16TH ILLINOIS TURFGRASS CONFERENCE

DECEMBER 10-12, 1975

Arranged and conducted by

COOPERATIVE EXTENSION SERVICE
COLLEGE OF AGRICULTURE
UNIVERSITY OF ILLINOIS
AT URBANA-CHAMPAIGN

In cooperation with

ILLINOIS TURFGRASS FOUNDATION

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SPECIAL SYMPOSIUM ON *FUSARIUM* BLIGHT

Prior to the introduction of Merion bluegrass, those who were involved in growing and maintaining Kentucky bluegrass had as an adversary the fungus *Helminthosporium*, which causes leaf spot and melting out. Merion's good resistance to this pathogen shifted our concern to other diseases such as rust, smut, and *Fusarium*.

We have learned to live with rust through some genetic improvement and culture practices, and genetic resistance has relegated the smuts to a minor problem, but *Fusarium* blight seems to be increasing in severity.

In discussion of a planned graduate study of *Fusarium*, the suggestion was made that a gathering such as this panel might be valuable in reviewing what is known and unknown about this disease and could be a guide for future investigation.

This group with us today represents many hours of study and thought devoted to this phenomenon. We are indeed fortunate to have them with us.--*Moderator: Ben Warren, President, Warren's Turf Nursery, Palos Park, Illinois.*

FUSARIUM BLIGHT OF TURFGRASSES—AN OVERVIEW

Houston B. Couch

In 1959 a severe foliar blighting was observed on Merion Kentucky bluegrass in southeastern Pennsylvania. The symptom pattern did not fit that of any of the known foliar diseases of turfgrasses, and isolations from diseased leaves only yielded pathogenic organisms that were known to incite symptoms distinct from those observed for the disease in question.

During 1960 and 1961 this same disease was found on Merion Kentucky bluegrass, bentgrasses, and creeping red fescues in eastern Pennsylvania, eastern Ohio, eastern New York, New Jersey, Delaware, Maryland, and the District of Columbia. Beginning in 1960 and continuing through the following three growing seasons, plant and soil samples were collected from the geographic areas that showed the characteristic symptoms of the disease. Isolations from the diseased leaves were attempted in order to determine if pathogenic fungi were present. The soil samples were also checked for the presence of parasitic nematodes.

Certain of the soil samples were found to contain parasitic nematodes of the genera *Hoploaimus*, *Xiphinema*, *Paratylenchus*, and *Tylenchorhynchus*. In some samples the populations were high enough to produce foliar stress. However, there was no consistency among the samples--neither in the frequency of occurrence of a given genus nor in populations high enough to cause foliar symptoms. Furthermore, many soil samples obtained from turfgrass that showed symptoms of the disease were free from parasitic nematodes. On the basis of this evidence, it was concluded that the disease was not caused by nematodes.

The isolations from diseased leaves consistently yielded two fungus species--*Fusarium roseum* and *Fusarium tricinctum* f. sp. *poae*. Both of these organisms were known to be turfgrass pathogens, but neither had been identified as foliar parasites. *Fusarium roseum* was known to cause a root and crown rot of turfgrasses, while *tricinctum* had been recognized for several years as the cause of "silver top," a disease of turfgrass floral tissue.

Pathogenicity tests with isolates of these two fungus species were made on Merion Kentucky bluegrass, Highland bentgrass, and Pennlawn creeping red fescue. While some of the isolates were weakly pathogenic, a very high percentage of those tested incited 100 percent foliar blighting within two to five days from the time of inoculation.

On the basis of (a) consistency of isolation from diseased turfgrass plants over a broad geographic area for several growing seasons, (b) the general lack of consistency of isolation of other microorganisms, and (c) the high degree of pathogenicity of *Fusarium roseum* and *Fusarium tricinctum*, we concluded that these two

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organisms were the actual incitants of the disease. With further research it was learned that the total syndrome of the disease consisted of two phases--a blighting of the leaves, and a crown and root rot. Because of the predominant leaf-symptom pattern, we named the disease "*Fusarium* blight."

SYMPTOMS

Leaf Blighting Stage

In overall view, affected turfgrass stands first show scattered, light-green patches 2 to 6 inches in diameter. Under environmental conditions favorable for disease development, the color of these patches changes in 36 to 48 hours to a dull reddish brown, then to tan, and finally to a light straw color. Initially, the shapes of the patches are elongated streaks, crescents, or circular patches.

The most characteristic feature of the gross symptomatology is seen in the later stages of disease development, when more or less circular patches of blighted turfgrass 1 to 3 feet in diameter are present. Light tan to straw colored, these patches often have reddish-brown margins 1 to 2 inches wide and contain center tufts of green, apparently unaffected, grass. This combination produces a distinctive "frog-eye" effect. When optimum conditions for disease development exist for an extended period of time, these affected areas coalesce. As a result, large areas of turfgrass may be blighted. Leaf lesions originate both at the cut tip and at random over the entire leaf. At first, lesions appear as irregularly shaped, dark-green blotches. These rapidly fade to a light green, then assume a reddish-brown hue, and finally become a dull tan. Individual lesions may involve the entire width of the leaf blade and may extend up to 1/2 inch long.

Root Rot Stage

Turfgrass plants affected primarily by the root rot phase of the disease are stunted, pale green in color, and do not readily recover from mowing or adverse weather conditions. Their roots are characterized by a brown to reddish-brown dry rot. As the disease progresses, these roots become darker in color due to the colonization of soil saprophytes. During periods of relatively high soil moisture, the pinkish growth of *Fusarium roseum* and *F. tricinctum* can be seen on the root and crown tissue near the soil surface.

DISEASE CYCLE

Sources of Inoculum

Both species of *Fusaria* have been reported to be transmitted on turfgrass seed. Also, they are known to be capable of surviving in the soil as saprophytes. These two sources constitute the main reservoirs of primary inoculum for the development of the disease in newly seeded stands of turfgrass. In established turfgrass, the main sources of inoculum are dormant mycelium in plants infected the previous season and thatch that has been colonized by the pathogens.

