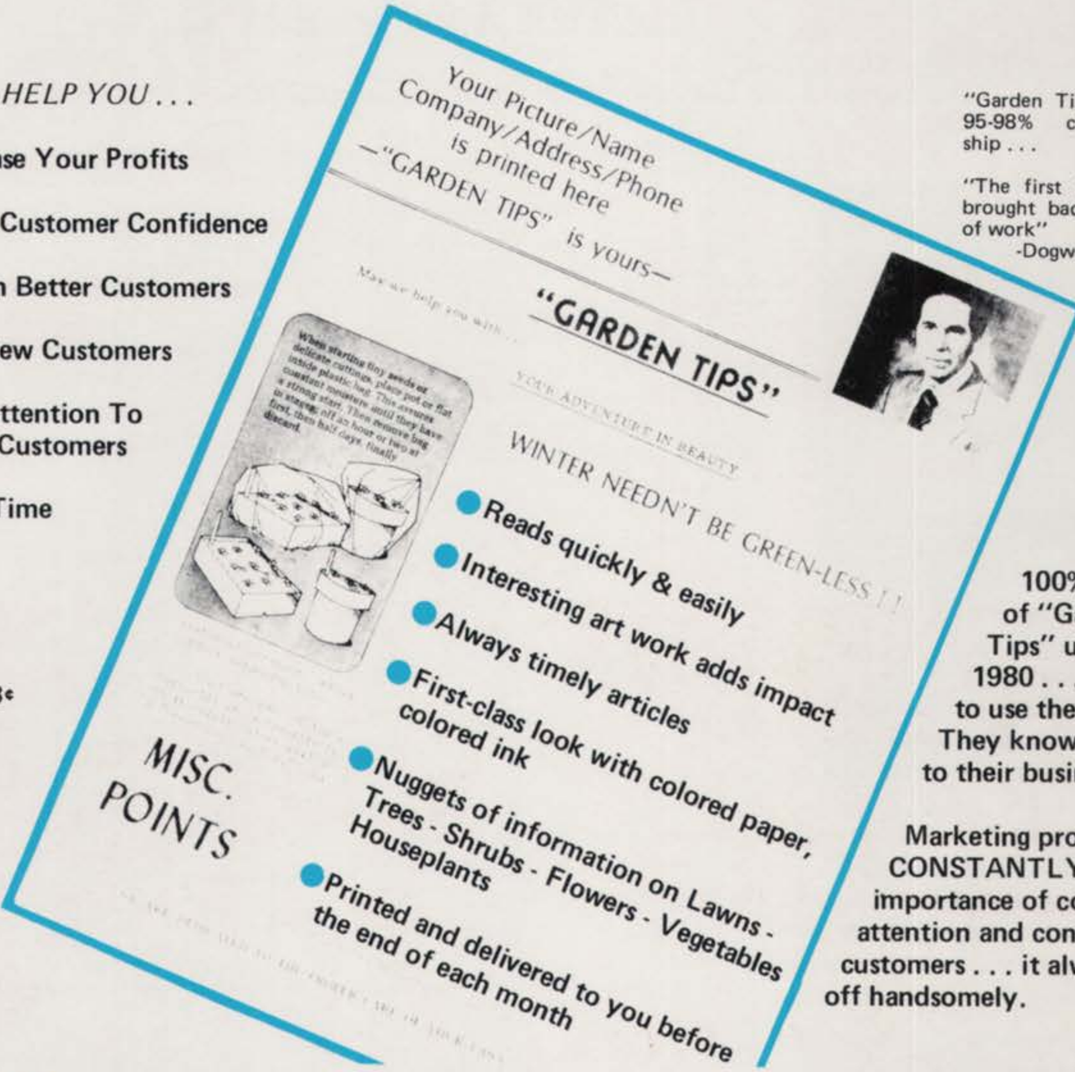
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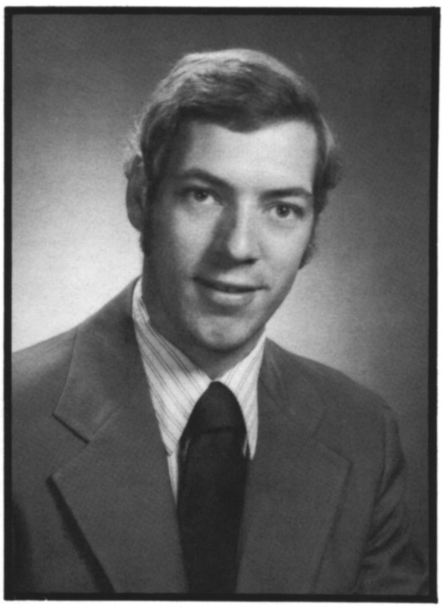
Aerifying: Its Role in Lawn Care

by Richard G. Rathjens, The Davey Tree Expert Company



Richard G. Rathjens received his Master of Science Degree in Turfgrass Management from Cook College, Rutgers University, New Jersey in 1978. He received his Bachelor of Science Degree in Agronomy in 1975, from Delaware Valley College of Science and Agriculture. He is currently employed in the Research & Development Center of The Davey Tree Expert Company, Kent, Ohio.

Successful lawn care businessmen have provided homeowners standard lawn maintenance programs which have included fertilization and weed, insect and disease control. As a complement to these routine maintenance practices, many lawn care companies now offer or are considering offering additional services such as liming, thatch removal and aerifying to maximize turfgrass quality.

Although the benefits of liming and thatch removal have long been recognized as a part of home lawn maintentance, the role of aerifying is not well established. Before making a decision to offer aerifying as part of a standard lawn maintenance program or recommending to an individual client that his/her lawn be aerified, a lawn care professional should be knowledgeable of the situations where aerifying could be utilized and what benefits can be anticipated from an aerifying treatment.

Aerification, which is frequently referred to as cultivation, is the selective tillage of a turfgrass area by mechanical means. Aerifying is practiced with the intent of improving the exchange of air and water between the soil below and the atmosphere above a turf cover. The two most commonly used methods of aerifying are spiking and coring *(figure 1)*.

Spiking involves the penetration of solid tines or metal spikes which make angular depressions into the turf and soil below. Coring, however, is perhaps the most popular method of aerifying. A core aerifier has hollow tines or metal tubes which punch a hole and remove a core of soil which is deposited on the turf's surface. It is this second method of aerifying or removal of a core of soil which is the subject of the following discussion.