How Fusarium Penetrates Leaves

Leaves are infected both by germinating spores and by mycelium from the saprophytic growth of the pathogens on the thatch and other organic matter. Most of the primary infections probably originate from the thatch. Spores germinate 12 hours from the onset of favorable environmental conditions. Penetration of intact leaf surfaces occurs at the junction of epidermal cells. At the points of direct leaf penetration, there is no evidence of degradation of the host cell walls.

The most common area of penetration of foliage by the pathogens appears to be cut ends of the leaves. With both direct penetration and entry through cut leaf tips, the fungus grows between the cells over an area of 12 or more cells and then becomes intracellular. This explains the sudden appearance of large blotches on the leaves, instead of small spots that progressively become larger.

Optimum Conditions for Disease Development

Certain isolates of *F. roseum* and *F. tricinctum* have been shown to vary in their temperature requirements for optimum pathogenicity. As a general rule, however, the foliar stage of *Fusarium* blight is most severe during prolonged periods of high atmospheric humidity with daytime air temperatures of 80° to 95° F. and night air temperatures of 70° F. or above.

Turfgrass grown under deficient calcium nutrition is more susceptible to *Fusarium* blight than well-nourished turfgrass. Incidence and severity of the disease is also greatest under conditions of high nitrogen fertilization. The development of *Fusarium* blight has been reported to be greater in turfgrass when the soil moisture content has been allowed to be extracted to the permanent wilting percentage.

CONTROL OF FUSARIUM BLIGHT

Cultural Practices

While high nitrogen fertilization does increase the susceptibility of turfgrass to *Fusarium* blight, it is unlikely that a significant reduction of the disease can be effected by reducing nitrogen levels. In general, the level of nitrogen fertilization required to significantly reduce the severity of *Fusarium* blight is well outside the range necessary to meet the basic nutritional requirements of the grass.* From a field standpoint, then, nitrogen fertilization, and its effects on the disease, should be considered with respect to thatch management.

Since the thatch serves as the major reservoir of inoculum in established stands of turfgrass, a successful program of *Fusarium* blight control requires that the quantity of this material be held to a minimum consistent with the proper management of the grass species in question. For most turfgrasses, this optimum thickness is approximately 1/2 inch. In order to keep the *Fusarium* blight potential of a stand of turfgrass to a minimum; therefore, increases in the rate of nitrogen fertilization should be balanced with concurrent increases in the intensification of the thatch management program.

Host Resistance

Ranked in order of susceptibility to *Fusarium* blight, the bentgrasses are the most prone to the disease. The Kentucky bluegrasses are next in susceptibility. The fescues are most resistant. Among certain varieties of Kentucky bluegrass, the range of susceptibility to *F. roseum* and *F. tricinctum* is determined by a complex interaction of air temperature and pathogen and host genotypes.

Chemical Control

A preventive fungicide program, coupled with thatch control, is essential for effective control of *Fusarium* blight. The fungicide application should be made immediately after the first occurrence of night temperatures that do not drop below 70° F.

For most effective control of *Fusarium* blight, spray 1,000 square feet with 6 gallons of water containing 5 to 8 ounces of benomyl 50-percent wettable powder.* The total amount of benomyl applied to the turfgrass within one calendar year should not exceed 8 ounces.

FACTORS AFFECTING *FUSARIUM* BLIGHT DEVELOPMENT

Herbert Cole, Jr.

This symposium provides a unique opportunity to explore in depth a disease that remains an enigma to all who work with turf. From the view of the research scientist, it is a frustrating challenge to gain understanding. From the view of the golf superintendent with bluegrass fairways, it has become an impossible monster. The papers in this symposium will, we hope, present the best knowledge currently available about *Fusarium* blight. There will not be agreement among the participants; in fact, agreement will be out of the question. Each view will be based on the geographic region and experience of the researcher.

The following discussion of factors affecting *Fusarium* blight is based on my personal observations in Pennsylvania and the mideastern United States, complemented by a review of the available research literature. I believe that we do not fully understand *Fusarium* blight development even 10 years after the report of its first occurrence and development (Couch and Bedford, 1966). Our lack of understanding includes all aspects of the disease: symptoms, turf age, water, grass nutrition, thatch, varietal susceptibility, and control practices. Some researchers believe the disease differs in symptoms as well as infection cycle in the various geographic areas of its occurrence.

Most, if not all, of the experimental research on the infection cycle of the disease has been done with seedling grass plants in growth chambers of greenhouses. The problem in the field is associated with aging of turf stands (three years and older), yet most of the research has been done with seedlings. Our knowledge with other plant diseases has always indicated that it is questionable to use seedlings to study a disease of mature or aged plants. Because of this, we desperately need new disease-cycle research on mature turf.

We are not certain if the predominant problem is a foliar blight phase or a root and crown rot infection phase. On seedling and mature turfgrass in a dew chamber, foliar lesions develop. However, on the golf course or home lawn during dry weather and moisture stress, turf may wilt and die in a period of days with no clear foliar lesion picture--merely badly rotted crowns and portions of roots. Californians feel strongly that in the West only crown and root rot are involved; in the East the battle rages between the foliar blighters and the nematode-root rot complexers. At this time we just don't have an understanding of the Midwest-Eastern problems. I believe the failure of classic protectant fungicides to provide control suggests a major role for the crown and root rot hypothesis in the East also.

No one has reproduced the frog eye, ring, or serpentine symptom through artificial inoculation, in either the greenhouse or the field. Classic foliar infection epidemiology cannot explain a ring or a frog-eye tuft in the center of a dead area.

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No other foliar-infection fungus disease produces similar symptoms on plants, including the grasses. The ring or frog eye seldom or never occurs in the Far West. To my knowledge, no turf pathologist has attempted to explain why rings or frog eyes may occur.

Most researchers would agree that the major factors influencing disease development include the physical and biological environments, especially cultural practices that affect these environments. The major factors that most of us would agree upon in terms of importance in disease development are grass variety, turf age, temperature, moisture and irrigation, thatch, and nitrogen fertilization. The role of plant parasitic nematodes in predisposing turf to *Fusarium* blight remains highly controversial at this date.

A serious study of the disease should include review of all the papers listed in the references, among others. In particular, the research and review papers of Cook (1968, 1970), who has worked extensively with a *Fusarium* root and crown rot of moisture-stressed winter wheat, may be among the most pertinent in understanding *Fusarium* blight of turfgrass.

Fusarium blight is primarily a disease of bluegrass fairways on golf courses and intensively managed bluegrass home lawns. Although some research would suggest that greenhouse growth chamber studies show bentgrass is most susceptible, the field experience indicates that in practice bentgrass green, tees, or fairways are seldom affected. It would seem this lack of disease is due to the vigorous nature of bentgrass summer growth and stolon production coupled with regular irrigation intervals. In the East we are seeing some problems on fescue and ryegrasses but certainly not any remotely approaching bluegrass disease incidence. Merion is the variety with by far the most problems. The new varieties vary in susceptibility but their ultimate field response is not clear. *Fusarium* is a highly variable fungus genus. Research so far suggests that there will be races and strains of the *Fusarium* organism interacting with different species and strains of grass. A variety may be resistant one place and susceptible in another. In all probability the dense, vigorous, decumbent bluegrasses will have problems with the disease if grown widely.

Temperature plays a major role in disease development. The most severe problems occur on the southern range of bluegrass adaptation, where high midsummer temperatures occur. A hot summer is always worse than a cool summer. In terms of microclimate a southern slope or exposure or warm bank is usually worse than a cool northern slope. Sites with poor air drainage that heat up are usually worse than well-cooled areas. Problems can appear whenever air temperatures reach the high 70's for prolonged periods during the day, such as mid-June through September in much of the Midwest and East. Data are lacking, however, on the critical precise temperature aspects of the problem under field conditions.

Moisture stress must be present for symptom appearance. It is not known whether soil moisture stress or internal plant moisture stress is the most critical factor for disease development and symptom appearance. However, in the field situation both moisture stresses will occur simultaneously. The work of Cook (1968) on *Fusarium* root rot of wheat may explain this aspect of the problem. For example, external moisture stress in the soil and thatch may enhance growth of the *Fusarium* fungus in these areas and suppress bacterial antagonists of the *Fusaria*. Internal moisture stress in the grass plant may enhance explosive colonization of the crown and roots as well as other areas by the *Fusarium* fungus. Much can be learned about the turf *Fusarium* blight problem, I believe, by analysis of the dry land wheat *Fusarium* root rot literature.

At first glance, regular summer irrigation would be the simple answer to this problem. However, most turf managers intentionally drought-stress Kentucky bluegrass turf during the summer to minimize competition from annual bluegrass and creeping bentgrass. Hence, a management practice to suppress one problem may accentuate another.

Thatch accumulation appears necessary for severe disease development, but there is not complete agreement on this issue. Usual thatch measurement procedures and dethatching experiments have not shed much light on the matter. Unfortunately, many unaccounted variables enter into any discussion of thatch. In certain soils grass may be growing roots and all in an accumulation of thatch with little soil penetration; in others, roots may be several inches deep in soil regardless of thatch accumulation. Most experimentation has involved a single season with no control over or observation of other variables beyond thatch *per se*. When extensive multi-year comprehensive experimentation is done, I believe thatch will be demonstrated to play a significant role in disease development, especially from the view of *Fusarium* survival and a food base for crown invasion. The need for thatch may partially explain the failure of artificial inoculation procedures employing spore (conidial) sprays on young, thatch-free turf plots.

Fusarium blight usually does not appear until a turfgrass planting reaches three or more years of age. The preceding thatch discussion may explain this delayed appearance. Another factor may be physiologic maturity changes in the turfgrass plant. It is well documented for many plant species that physiologic chemistry and even anatomical details change with increasing age. In addition, alterations in characteristics of tillers may take place through nutrient depletion or accumulation, crowding, or soil physical changes. Hence, an individual tiller in a turfgrass planting at an age of three years may differ in susceptibility and response from the original seedling plants.

Many field observations and greenhouse experiments suggest that high levels of available soil nitrogen increase disease severity. However, there is not complete agreement on this point, and some greenhouse studies have not demonstrated any nitrogen fertilizer effects. Cook's research (1968) with wheat root rot may shed light on this apparent paradox. In that instance, the nitrogen fertilizer effect induced development of a vigorous plant, which resulted in accentuated water extraction and greatly increased water stress both within the plant and within the soil. The resulting water stress allowed explosive invasion and colonization of the crown and root area of the plant as well as reduction of soil bacterial antagonism against the *Fusarium* fungus. A possible explanation of the confused results regarding nitrogen fertility in bluegrass may be the recycling of nitrogen through organic matter decay. A single year's shift in fertilization practices will not offset several preceding years of high nitrogen treatments. Fertilization management must be considered in terms of multiple years, preferably beginning with a new planting. Attempts to manipulate nitrogen in a 5-year-old turf stand may be hopeless from a commercial or research viewpoint, if considerable organic nitrogen is present.

The nematode question with regard to *Fusarium* blight remains a sticky, unresolved issue at the nationwide level. In Pennsylvania we have not been able to demonstrate an associative or causative relationship between any plant parasitic nematode and the presence of or control of *Fusarium* blight. One of our worst *Fusarium*-blighted golf courses had almost no plant parasitic nematodes, and extensive nematicide treatment did not suppress the disease in any way. However, I believe that such a relationship is possible and may be present in the East, but we have not yet worked with the site where it may be present. The nematodes' role, as I view it, could be twofold: They could provide infection sites, as demonstrated with other *Fusarium* diseases, and they could restrict root development and water uptake, thus predisposing the plants to infection through moisture stress. I do not feel that a nematode presence is essential for disease development.