Aerifying typically is used to alleviate the adverse effects of soil compaction, a situation where individual

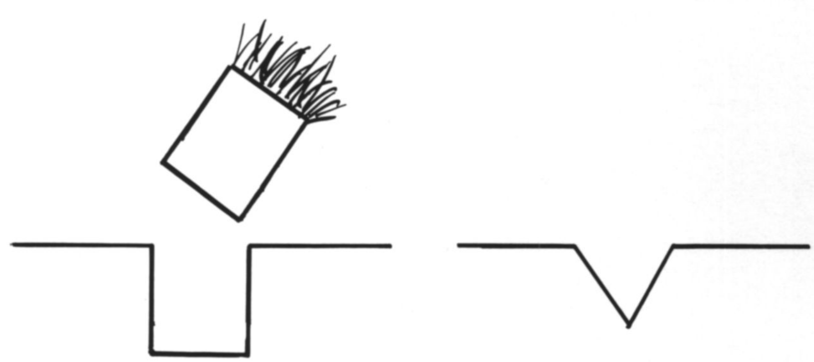


Figure 1: A cross-sectional view of the soil profile following coring and spiking.

soil particles are pressed together resulting in elimination of the pore spaces which hold air and water between the soil particles. Compaction can be caused by both natural and artificial forces. Even the impact of falling water droplets from either rainfall or irrigation water (particularly on bare soil) can lead to the formation of a compacted layer near the surface of the soil.

Turfgrass areas which normally suffer from soil compaction are those subject to artificial forces of foot or vehicular traffic. The soil compaction which results from these artificial forces is most often associated with turf areas of intense use and maintenance for sporting events or areas such as golf course greens, grass tennis courts and football and soccer fields. Although not exposed to this same intensity of use, home lawns can contain compacted soil layers caused by the artificial forces of construction and grading equipment utilized around a home prior to lawn establishment, excessive rolling of the soil (particularly when wet) or overworking or excessive tillage of the soil in preparing a seedbed for lawn establishment.

The direct effect of compacting forces is destruction of soil structure *(figure 2)*. In a compacted soil, bulk density increases while pore space decreases (especially large pore spaces). In other words, while the amount of soil for a given volume increases, the amount of space occupied by air and water within the same volume decreases.

The detrimental change in soil structure reduces the infiltration of water into the soil and, depending on slope, results in either an increase in the amount of water lost via runoff or puddling of water at the soil's surface. Formation of a compacted layer near the surface of the soil can form a barrier which impedes soil aeration. Poor soil aeration (aeration refers to the exchange of air between the soil and atmosphere) can limit the supply of oxygen for root growth and trap carbon dioxide within the soil profile. A compacted layer of soil can also act as a physical obstruction to root growth. In terms of the turfgrass plant, soil compaction can result in an overall reduction in vigor and increased susceptibility to environmental stress and pest invasion.

In addition to relieving the adverse effects of compaction, aerification has been utilized as a method of 1) correcting soil interfaces, 2) modifying an excessive thatch layer, 3) seedbed preparation during lawn renovation procedures, and 4) introducing topdressing, lime and phosphorus into the turfgrass root zone.

Direct effect of compacting is destruction of soil structure

A soil interface or soil layering as it is sometimes called, occurs when one soil type overlays another distinctly different soil type. An example of an interface is when a sod grown on a muck soil (high organic matter containing soil) is laid over a clay soil without providing a transition between the two soil types. As a result, applied water and fertilizers may not uniformly penetrate through the interface leading to poor root development and inconsistent shoot growth response.

The concept of thatch modification proposed by Hurto and Turgeon (3) is based on the premise that as an excessive thatch layer forms; it— rather than the soil below— serves as the medium for turfgrass growth. The researchers suggest that aerifying with the incorporation of native soil removed with the core will improve the poor water and nutrient holding capacity of thatch. Aerification has been

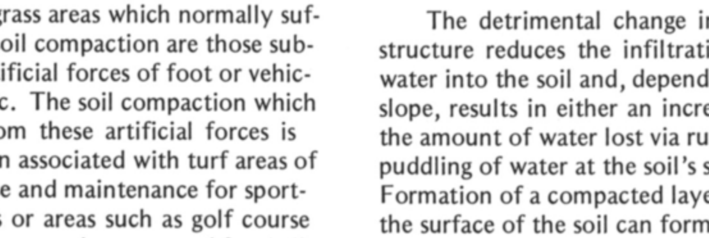


Figure 2: The influence of soil compaction on bulk density.

Aerifying

used successfully alone or in conjunction with dethatching in the preparation of a suitable seedbed during turfgrass renovation. In either case, multiple passes with the core aerifier over the area to be renovated and the breaking up of soil cores help to insure seed/soil contact.

For years golf course superintendents have topdressed golf course greens with soil following aerification. This allows a method of introducing amended soil or sand directly into the turf's root zone. In addition to soil, fertilizer elements such as phosphorus, which is relatively immobile in the soil profile, can be placed near feeder roots. Harper (2) found an increase of 25.5% more phosphorus at 3-6" root zone depth following aerification. Research has demonstrated that two or more aerifications per year using a mechanical core aerifier on soils which did not contain a detrimental compacted layer gave no significant increase in the infiltration rate of water into the soil profile (1,4,8), decrease in the incidence of dry spots (1), or improvement in soil aeration (1,6). Conflicting results are reported following multiple aerifications which showed both failures (1,6) and successes (5,7) in improving turf quality.

On the basis of the research conducted on soils which did not truly contain a compacted layer, aerifying should be recommended for use on a home lawn with discretion rather than presuming an improvement in turfgrass quality. This principle is particularly important since the process of aerifying may be a soil compactive force in itself. Petrovic (6) found that increased soil bulk densities (used as a measure of compaction) of 9 and 17% at the side walls and bottom of the coring hole following a single aerification.

In summary, rather than offering aerification as part of a standard lawn care program, aerifying should only be recommended to correct a specific problem. Aerifying should be performed on a home lawn if the soil has been compacted as a result of excessive rolling, construction equipment or excessive tillage. Likewise, aerifying can be justified as a means of disrupting soil interfaces, improving thatch has a growth medium for large areas where mechanical dethatching is not feasible, or introducing a deficient element such as phosphorus into the root zone.

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Postemergence Control of Winter Weeds in Dormant Bermudagrass

by B. J. Johnson, Univ. of Georgia

Professor of agronomy, University of Georgia, Georgia Station, Experiment, Georgia 30212. *Supported by State, Hatch, and other funds allocated to the Georgia Agricultural Experiment Stations.* *This is a report on the current status of research involving use of certain chemicals that requires registration under the Federal Insecticide, Fungicide, and Rodenticide Act. It does not contain recommendations for use of such chemicals, nor does it imply that the uses discussed have been registered. All uses of these chemicals must be registered by the appropriate State and Federal agencies before they can be recommended.*

Seeds are commonly found in bermudagrass turf during the winter and early spring throughout the southeastern United States whether the turf is used for lawns, parks, athletic fields, or golf courses. Mild winter temperatures favor rapid growth of these annuals. When bermudagrass goes dormant in the fall after the first killing frost, it offers little competition to germinating winter weeds. A well managed, good quality dormant bermudagrass will offer some competition to the weeds; however, weeds will usually continue to be a major problem in most bermudagrass areas and will detract from the appearance of the area (Fig. 1).

ANNUAL BLUEGRASS (*POA ANNUA* L.) CONTROL:

Several herbicides resulted in excellent postemergence control of annual bluegrass in dormant bermudagrass in Georgia (Table 2). All treatments were applied prior to formation of seed heads. Paraquat and cacodylic acid controlled the weeds within a few days after treatment while pronamide, atrazine, simazine, and glyphosate required several weeks for maximum control. Paraquat and cacodylic acid are absorbed very rapidly by the foliage and resulted in rapid control; glyphosate is absorbed through the forage and translocated throughout the plant; atrazine is absorbed by foliage and roots; and

Figure 1: Winter weeds not controlled detract from the surrounding beauty.

Table 1: Nomenclature of herbicides

Name		
Common	Trade[a]	Company
Atrazine	AAtrex	CIBA-Geigy
Bromoxynil	Nu-Lawn Weeder	Union Carbide
Cacodylic acid	Contax	Chevron
Dicamba	Banvel	Velsicol
Glyphosate	Roundup	Monsanto
Mecoprop+chloroflurenol	Weed-B-Gon for Southern Grasses	Chevron
Metribuzin	Sencor	Mobay
Paraquat	Paraquat	Chevron
Simazine	Princep	CIBA-Geigy
2,4-D	Dacamine	Diamond-Shamrock
2,4-D+dicamba[b]	–	–
2,4-D+mecoprop + dicamba	Trimec	Gordon

[a]Trade and company names are included for the benefit of the reader and do not imply any endorsement or preferential treatments. A given herbicide may have more than one trade name and the one used is from the company furnishing the chemical.

[b]2,4-D and dicamba were applied as a tank mixture.

simazine and pronamide are absorbed only by roots. When chemicals are translocated by the plants, this requires a longer period (4 to 6 weeks) for the chemical to control the weeds.

Annual bluegrass can be effectively controlled in dormant bermudagrass turf with single applications of several postemergence herbicides included in this experiment. For most effective control, treatments should be applied prior to seed head formation in early spring.

BROADLEAF WEED CONTROL

SINGLE VS REPEATED HERBICIDE TREATMENTS:

When herbicides are applied for postemergence control of winter annuals, it is uaually necessary to apply repeated treatments for effective and complete control. For example, the effectiveness of control from a second 2,4-D treatment compared to a single treatment is clearly shown in Fig. 2.

In most instances a higher percentage of winter broadleaf weeds was controlled when 2,4-D was applied in combination with dicamba or mecoprop + dicamba than from 2,4-D alone (Table 3). Two applications of 2,4-D applied alone at 2-week intervals controlled 98% common chickweed (*Stellaria media* (L.) Cyrillo) and 70% of corn speedwell (*Veronica arvensis* L.) but did not control parsley-piert ((*Alchemilla microcorpa* Boissier Reuter) or henbit (*Lamium amplexicaule* L.). When dicamba or mecoprop + dicamba were applied with 2,4-D, the number of additional weed species was increased to include parsley-piert and henbit. With exception of common chickweed, it was necessary to apply a second application of the combination treatments to obtain at least 90% control of all of these weeds. The combination treatments also controlled spur weed (*Soliva* sp.) effectively. Dicamba at 1.0 lb/A applied alone, generally resulted in similar weed control as when the chemical was applied in combination with 2,4-D or 2,4-D + mecoprop at lower rates.

Bromoxynil applied at 0.5 lb/A controlled parsley-piert with a single application, but two treatments were needed for control of henbit and spur weed (Table 3). It was necessary to increase bromoxynil rate to 1.0 lb/A in each of two applications to obtain effective corn speedwell control. Common chickweed was not controlled with the chemical regardless of rate and number of applications.

Combinations of mecoprop + chloroflurenol applied in two applications at 0.75 + 0.25 lb/A controlled 78% parsley-piert, 83% corn speedwell, and 100% of common chickweed and henbit (Table 3). The control of parsley-piert and corn speedwell was improved slightly with two applications applied at a higher rate (1.5 + 0.5 lb/A.

Postemergence treatments of either glyphosate or paraquat controlled all weeds in our studies (Table 3). However, it was necessary to repeat paraquat and glyphosate (0.25 lb/A) treatment for effective parsley-piert and

Table 2. Postemergence herbicide treatments for annual bluegrass control in dormant bermudagrass turf.

Treatments[a]		Annual bluegrass control
Herbicide	Rate lb/A	%[b]
Pronamide	0.75	98
	1.5	100
Atrazine	1.0	82
	2.0	94
Simazine	1.0	80
	2.0	96
Paraquat	0.5	100
Cacodylic acid	8.0	88
	11.0	92
	14.0	93
Glyphosate	0.25	92
	0.5	100

[a]Treatments were applied as single applications in January. A surfactant was applied with paraquat and cacodylic acid.

[b]Control ratings were made 6 to 8 weeks after treatment and based on 0 = no control and 100 = complete control.

Figure 2: Comparison of corn speedwell and common chickweed control with 1 and 2 applications of 2,4-D at 1.0 lb/A. Upper: Plot on left treated once compared with untreated plot on right. Lower: Plot on left treated twice compared with untreated plot on right. Treatments were applied February 26 and March 12, 1973. Pictures were made March 26, 1973.

henbit control. Either herbicide will control a broad spectrum of weeds in bermudagrass turf as shown by glyphosate treatment in Fig. 3. When these chemicals are used for postemergence weed control, the turfgrass must be completely dormant to prevent injury to the turf.

These results show that in most instances it is necessary to follow the initial 2,4-D type herbicide treatment with a second treatment at 2-week interval for optimum control of winter weeds. Atrazine, simazine, paraquat, and metribuzin generally controlled a higher percentage of more weed species than did the 2,4-D related chemicals.