Fungicide tolerance has recently appeared among the *Fusarium* species. This has been reported for turf from New York (Smiley, personal communication) and observed recently in Pennsylvania. In one instance benomyl was successfully used in a course-wide program during 1974 for *Fusarium* blight suppression; the next year massive course-wide tolerance to benomyl appeared--16 to 19 ounces of product per 1,000 square feet applied in two applications on a preventive basis gave no control. Because of the problem of cross-tolerance among all benzimidazoles, all currently registered fungicides are eliminated for 1976 for effective use on *this* golf course for the disease.

In summary, *Fusarium* blight is a many-sided problem affected by various aspects of the environment. Most turfgrass scientists will agree that warm air and soil temperatures, soil moisture stress, high nitrogen fertility, thatch accumulation, turfgrass age, and turfgrass variety play a major role in disease development. However, for most of these factors the specific details of their influence have not been worked out, and we can speak at present in generalities only. For certain critical aspects of the disease cycle, such as symptom appearance and crown-root rot infection vs. foliar infection, I do not believe that we have a sound basis for understanding the natural situation in the field. We need much more information in all areas if we are to cope with this problem in a rational manner. Hence, we in turfgrass research must direct our efforts to further understanding of *Fusarium* blight if we are to provide meaningful recommendations to the turf industry. My first priority would be to resolve the crown and root rot vs. foliar infection controversy. After this is resolved, I believe many other things will fall into place quite rapidly.

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FACTORS AFFECTING *FUSARIUM* BLIGHT IN KENTUCKY BLUEGRASS

R.E. Partyka

Fusarium blight on Kentucky bluegrass varieties is a major disease in the Midwestern and Eastern States. In general, it is assumed that the organisms are present in most turf areas, and infection is related to stress conditions. Some consideration should be given to what causes the turf to go into stress.

Two components of stress are soil drought and temperature. These problems prevail where there are heat sink areas, such as curb stones, sidewalks, or driveways. Poor soils (gravel) in these areas dry out sooner, allowing the turf to go into stress. Sloping terrain with a southern exposure is often stressed before other areas.

Another consideration is the physiological drought of the plant and its relation to temperature. Plants with restricted roots will stress easily. Reasons for a limited root system are varied but most include clay soils where oxygen and carbon dioxide levels are not conducive to good root growth. Soil pH may be a limiting factor as may be nutrient levels, especially phosphorus. Compaction may be important in some areas, especially if heavy riding equipment is used on wet soils at the wrong times.

Thatch contributes to the potential of inoculum carryover, but it may also interfere with active root development. Careful examination of turf growing in a thick thatch layer will reveal active roots in the thatch layer with little contact with the soil and, thus, out of contact with the capillary moisture level. Thatch may actually develop to become a definite moisture barrier. Some concern may exist as to the gasses produced in the thatch level from microbial activity and their effect on root growth and nutrient absorption; this could be a factor if high levels of carbon dioxide are involved.

Stress may be related to improper practices of handling sod after it is harvested. Dry sod or sod allowed to heat in transit may be damaged so that *Fusarium* can become established without being evident until some later date. Sod laid down on dry soil or not watered for a long time can be stressed. Another phase of stress may be associated with a sod-soil (clay) interface problem. Poor permeation of water or capillary action at the interface will result in a poor root system, which can result in a stress situation. If temperature conditions are favorable and the organism is present, *Fusarium* blight will become evident.

Other root-damaging causes are often related to insect feeding, nematodes, and, if present, possibly garden symphylans. Any one or a combination of these causes may result in stressed turf.

Predisposing root organisms may be involved under certain conditions. One may question whether organisms such as *Pythium* or *Rhizoctonia* may be present at low levels of activity early in the growing season and are capable of weakening the turf so that *Fusarium* becomes established readily under favorable conditions.

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Nutritional imbalance that favors rapid top growth and poor root development may result in stressed plants. Calcium levels in plant tissue as related to soil and thatch levels have been discussed in the literature. The question of calcium nutrition in plants with the entire root system in the thatch layer may relate to pH levels and stress.

Cultural factors that relate to the area may have to be considered in some cases. Construction site and soil type are important with modern building practices. Bulldozer work and fill soils do not provide optimum soils for turf. The degree of the grade coupled with thatch may result in poor water penetration and predispose the turf to stress conditions. Irrigation practices based on weather requirements or a time clock may be a factor in creating less than optimum growing conditions. Nutrient levels used to maintain turf at a specific aesthetic quality may be providing nutrients favorable for pathogen buildup. In some cases, one may question major shifts in climate or community design that favor the buildup of disease-causing organisms.

Improved turfgrass varieties may be a better host for the pathogen or provide better microclimate conditions for the fungus to grow. A greater need for instant grass has resulted in more sod being grown on soils that may be contaminated with *Fusarium*, or there may be selectivity for *Fusarium* associated with the use of fungicides or related pesticides. The changing air pollution load in some areas may be associated with stress. Sod handling practices by subcontractors leave much to be desired at times when sod stress is the issue.

The degree of *Fusarium* blight indicates that the complexity of the problem is more than realized initially. To determine whether this is strictly associated with the pathogen or whether changing cultural practices also influence the level of stress will require further research to identify the situation as it currently exists.

EFFECTS OF CULTURAL PRACTICES ON *FUSARIUM* BLIGHT INCIDENCE IN KENTUCKY BLUEGRASS

A.J. Turgeon

Diseases of turf result from the combination of a susceptible host and environmental conditions conducive to the pathogenic activity of specific disease-causing organisms. For example, leaf spot *(Helminthosporium vagans)* disease typically occurs in susceptible varieties of Kentucky bluegrass under the cool, moist conditions occurring in midspring, while brown patch *(Rhizoctonia solani)* develops on closely clipped turfs during the hot, humid weather of midsummer. However, the extent of turfgrass deterioration from pathogenic organisms is frequently associated with additional factors as well. The cultural program of fertilizing, mowing, and irrigating may substantially affect the severity of disease incidence in a turf during certain periods in the growing season.