COMBINATION OF PARAQUAT WITH OTHER HERBICIDES:

In most instances there is little advantage in applying combinations of paraquat with other chemicals as a single treatment for weed control (Table 4). An exception occurred for spur weed since paraquat applied with any herbicide controlled a higher percentage of the weeds than did single treatments of either chemical applied alone. However, a second application of paraquat applied alone at 2-week intervals controlled spur weed completely (Table 3). Therefore a choice could be made between the use of a combination of chemicals applied in a single application, and the use of paraquat applied alone in two applications.

Table 3. **Postemergence herbicide treatments for winter weed control in dormant bermudagrass turf.**

Treatments[a]			Weed species				
Herbicide	Rate	Appli-cation	Parsley-piert	Common chickweed	Corn speedwell	Henbit	Spur weed
	1b/A	No.	-- -- -- -- --	% control[b]	-- -- -- -		
2-4-D	1.0	1	34	43	30	43	-
		2	56	98	70	40	-
	2.0	1	45	98	83	65	-
		2	81	100	97	82	-
Dicamba	1.0	1	58	93	55	97	81
		2	79	100	78	100	-
	2.0	1	62	98	71	97	-
		2	91	100	90	100	-
2,4-D + dicamba	1.0+0.5	1	81	100	30	75	89
		2	76	100	70	98	98
2,4-D + mecoprop + dicamba	1.0+0.5+0.1	1	46	95	49	63	88
		2	76	100	74	93	100
Paraquat	0.5	1	61	100	90	57	91
		2	98	100	99	99	100
Bromoxynil	0.5	1	88	10	14	28	23
		2	100	31	47	81	85
	1.0	1	84	8	58	50	46
		2	100	66	99	100	99
Mecoprop + chloroflurenol	0.75+0.25	1	39	95	66	83	-
		2	78	100	83	100	-
	1.5+0.5	1	52	99	80	91	
		2	82	100	90	100	-
Metribuzin	0.5	1	99	100	99	100	91
		2	100	100	100	100	100
Glyphosate	0.25	1	71	100	96	77	90
		2	95	100	99	94	99
	0.5	1	81	100	99	89	91
		2	96	100	99	99	99
Atrazine	1.0	1	-	-	100	-	55
		2	100	100	100	100	98
Simazine	1.0	1	100	-	100	-	65
		2	-	100	100	100	86

[a] *First treatments were applied from January 31 to February 26 and second treatments were made at 2-week intervals.*

[b] *Weed control ratings approximately 6 weeks after treatment and based on 0 = no control and 100 = complete control. A surfactant was applied with all herbicides except metribuzin, glyphosate, atrazine, and simazine.*

Figure 3: Glyphosate controlled all winter annuals in dormant bermudagrass turf in the right plot when compared with untreated plot on the left.

These results show that paraquat alone controlled annual bluegrass and corn speedwell as well as did combination treatments of paraquat with other herbicides. Even though paraqua applied alone controlled 82% of spur weed, the control was improved from combinations of paraquat and broadleaf type herbicides. Therefore, the determining factor in using combination treatments would depend on weed species and amount of weed control desired in a given lawn.

FREQUENCY AND RATES OF HERBICIDE TREATMENTS:

Since repeated applications of 2,4-D + mecoprop + dicamba are usually necessary for acceptable control of many broadleaf winter weeds in turfgrasses, additional information was needed on rates and frequency of treatment needed to obtain the highest consistent control. The control of parsley-piert was not acceptable with 2,4-D + mecoprop + dicamba at rates of 3/4X or less in single or repeated treatments (Table 5). The amount of 2,4-D + mecoprop + dicamba for 1X rate equals 1.0 + 0.1 lb/A and other rates are in proportion. The 1X rate applied as single treatment controlled only 73% of the weeds while two applications at 1/2X controlled 89% of the weeds. The control was further improved (97%) with three applications at 1/2X rates. For the chemical to be effective for corn speedwell control, the rates of application must be 1 1/2X in partial repeated treatments or higher. When two applications were used, it was necessary to apply at least 1X rate at the first application in order to obtain satisfactory control. When three applications were used, the first treatment could be as low as 1/2X rate and still obtain acceptable corn speedwell control.

Postemergence Control

Single application of 2,4-D + mecoprop + dicamba at 2/3X was the only treatment evaluated in this study that did not satisfactorily control spur weed (Table 5). However, the control was good (88%) when the same amount of chemical was applied in a split application of 1/3X rate in each of two treatments. Single full rates higher than 2/3X and all partial repeated treatments resulted in good to excellent spur weed control.

These results show that the rate of 3,4-D + mecoprop + dicamba applications should be determined by the weed species present. When spur weed and parsley-piert are present, two applications of 1/2X rate per treatment can be effective. However, when corn speedwell is present the rates must be increased and included two applications of 1 + 1/2X rates or three applications of 1/2X for each treatment are necessary for acceptable control.

Figure 4: Turf in the right plot treated with herbicides for winter weed control resulted in excellent turf in early spring when compared with poor turf in left untreated plot. Picture was made May 16, 1972.

Table 4. Combination of paraquat with other herbicides for winter weed control in dormant bermudagrass turf.

Treatments[a]			Weed control[c]			
Herbicide	Rate	Paraquat[b]	Annual bluegrass	Spur weed	Corn speedwell	Parsley piert
			- - - - - - - - - % - - - - - - - - - - -			
Paraquat	0.5	-	100	82	98	88
2,4-D + mecoprop + dicamba	1.0+0.5+0.1	No	7	78	52	76
		Yes	100	94	99	89
2,4-D+dicamba	0.75+0.25	No	5	79	29	84
		Yes	100	91	99	86
Dicamba	1.0	No	5	80	41	81
		Yes	100	95	100	96
Bromoxynil	0.5	No	0	36	59	78
		Yes	100	97	99	97

[a] *Treatments were applied as single application in February. A surfactant was applied with all herbicides.*

[b] *Paraquat was applied at 0.5 lb/A with combination treatments.*

[c] *Ratings were made 4 to 6 weeks after treatment and based on 0 = no control and 100 = complete control.*

ADVANTAGE OF HERBICIDE USAGE:

Herbicides applied as postemergence treatments for control of winter annual weeds generally did not delay turf green-up or affect growth in the spring when the chemicals were applied to dormant bermudagrass. The primary usage of herbicides is for weed control. If the weeds are not controlled, they will compete with bermudagrass the following spring and contribute to a low quality turf having poor spring growth. Bermudagrass cannot initiate good spring growth until hot weather kills the existing winter weeds. When

Table 5. Rates and frequency of 2,4-D 3 mecoprop + dicamba treatments on winter weeds in dormant bermudagrass turf.