Field research and practical experience in managing turfs have resulted in the evolution of certain principles of turfgrass culture that are based, in part, on the association of mowing height and frequency, fertilization rate and timing, and other such factors with the incidence and severity of diseases. Most of these observations have been on Kenblue-type (common) or Merion Kentucky bluegrasses and traditionally have used cultivars of other turfgrass species. Today, increasing numbers of superior cultivars are being planted for many different uses and cultural intensities. Questions arise regarding the application of established principles of culture to the newer varieties. Apparent differences in turfgrass density, vigor, disease susceptibility, and other parameters suggest that the principles of culture may change somewhat from cultivar to cultivar.

A study was initiated at the University of Illinois in which five Kentucky bluegrass cultivars (Nugget, Merion, Fylking, Pennstar, and Kenblue) were maintained under two mowing heights (0.75 and 1.5 inches) and four fertilization regimes (2, 4, 6, and 8 pounds of nitrogen per 1,000 square feet annually) beginning April, 1973. By early August, with half of the fertilizer applications made, differential development of *Fusarium* blight disease was observed in plots (Turgeon and Meyers, 1974). Generally, higher spring fertilization rates were associated with substantially higher incidence of the disease in summer. This was evident in all cultivars except Kenblue, which was severely affected regardless of fertility level. Pennstar was essentially unaffected at the lowest (2 pounds) level of nitrogen fertilization, while slight to moderate blighting occurred in plots receiving the 4-pound level of nitrogen. The 6- and 8-pound nitrogen levels were associated with a severe incidence of *Fusarium* blight. Fylking was slightly to moderately blighted at the 2- and 4-pound nitrogen levels and severely diseased at higher levels. Merion responded in much the same manner as Pennstar, and Nugget was largely unaffected except at the highest nitrogen level. The incidence of *Fusarium* blight in Nugget, Merion, and Fylking was slightly higher in plots maintained at the 1.5-inch mowing height. No such difference was apparent in the Pennstar and Kenblue plots.

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Continuation and expansion of this study with the inclusion of Windsor and A-20 Kentucky bluegrasses provided similar results during the next two growing seasons. No *Fusarium* blight symptoms were observed in Windsor or A-20, while Nugget, Merion, Fylking, and Pennstar characteristically showed more disease with increasing spring fertilization rates (Table 1). As in 1973 the severity of *Fusarium* blight disease was uniformly high in the Kenblue plots. Random probing of the plots revealed very severe soil compaction in the section of the field where the Kenblue plots were located, suggesting that compacted soil conditions may so weaken the turf that its susceptibility to *Fusarium* blight disease is much greater. Data from the Kentucky bluegrass variety plots, established in April, 1972, do not show Kenblue to be inherently more susceptible to *Fusarium* blight than Fylking, Pennstar, or Nugget under a moderate intensity of culture (4 pounds of nitrogen per 1,000 square feet a year, 1.5 inches mowing height) and fairly uniform soil physical conditions (Table 2).

Table 1. Effects of Mowing Height and Fertilization on the Incidence of Fusarium Blight Disease in Seven Kentucky Bluegrass Varieties in 1975[a]

Mowing height (in.)	Fert.[b] (lb. N/ 1,000 sq. ft./yr.)	Variety						
		Windsor	A-20	Nugget	Merion	Fylking	Pennstar	Kenblue
.75	2	1.0	1.0	1.0	1.3	1.3	1.3	5.7
1.50	2	1.0	1.0	1.0	1.3	1.0	1.3	6.0
.75	4	1.0	1.0	1.0	1.3	1.7	2.0	5.7
1.50	4	1.0	1.0	1.0	1.3	1.7	1.3	4.7
.75	6	1.0	1.0	1.0	2.0	4.0	4.7	6.0
1.50	6	1.0	1.0	1.0	2.0	2.7	4.3	5.7
.75	8	1.0	1.0	1.7	4.3	6.0	6.3	7.0
1.50	8	1.0	1.0	1.3	4.3	5.0	6.0	7.0

[a]Visual ratings of disease were made using a scale of 1 through 9 with 1 representing no disease and 9 representing complete necrosis of the turf.

[b]Fertilization was performed using a 10-6-4 ($N:P_2O_5:K_2O$) analysis water-soluble fertilizer applied in equal amounts in April, May, August, and September for two years on Windsor and A-20 and for three years on Nugget, Merion, Fylking, Pennstar, and Kenblue.

Table 2. Relative Susceptibility of Kentucky Bluegrass Varieties to Fusarium Blight in Illinois

Disease susceptibility levels						
High	Moderate		Low		No symptoms	
Delft	Ba 61-91	Kenblue	A-34	Merion	A-20	Monopoly
EVB-305	Brunswick	IL-3817	Ba 62-55	Cheri	Adelphi	P-59
K1-138	EVB-307	Nugget	Baron	Parade	Campina	P-140
	Fylking	PSU-197	Bonnieblue	Plush	Edmundi	PSU-150
	Geronimo	Park	EVB-391	PSU-169	Glade	Sodco
	K1-157	Pennstar	Galaxy	PSU-190	K1-132	Touchdown
	K1-187	RAM #2	K1-131	RAM #1	K1-143	Victa
			K1-133	Sydsport	Majestic	Windsor
			K1-155	Vantage		
			K1-158			

Based on these observations, the varieties Delft, EVB-305, and K1-138 should not be planted on sites where *Fusarium* blight is a concern; other varieties, including A-20, Adelphi, Glade, Majestic, Sodco, Touchdown, and Victa, appear promising because of the apparent lack of *Fusarium* blight symptoms during the period of observation.

Another factor believed to be of importance in the development of *Fusarium* blight disease is thatch. Many turfgrass scientists feel that the susceptibility of a turf to *Fusarium* blight may be greatly increased where substantial levels of thatch have been allowed to develop. While this may be true, there was no clear correlation between the thatching tendency of Kentucky bluegrass varieties (Table 3) and their relative susceptibility to *Fusarium* blight. For example, Touchdown Kentucky bluegrass was the most thatch-prone variety--its thatch layer averaged over 1.9 centimeters thick--while Park was the least thatch-prone variety, with only 0.71 centimeters of thatch. Yet, Park was found to be moderately susceptible to *Fusarium* blight while Touchdown showed no symptoms of the disease. Since recent results from tests at Rutgers showed that *Fusarium* blight incidence in Kentucky bluegrass varieties was dramatically increased where thatch-inducing calcium arsenate was applied to the plots (Funk, 1975), it is likely that thatch development is associated with more severe incidence of this disease in susceptible varieties. However, this relationship apparently does not exist when comparing the differential thatching tendancy and *Fusarium* blight susceptibility of different Kentucky bluegrass varieties.