Treatment[a]		Weed control[b]		
Total	Frequency	Spur weed	Corn speedwell	Parsley-piert
		%		
2/3	2/3	79	14	60
	1/3 + 1/3	88	23	62
3/4	3/4	85	8	61
	1/2 + 1/4	86	27	63
1	1	92	38	73
	1/2 + 1/2	93	48	89
	1/3 + 1/3 + 1/3	90	39	89
	2/3 + 1/3	98	58	89
	3/4 + 1/4	96	54	88
	1/2 + 1/4 + 1/4	99	45	86
1 1/4	1 1/4	97	49	84
	3/4 + 1/2	98	77	90
1 1/2	1 1/2	96	65	85
	1 + 1/2	99	81	93
	3/4 + 3/4	99	70	91
	1/2 + 1/2 + 1/2	99	87	97
	3/4 + 1/2 + 1/4	100	95	97
1 3/4	1 + 3/4	99	90	89
	3/4 + 1/2 + 1/2	99	95	98
2	1 + 1	99	89	96

[a] *Treatments were applied in February or March and repeated applications were made at 7 to 9-day intervals. The amount of 2,4-D + mecoprop + dicamba for 1X rate equals 1.0 + 0.5 + 0.1 lb/A and other rates are in proportion. A surfactant was applied with all treatments.;*

[b] *Control ratings were made 6 weeks after the first treatment and based on 0 = no control and 100 = complete control.*

the weeds die, the turf requires time before it can produce enough growth to fill in vacancies left by the dead weeds. Herbicides will eliminate competition from winter weeds and will promote a good quality turf immediately after green-up in early spring. The difference in quality of bermudagrass turf between treated and untreated turf is shown in Fig. 4.

When herbicides are used in turfgrasses for weed control, care should be taken to determine that the spray equipment is correctly calibrated. Additional care should be taken during chemical applications to prevent nozzle stoppage or failure to lap the chemicals during application. When either occurs, strips of untreated turf will remain weedy and results in an overall poor quality turf.

Table 6. Summary of postemergence herbicide treatments on control of winter annuals.

Herbicides	Winter weeds					
	Henbit	Common chickweed	Spur weed	Parsley-piert	Corn speedwell	Annual bluegrass
	weed control[b]					
Atrazine	E	E	E	E	E*	G*
Glyphosate[a]	E	E*	E*	E	E*	E*
Metribuzin	E*	E*	E*	E*	E*	E*
Paraquat[a]	E	E*	E*	E	E*	E*
2,4-D	P	E	–	P	F	P
2,4-D+dicamba	E	E*	E	E	F	P
2,4-D+mecoprop + dicamba	E	E*	E	F	F	P
Simazine	E	E	G	E*	E*	G*
Bromoxynil	G	P	G	E	P	P
Mecoprop + chloroflurenol	E	E*	–	F	G	P
Dicamba	E*	E*	G*	F	F	P

[a] *Turfgrass must be completely dormant when glyphosate and paraquat are used.*

[b] *Weed control ratings were based on E = 90 to 100, G = 80 to 89, F = 70 to 79, and P = below 70. Asterisk indicates the control was obtained with a single application and no asterisk indicates the control was obtained with two applications.*

Postemergence Control

SUMMARY

In conclusion, these results show that several herbicides applied as postemergence treatments for winter weed control in dormant bermudagrass turf will effectively control the weeds without injuring the turf during the following spring. In general, a higher percentage of more weed species was controlled from combination of 2,4-D with dicamba or mecoprop and dicamba than with 2,4-D alone (Table 6). The 2,4-D treatments resulted in excellent common chickweed control and fair corn speedwell control, while combination treatments controlled at least 70% of all broadleaf weeds. Excellent control was obtained for all weeds when treated with glyphosate, metribuzin, or paraquat. Atrazine resulted in excellent control of all broadleaf weeds and good control of annual bluegrass. Simazine gave good control of spur weed and annual bluegrass and excellent control of all other weeds. With the proper selection of herbicides and frequency of treatments, winter weeds can be effectively controlled in dormant bermudagrass turf.

xxx

Letter to the Editor

Dear Mr. Brown,

I am writing to you in response to your September/October (1981) "little bugger" article. I feel Hydro Lawn uses as good a system as any lawn care company to determine turfgrass problems, especially diseases.

When a technician or customer service manager finds an intriguing or puzzling lawn problem, a sample is taken, placed in a plastic bag and sent to our small laboratory. Our lab is equipped with such instruments as a binocular microscope, a compound microscope, pH meters and all the necessary hardware to diagnose turfgrass problems. By making a small annual donation to the University of Maryland Plant Diagnostic Clinic, we obtain plates of potato dextrose agar (PDA) on a regular basis. This enables us to plate out and determine most common turf diseases within a couple of days.

You do not need to have a PhD in turf pathology to observe mycelium and spores under a microscope and check available reference material to determine what disease, if any, is causing a decline in turf quality. By organizing a quick delivery system, we are able to determine if a pathogenic fungus is present, call the branch and treat the lawn with a fungicide within a few days. By correctly diagnosing *Nigrospora* vs. *Fusarium*, for example, the proper fungicide and rates can be applied, decreasing the chance of losing a customer.

The establishment of a small laboratory is relatively inexpensive, especially when considering customer satisfaction and retention.

Gregory Richards
Research Agronomist, Hydro Lawn

IBDU® Fertilzer Used to Revegetate Mt. St. Helens

In an effort to control rampant erosion in the area around Mount Saint Helens, the Washington State Soil Conservation Service has applied a unique kind of fertilizer in an attempt to revegetate the region.

Recently, 70 tons of IBDU was applied to 1,000 acres which is being seeded with grass. IBDU is a special slow-release nitrogen fertilizer that does not depend on soil bacteria to work. Efforts to revegetate the area with conventional fertilizers have been unsuccessful. According to SCS sources, there apparently is not sufficient bacteria in the volcanic debris to activate conventional fertilizers.

For the past 16 months, the SCS has been involved with revegetation attempts to control erosion on the 200,000 acres in the erosion zone caused by the blast. The SCS estimates 380 tons of soil per acre per year will be lost to erosion on the land compared to the national average of 4.2 tons of soil erosion on disturbed forest land.

IBDU depends almost entirely upon water (hydrolysis) for its release into the soil. It is not affected by variations in temperature or soil bacterial activity. The product is marketed by PAR EX Professional Products Division of Estech, Inc. IBDU is widely used for turfgrass and horticultural operations.

The SCS expects IBDU to remain in the soil for six months after the initial application, which should allow the vegetation to develop sufficient root systems to control erosion. Soil tests will be taken periodically to determine the effectiveness of the application. For further information contact Erv Stacy, Estech, Inc., P.O. Box 1996, Winter Haven, FL 33880, or use reply card.