An additional factor frequently associated with the severity of turfgrass diseases is whether or not clippings are removed as part of the mowing operations. Results from a study initiated in early 1974 showed that, at high nitrogen fertilization rates, the severity of *Fusarium* blight was reduced by clipping removal (Table 4). The basis for this relationship is not clearly understood; however, it does appear that clipping removal with mowing should be considered on highly fertilized sites where *Fusarium* blight has been a recurring problem.

Table 3. Relative Thatching Tendency of Kentucky Bluegrass Varieties During the Fourth Season After Planting

Thatch depth, cm[a]	Varieties
More than 1.50	Brunswick, EVB-305, Glade, Cheri, Nugget, P-140, RAM #1, Touchdown
1.50 - 1.25	A-20, Ba 62-55, Baron, EVB-391, Fylking, K1-131, K1-132, K1-143, K1-187, Majestic, P-59, Plush, PSU-190, RAM #2, Sodco, Victa
1.25 - 1.00	A-34, Adelphi, Ba 61-91, Bonnieblue, Campina, Delft, Edmundi, EVB-307, Galaxy, Geronimo, K1-133, K1-138, K1-155, K1-157, K1-158, IL-3817, Merion, Monopoly, Parade, Pennstar, PSU-150, PSU-169, Sydsport, Vantage, Windsor
Less than 1.00	Kenblue, Park, PSU-197

[a]Thatching depth was determined by measuring the thickness of the thatch at four places on two plugs 2 inches in diameter taken from each of the three replicate plots of each variety.

Table 4. Effects of Clipping Removal and Fertilization on Fusarium Blight Incidence in Kenblue Kentucky Bluegrass Turf

Fertilization[a] (lb. N/1,000 sq. ft./yr.)	*Fusarium* blight rating[b]	
	Clippings removed	Clippings returned
2	1.3	1.2
5	1.5	1.7
8	1.5	3.7

[a]A 10-6-4 ($N:P_2O_5:K_2O$) analysis water-soluble fertilizer was applied in equal amounts in April, May, August, and September for two years.

[b]Visual ratings of disease were made using a scale of 1 through 9 with 1 representing no disease and 9 representing complete necrosis of the turf.

A final cultural factor of importance in controlling *Fusarium* blight is irrigation. This is most evident during midsummer stress or drouthy periods when light watering has been instrumental in reducing disease symptoms and promoting turfgrass survival. A turf with a deteriorated root system cannot survive prolonged stress periods unless supplemental irrigation is frequent enough to prevent desiccation of the plants. Although this practice is inconsistent with traditional principles of turfgrass culture, it may be necessary for the survival of a severely diseased turf.

In conclusion, there are two fundamental approaches to controlling *Fusarium* blight in Kentucky bluegrass. The "environment-oriented" approach is to adjust the cultural program by avoiding excessive nitrogen fertilization during spring, providing adequate moisture for turfgrass survival during stress periods through irrigation, performing appropriate cultivation practices to control thatch and alleviate soil compaction and applying effective fungicides properly. The "plant-oriented" approach involves the introduction of superior Kentucky bluegrass varieties that, under local conditions, do not appear to be adversely affected by the *Fusarium* organism.

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THE ROLE OF NEMATODES IN THE DEVELOPMENT OF *FUSARIUM* BLIGHT

J.M. Vargas, Jr.

Extensive surveys were made to determine if factors other than *Fusarium roseum* and *Fusarium tricinctum* were involved in the development of *Fusarium* blight. The surveys revealed that high populations of nematodes, especially the nematodes *Tylenchorhynchus dubius* and *Creconemoides* spp., occurred in *Fusarium*-blighted turfs.

A greenhouse study was conducted to determine what role, if any, the stunt *(T. dubius)* nematode played in the development of *Fusarium* blight. In this study, only *T. dubius* was able to produce most severely stunted top growth and root systems, the two characteristic symptoms normally associated with *Fusarium* blight-infected turfgrass plants. The *F. roseum*-treated plants had reduced root and top growth, but the reduction was not significant when compared to the untreated controls. It appeared that the nematode was the dominant pathogen in the *F. roseum/T. dubius* interaction, which is responsible for *Fusarium* blight in Michigan.

It must be remembered that Michigan is really borderline for *Fusarium* blight development. Michigan does not have the long periods of hot, humid weather normally associated with *Fusarium* blight development in more southern areas. In fact, our *Fusarium* blight outbreaks usually occur during periods of drought stress, whether it is hot and dry or cool and dry. Our worst outbreaks have been in late September and early October when the daily temperature did not go above the high 70's. So while the nematodes may be important in Michigan and other northern edges of the *Fusarium* blight region, they may not be as important in the more southern regions.

Before we had determined that nematodes were involved in the disease interaction, we had obtained control of the disease with the systemic fungicide Tersan 1991, but only where we drenched the material into the root zone. We originally thought this was related to the upward translocation in the plant of the systemic fungicide. These results were puzzling in light of the involvement of the nematodes in the development of the disease. Upon further investigation, Tersan 1991 was shown to be a nematicide in addition to a systemic fungicide. We now believe if it is drenched into the root zone the grass plants roots will pick it up and prevent nematodes from feeding. Tersan 1991, of course, can also protect the plant from infection by the *F. roseum* fungus.

If *Fusarium* blight is an interaction between a nematode and a fungus, with the nematode being the dominant pathogen, then one should be able to control the disease with nematicides. Control of *Fusarium* blight has been demonstrated in Michigan with the nematicides Dasanit and Oxymal. However, it appears that they must be applied early in the season, before the *Fusarium* blight symptoms begin to appear.

Drought stress appears to be the main factor in symptom development after infection has taken place. This is logical, since you have a weakened grass plant with a poorly developed root system; as soon as drought stress is applied, it will begin to wilt and eventually die.

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Light, frequent watering of *Fusarium*-blighted turfs during periods of drought stress can prevent *Fusarium* blight symptom development. During hot, dry weather, syringing lightly about midday may also be necessary, and symptom development of the disease can be prevented by following such a watering program.

Not enough information is known to make recommendations concerning varieties that are resistant to *Fusarium* blight. However, there is enough evidence to show that Merion, Fylking, and Pennstar are three very susceptible Kentucky bluegrass varieties that should not be used in areas where *Fusarium* blight is a problem.

SUMMARY

The disease *Fusarium* blight appears to be an interaction between nematodes and a fungus in which the nematode is the dominant pathogen. The symptoms of the disease occur during periods of drought stress in warm or cold weather. The disease can be controlled culturally by light, frequent watering during periods of drought stress or chemically with one of the recommended systemic fungicides or nematicides. Check with the turfgrass experts in your area for specific recommendation.

CAUTION: Nematicides are extremely dangerous to human health, and proper clothing and equipment must be worn when applying them. Again, it is advisable to check with an expert in your area before applying nematicides.

DEVELOPING GENETIC RESISTANCE TO *FUSARIUM* BLIGHT

C. Reed Funk

The development of improved levels of a stable, race-nonspecific resistance to *Fusarium* blight should receive high priority in all areas where this disease is a present or potential hazard. This resistance must be combined with other genetic factors involved in the creation of attractive, dependable turfgrass cultivars with good turf-forming properties, tolerance of environmental stress, and good resistance to other important pests. These improved turfgrasses need to be widely adapted and have reduced maintenance requirements.

TYPES OF DISEASE RESISTANCE

Disease resistance in plants has been characterized as either race-specific or race-nonspecific. Race-specific resistance has been widely used in the genetic control of plant disease. It generally is controlled by a single, usually dominant, gene and produces a high degree of resistance to one or more specific races of the disease pathogen. Unfortunately, a variety possessing such resistance may be highly susceptible to other races of the same pathogen. Breeding programs using this race-specific form of disease resistance are frequently faced with the task of continually finding and adding new resistance genes to combat new races of the pathogen. This race-specific resistance has been used extensively in annual crops where new resistant varieties can readily be substituted as resistance in old varieties breaks down. Obviously, it is of much less value in our long-lived perennial turfgrasses.

Race-nonspecific resistance is normally conditioned by the combined action of several genes. It imparts a degree of resistance to all races of the pathogen and is generally relatively stable over long periods of time. In most cases race-nonspecific resistance does not confer the high level of disease resistance normally observed in varieties possessing a race-specific type of resistance. Plant breeding procedures using race-nonspecific resistance are also more difficult. Nevertheless, the development of varieties having the highest possible and most stable forms of race-nonspecific forms of disease resistance should be the primary goal of breeders of perennial species.

PREDISPOSING FACTORS

Observational and experimental evidence suggest that the *Fusarium* blight disease is more serious on turfgrass weakened by one or more environmental stress factors. Factors predisposing the turf to *Fusarium* blight might include the following:

1. High temperatures.
2. High humidity.
3. Recurring drought stress.
4. Reduced air circulation.

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5. Excessive nitrogen.
6. Dense, lush growth.
7. Thatch.
8. Close mowing.
9. Nematodes.
10. Other diseases.

Varieties better able to tolerate the weakening effects of any of the above factors, which may occur at a critical stage in disease development, are less likely to be seriously damaged by *Fusarium* blight. This might account for much of the variety x test interaction observed in ratings of variety resistance. A variety such as Vantage, which is less tolerant of close mowing than some compact turf-types, may show very little *Fusarium* blight at a 2-inch mowing height but can be weakened by closer mowing to the extent that it becomes moderately susceptible. A variety growing in its area of best adaptation and receiving the management most favorable to its best performance is likely to be damaged less by this disease.

The above factors, considered in connection with a highly variable pathogen and our present less than adequate evaluation techniques and information exchange, complicate our understanding of the amount and stability of the genetic resistance available. Nevertheless, we do see substantial variation in the amount of *Fusarium* blight damage to different turfgrass selections. The genetic components of this variation can be used in breeding varieties of improved resistance.

KENTUCKY BLUEGRASS

Kentucky bluegrass, *Poa pratensis* L., is the most important lawn-type turfgrass in the northern half of the United States. It is hardy, attractive, and widely adapted. A number of attractive turf-type bluegrasses with good resistance to the *Helminthosporium* leaf spot and crown rot disease have been developed in recent years. Most of these improved varieties are giving good performance in areas where summer stress conditions are not too severe. Nevertheless, the development of bluegrasses with greater tolerance of the long, hot summers of the transition zone remains a real challenge to the turfgrass breeder. An extensive program to collect and evaluate adapted germ plasm from summer stress areas should provide germ plasm to produce varieties with greatly improved summer performance and dependability.

Detailed examination of old turfgrass stands and variety trials located in summer stress areas of the Middle Atlantic region is providing us with valuable insights into different types of Kentucky bluegrass. Under conditions of moderately low nitrogen fertility and high, infrequent mowing, the tall, erect-growing, narrow-leafed common types such as Kenblue dominate. However, old turf areas that have been mowed regularly have very few bluegrasses of the erect, narrow-leaf common type. The narrow-leafed common types have apparently been weakened by leaf spot and replaced by large patches of a broader leafed, more prostrate, moderately open type with extensive deep rhizomes. These might be referred to as a Middle Atlantic common. Vantage, PS#2, and P-154 are selections of this type. This Middle Atlantic common type of bluegrass with its deep rhizomes, somewhat greater intrinsic tolerance of heat, greater summer food reserves, deeper roots, and somewhat open growth is well suited to survive summer stress, especially if not overfertilized or mowed too closely.