Circle No. 8 on Reader Reply Card

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How Turfgrasses Tolerate Freezing

by Richard J. Hull, University of Rhode Island

Richard J. Hull is a Professor of Plant and Soil Science at the University of Rhode Island. He received his B.S. and M.S. degrees from the University of Rhode Island in agriculture and agronomy respectively and his PhD. in botany from the University of California at Davis. For five years, Dr. Hull studied the physiology of perennial weeds at Purdue University in Indiana. At Rhode Island, his research has concentrated on the nutrition of turfgrass, woody ornamentals, and tidal salt marsh vegetation.

Throughout most of the United States, lawn grasses must tolerate subfreezing temperatures during the winter season. This environmental stress cannot be prevented through the lawn management practices. Only the grass can adjust its cellular properties to withstand freezing and not suffer inrreparable injury. By understanding the causes of frost damage and the mechanisms by which plants cope with it, the turf manager may be able to adjust cultural practices and maximize grass resistance to freezing injury. This article is an attempt to provide that understanding bases on recent studies of frost tolerance physiology.

It is necessary to understand the freezing process in order to appreciate how plants resist injury under subfreezing conditions. As the temperature falls to the freezing point of pure water and then below, the cell sap remains unfrozen due to its relatively high solute concentration. As -2 or -3^{o}C, ice crystals form within the cell walls separating the individual cells. These crystals grow rapidly and in so doing reduce the free water content outside the cells. If the plasma membrane surrounding the cell protoplasts is sufficiently permeable to water, an efflux of water from the cell will occur and ice crystals will continue to grow outside the cells. If the temperature drops too rapidly or the plant is not adequately hardened, ice may form within the cell and invariably cause cellular death. As the temperature declines further, extracellular ice continues to form as water leaves the cells. This water loss from the cells cause the protoplast to shrink or become plasmolyzed. When this happens, the plasma membrane pulls away from the ridged cell walls leaving a space which is rapidly filled by growing ice crystals. Thus as the temperature falls, the plant cells become dehydrated as water leaves the protoplasts and freezes in the spaces between cells.

Intracelluler ice formation which is almost always lethal...

This frost dehydration causes materials dissolved in the cell sap to become more concentrated as the solvent water leaves the cell. Some of these materials may precipitate out of solution or interact with intracellular membrane structures and thereby cause injury which might result in cell death. There is little agreement as to which if any of these dehydration effects contributes to frost injury. Many researchers believe that, beside intracellular ice formation which is almost always lethal, freezing injury involves irreversiable damage to the contracting plasma membrane (Rajashekar, Gusta, and Burke, 1979).

One explanation for freezing damage is provided by the work of Cornell University's Peter Steponkus (1979) who made direct microscopic observations of the freeze-thaw cycle in isolated rye and spinach protoplasts. He observed that after freezing and contraction of the plasma membrane around the plasmoyzed protoplasts, the plasma membrane would rupture during thawing before the cells had regained their prefreezing size (Fig. 1). This loss of membrane resiliency during freezing could result from an infolding of the plasma membrane during plasmoysis followed by a pinching off and reabsorption of the membrane folds as the membrane adjusted to the smaller protoplast size. During thawing, water reentered the protoplast and expansion of the membrane occurred but because there was less plasma membrane than there was before freezing, the cell burst before it reached its original size. Cells of frozen leaves or roots could rupture when thawed before they had refilled the volume enclosed by the cell walls.

This idea of irreversible plasma membrane damage during freezing which causes cells to burst when thawed would partially explain the release of hydrogen cyanide from deep frozen *Amelanchier* twigs as reported by Darryl Stout and his coworkers at Kamloops, British Columbia (1981). If the kind of irreversible contraction that Steponkus described for the plasma membrane also occurs during freezing to other cellular membranes such as that surrounding the vacuole, there could occur an uncontrolled mixing of contents from several cell compartments as these membranes pinch off within the protoplasm or rupture during thawing. At Michigan, Olien and Marchetti (1976) observed that toxic substances released from freeze injured barley roots prevented the reestablishment of crown tissues and ultimately caused plant death. Thus a major cause of frost injury to plants appears to involve damage to the plasma membrane or even to membranes inside the cell.

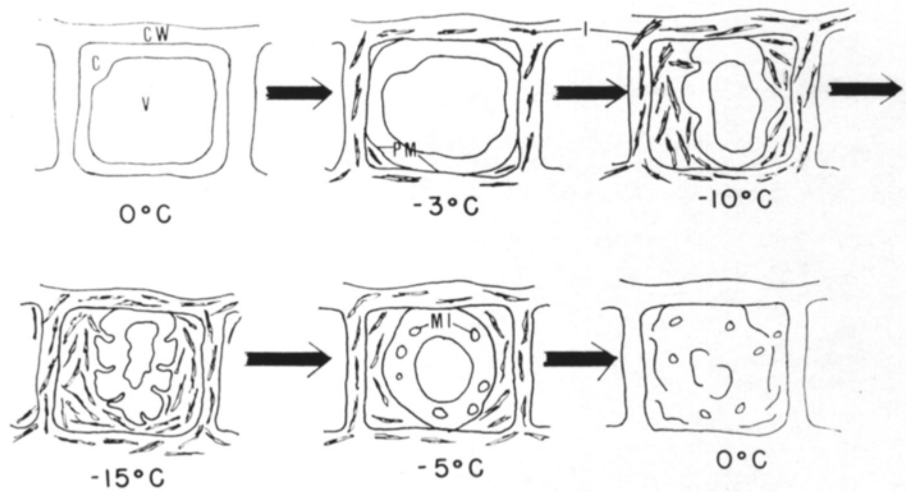

Fig. 1: Cellular changes occurring during a freeze-thaw cycle of a partially hardened plant. CW = cell wall, V = vacuole, PM = plasma membrane, I = Ice, MI = membrane inclusions derived from contracted plasma membrane and vacuole membrane.

Despite the evidence cited above, plants do become frost hardy and can tolerate extreme cold. Most perennial herbaceous plants, adapted to the temperature zones, can resist freezing if they have first been exposed to hardening conditions. Hardening occurs under cold but not freezing temperatures, short days, and light. The short days often induce hormonal changes which cause growth to slow or dormancy to occur. Light allows photosynthesis to continue which provides an energy supply and low temperatures reduce respiration and permit the accumulation of carbohydrates within plant cells. A supply of photosynthetic products, usually short chain carbohydrates, appears to be critical for hardening. There is much evidence that when herbaceous plants become acclimated to freezing temperatures, the soluble carbohydrate content increases. This was apparent from studies in Virginia (Powell et al. 1967) where Cohansey creeping bentgrass and Kentucky 31 tall fescue turf exhibited greater carbohydrate levels in leaf and stem tissues during January when the grass was cold hardy than during May when the grass was growing rapidly (Table 1). The generally lower carbohydrate content in October compared to January suggests that as grass becomes frost tolerant the soluble carbohydrates increase. While the correlation between cold acclimation and carbohydrate content does not prove a cause and effect relationship, there are good theoretical reasons to believe that two factors are related.

The exact mechanism of cold hardiness is not understood but from the discussion presented earlier it follows that any condition which would

TABLE 1. Nonstructural carbohydrate content of turfgrass plants during fall, winter, and spring.*

Turf Species	Fertilizer Rate	Plant Part	Date Samples: 15 Oct.	15 Jan.	15 May
	lbs. N/1000 sq. ft.		% carbohydrate		
Creeping bentgrass 'Cohansey'	1	leaves	18	30	9
		stems	25	39	13
	10	leaves	17	29	7
		stems	25	33	10
Tall fescue 'Kentucky 31'	1	leaves	15	27	18
		stems	44	39	22
	10	leaves	15	20	15
		stems	44	27	18

***Adapted from Powell et al. 1967. Agron. J. 59:303-307.**

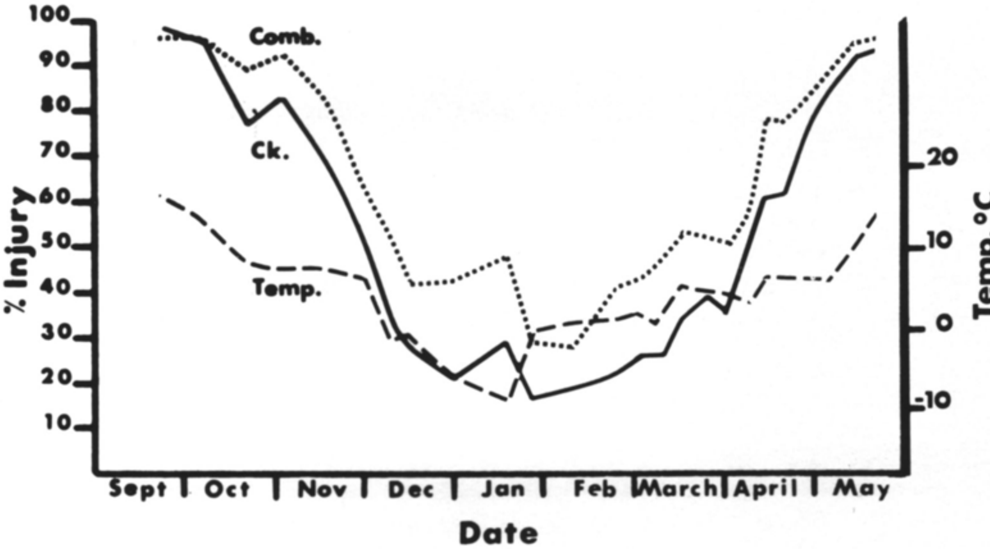

Fig. 2: Seasonal changes in Kentucky bluegrass cold hardiness based on electrolyte loss from tissue frozen at -7°C for 4 hours. 1 Oct. and 15 Dec. CK = no N applied during fall-winter season. From Wilkinson and Duff. 1972. Agron. J. 64:345-348.

reduce cellular dehydration while preventing ice formation within the cells should make the plant more cold tolerant. High levels of soluble carbohydrates in the vacuoles and cytoplasm of plant cells will depress the freezing point and allow time for water to leave the cells and form ice in extracellular spaces. Because sugars have many OH groups, they readily form weak hydrogen bonds with membranes and soluble proteins as well as cellular water. In this way they 'stabilize' the cytoplasm and resist excessive water loss while protecting membranes from deformation and damaging contraction. Obviously other photosynthetic products can function in much the same way. In some plants amino acids, organic acids, or sugar alcohols can accumulate during cold hardening. All of these materials will have a protective effect on plant cells during periods of extreme cold and tissue freezing.

Does this understanding of cold tolerance mechanisms help the lawn care professional serve his clients better? The answer to this question depends on how much the home owner is willing to be educated concerning lawn care. Any management practice, which will promote photosynthesis during the hardening and winter period and allow carbohydrates to accumulate within the plant, should increase cold tolerance. Such practices as retaining at least one inch grass blades during the last autumn mowing will insure an adequate photosynthetic surface during the cold season. Removing tree leaves or dead grass will also insure light penetration to the green leaves. Fall applications of nitrogen fertilizer might be expected to reduce carbohydrate levels because of growth stimulation. However, during mid-October when hardening should be commencing, Larry Smith and I noted that both simple sugars

TABLE 2. Soluble carbohydrate content of 'Merion' Kentucky bluegrass turf during spring, summer, and fall.*

Fertilizer Rate**	Plant part	Simple Sugars 25 May	26 July	17 Oct.	Fructosans 25 May	26 July	17 Oct.
		mg/g dry wt.					
2.5-1-1	leaves	100	82	120	43	85	112
	crowns	68	66	60	120	214	157
10-4-4	leaves	78	100	143	6	14	34
	crowns	47	90	69	26	92	129

* From Smith and Hull unpublished.
** Fertilizer rates: lbs. N-P_2O_5O per 1000 sq. ft.

Fig. 3: Merion Kentucky bluegrass plots fertilized (left to right with 2.5, 5 and 10 lbs N/1000 sq. ft. Photographed 3 March 1981.

and the larger molecular weight fructosans were present in heavily fertilized Merion Kentucky bluegrass crowns in concentrations only slightly less than that in lower fertility grass (Table 2). This was confirmed by studies of Wilkinson and Duff (1972) at Rhode Island who found that Kentucky bluegrass turf receiving 2 or 6 lbs. of N per 1,000 sq. ft. in the fall became almost equally cold resistant by January when the grass was most frost tolerant (Fig. 2). The 6 pound nitrogen rate applied in increments between October 1 and December 15 decreased cold hardiness somewhat but only leaf injury was noted under field conditions. It appears that the improved grass nutrition obtained by fall fertilization prolongs the functional life of leaves and the resulting increased photosynthesis maintains adequate carbohydrate levels to insure cold tolerance.

This can be observed in the field. Turf fertilized with 5 or 10 pounds of N per 1000 sq. ft. (Fig. 3 plots center and right) was much greener during the winter than turf which had received only 2.5 pounds of N (Fig. 3 plot left). A detailed view of the 10 pound N turf (Fig. 4) showed much green leaf tissue which was capable of photosynthesis during nonfreezing conditions and could maintain high carbohydrate levels in leaves and stems. As a result the grass was tolerant of subfreezing temperatures even though it remained green. The 2.5 pound N turf (Fig. 5) contained little exposed green tissue indicating less frost hardy leaves. Even this grass had substantial green tissue deeper in the leaf canopy and was photosynthetically active which probably contributed to its winter survival. The retention of green color throughout the winter is a desirable feature of fall fertilized turf.

Some previsions to reduce freezing injury can be taken when a lawn is established. Selecting a grass possessing superior cold tolerance characteristics will off-set future problems in cold regions. James Beard (1966) evaluated nineteen turfgrasses for low temperature injury in central Michigan. He found that creeping bentgrasses and roughstalk bluegrass were most cold tolerant. Colonial bentgrass cv. Astoria, Kentucky bluegrasses, and redtop possessed intermediate cold resistance, while red fescue cv. Pennlawn, tall fescues, and annual bluegrass were only somewhat cold tolerant. Least cold hardy were perennial and annual ryegrasses. While individual cultivars of turfgrass species probabily will differ in cold tolerance, it appears that grass mixtures composed of red fescues or perennial ryegrasses should be avoided if freezing injury is likely to be a problem.

Fig. 4: Merion Kentucky bluegrass in mid-February after receiving 10 lbs. N/1000 sq. ft. during the previous season.

Grading a lawn to provide good water drainage will also help avoid cold injury problems. Beard (1964) observed that freezing grass in ice was more damaging than when frozen in the absence of free water. During a freeze-thaw cycle, soaked grass experiences more ice crystal formation in the tissues and greater injury. Again creeping bentgrass was most tolerant of freezing in water but annual bluegrass and Kentucky bluegrass were killed during 15 and 45 days of freezing respectively.

Managing turf to avoid thatch accumulation will also improve grass resistance to cold. Grass plants with much of their root system growing in thatch are more vulnerable to winter desiccation when the thatch becomes dry or freezes. Under wet conditions, a thatch layer will become water soaked and subject the grass plants to excessive hydration which will aggravate freezing injury when frost returns.

Thus, while little can be done to avoid freezing conditions, the lawn care professional, with the cooperation of his clients, can improve the chances of grass survival through appropriate turf

Fig. 5: Merion Kentucky bluegrass in mid-February after receiving 2.5 lbs. N/1000 sq. ft. during the previous season.

management strategies. Understanding the basic mechanisms of freezing injury and how plants resist it, can help the turf manager design a lawn care program which will favor the grasses' survival.

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Bulkkem Corporation was recently formed with the sole purpose of distributing chemicals in bulk form to lawn care companies. Products such as Trimec, Betasan, 2,4-D and MCPP will be available in containers ranging in size from returnable 55 gallon drums to 250 gallon shippers. Companies needing larger quantities, can have a tank truck delivery system which will fill tanks at their locations.

Storage of chemicals and disposal of the containers are two of the largest problems facing the lawn care professional. The bulk system eliminates both of these problems efficiently and economically. Bulkkem's Will West puts it this way; "All a company has to do is let us know how much they need and when they want it. Our truck will fill their tanks at their locations and they won't have to dispose of a single container."

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Terminals for Bulkkem will be located in Cleveland, Ohio; Normal, Illinois; and Philadelphia, Pennsylvania. John Latting, company president, put it this way, "We've spent two years working out the logistics for bulk delivery. During this season we test marketed our on site delivery system in the Illinois market and shipped our 250 gallon shippers as far away as Omaha. We are now ready to ship any place in the U.S."

With increasing EPA regulations concerning container disposal and the cost efficiency of bulk delivery, the "bulk concept" could very well be the way of the future. For more information concerning bulk chemical delivery in your area, contact John Latting, Bulkkem Corporation, 400 Northtown, Normal IL 61761, or use reader reply card.

Circle No. 12 on Reader Reply Card

PLCAA Offers Casualty Insurance Program to Membership

At their September 17, 1981 meeting, the Board of Directors gave final approval for the implementation of a Casualty Insurance Program for members of the PLCAA.

It is expected that the average member will be able to save between 10% to 30% compared to his present coverage, with the possibility of a dividend of up to 25% if the Program's loss experience is favorable.

In addition, the new Program will enable the Lawn Care Industry to develop a credible data base of premium and loss information, which will be of vital assistance in helping the industry to gain more favorable treatment from Underwriters. With no such information currently available on an industry-wide basis it is difficult to prove the widely held belief that the Lawn Care Industry is being overcharged for its Casualty Insurance Coverage.

The Program will be administered for the PLCAA by Marsh & McLennan, Inc. Members may apply either directly or through their present insurance broker.

Applications and brochures are currently being printed. However, inquiries about the Program can be directed to Steven W. Wilcox, Vice President at Marsh & McLennan, Inc., 222 S. Riverside Plaza, Chicago, IL 60606.

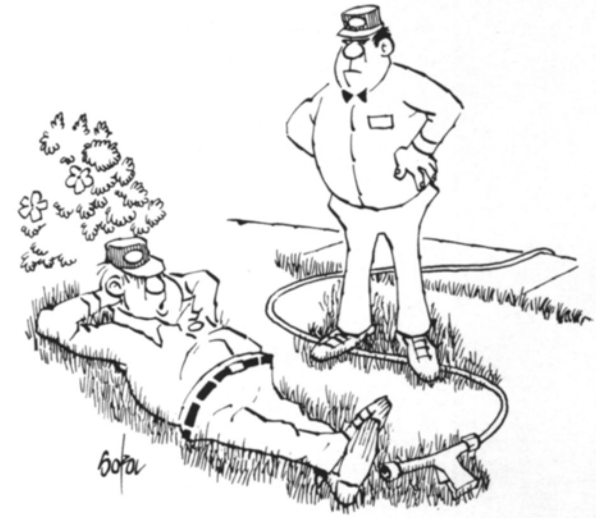
Attention!

January— "Training Effective Management"
January 25 & 26, Oakland County Government Complex. Pontiac, Michigan.

February— "Soil & Fertilizing Workshop"
Dr. Paul Rieke, MSU.
February 8-9 & 15-16, Oakland County Government Complex. Pontiac, Michigan.

March— "Ornamental Disease Seminar"
Dr. Powell, Ohio State. Oakland County Government Complex. Pontiac, Michigan.

For more information on any of the above, contact Greg Patchen. (313) 858-0884.



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