Many of the very attractive, dense, lower-growing turf-type bluegrasses selected from cooler summer climates of Northern Europe and from other breeding and evaluation trials in less severe environments are often disappointing in southern trials.

Their dense, attractive turf is the result of a very high population of tillers per unit area. This results in increased competition between each tiller for light, water, carbon dioxide, and nutrients. Each tiller has a smaller percentage of the root system for support and is more subject to drought stress. A higher humidity develops in this dense turf. Excessive thatch accumulation is more likely to occur. This favors many disease organisms, including *Fusarium*.

Kentucky bluegrass is best able to tolerate the frequent close mowing, high fertility, and other factors associated with the production of dense, compact turf desired on golf course fairways and similar turf areas in regions of high light intensity, cool temperature, and low to moderate humidity. As we go into less favorable climates, we must compensate with improved varieties and better management.

There may be a fourth type of bluegrass, which we might refer to as a southern turf-type, that is widely adapted, pest resistant, and tolerant of heat and drought. This type has the ability to produce an attractive, compact, dense, disease-free turf in favorable environments. It also has the phenotypic plasticity to produce the deeper roots and rhizomes and the more open growth habit of the Middle Atlantic common type in areas of severe and prolonged summer stress. It has good heat tolerance and the ability to maintain higher levels of carbohydrate reserves through prolonged periods of hot weather. A few of our very best bluegrasses are approaching this description. Further improvements in heat tolerance and pest resistance, including better resistance to *Fusarium* blight, will be most helpful in meeting the challenge of the transition zone. For commercial success these varieties also have to be economical seed producers. Expanded efforts should be made to develop and identify these grasses.

New Brunswick Trials

Turf trials at New Brunswick, New Jersey, show that bluegrass varieties exhibit a wide variation in resistance to *Fusarium* blight under the conditions of our evaluation program (Table 1). We have had very little damage from *Fusarium* blight on most test fields. High levels of earthworm activity and perhaps other factors have virtually eliminated any thatch buildup except on fields treated with tricalcium arsenate or chlordane.

Three bluegrass tests on fields treated with tricalcium arsenate all show considerable thatch buildup and substantial damage from *Fusarium* blight. One half of each plot on the 1972 regional bluegrass test was treated with 4.8 pounds of tricalcium arsenate in both the spring and the fall of 1973. Thatch buildup has occurred on the treated half but not on the untreated half. The treated half shows four times as much damage from *Fusarium* blight as the untreated half. At our Adelphia location we have seen considerable *Fusarium* blight disease in fields not treated with tricalcium arsenate. Areas of these fields having reduced air circulation show substantially more damage from *Fusarium* blight.

THE FINE FESCUES

Fine fescues are generally tolerant of acid soils, low fertility, and shade. They perform best in cool climates and during cool seasons. They are intolerant of higher levels of nitrogen fertilizer and poor drainage during hot weather. The fine fescues currently showing the greatest potential for turf use can be classified into five types. Dr. Robert W. Duell, who is working closely with the fine fescues at Rutgers, refers to them as the Chewings, Creeping, Spreading, Hard, and Sheeps fescues. The Chewings, Creeping, and Spreading fescues are currently included in one species, *Festuca rubra* L. However, these three types are very

Table 1. Fusarium Blight Incidence on Kentucky Bluegrass Varieties, Blends, and Mixtures Grown at New Brunswick, New Jersey, 1975[a]

Variety	Percent diseased	Variety	Percent diseased
Edmundi	1	Merion	15
Windsor	1	Park	16
Adelphi	1	Victa	18
P-59	1	Baron	18
Parade	1	Cheri	21
Sydsport	3	Merion-Pennstar	23
Bonnieblue	4	Merion-Kenblue	24
Adelphi-Kenblue	4	Fylking-C26	27
Adelphi-Nugget	5	Nugget	29
Sodco	5	Nugget-Pennstar	29
Glade-Nugget	6	Fylking	31
Vantage	7	Pennstar	31
Glade	7	Delft	37
Adelphi-Fylking	8	Fylking-Pennlawn	37
Touchdown	8	Nugget-Park	38
Majestic	8	Fylking-Jamestown	45
Glade-Adelphi	10	Modena	52
Vantage-Victa	10	Enita	59

[a]Test planted April, 1972. Half of each plot received tricalcium arsenate treatment, which produced a four-fold increase in *Fusarium* blight. Plots were mowed at 3/4-inch height with moderately high fertility.

different in appearance, growth habit, management requirements, adaptation, breeding behavior, and cytological characteristics. They should be classified as separate species.

The Chewings type, *F. rubra* L. subsp. *commutata* Gaud., is a fine-leafed, lower growing grass without rhizomes. Under mowing, these plants spread slowly by basal tillering. Where summers are cool, they will tolerate rather close mowing and will produce attractive dense turf requiring less fertilizer and less mowing than needed for a good bluegrass turf. A number of very attractive varieties of Chewings fescue have been developed in recent years by breeders in the United States and Europe. 'Jamestown,' 'Banner,' 'Koket,' and 'Highlight' are representative of the improved varieties within this group. Their dense growth habit can make them much more competitive and persistent in mixtures with Kentucky bluegrass than fescue varieties formerly available. This can be either an advantage or a disadvantage.

The Creeping type, *F. rubra* L. subsp. *trichophylla* Gaud., is represented by European varieties such as 'Cumberland Marsh,' 'Dawson,' 'Golfrood,' and 'Oasis.' They are fine-leafed, low-growing varieties with short, thin rhizomes. Under mowing, they develop a turf similar in appearance to the improved Chewings type fescues. Some varieties within this group have demonstrated good salt tolerance. Currently available Creeping types are highly susceptible to dollar spot and are generally low seed producers. These factors limit the potential use of the Creeping types. It is hoped that improvements can be made in these characteristics, for some of our most leafspot-resistant germ plasm is found within this group.

The Spreading type, *F. rubra* L. subsp. *rubra* Hack, is represented by varieties such as 'Fortress' and 'Ruby.' Spreading fescues have 56 chromosomes while Chewings and Creeping fescues have 42 chromosomes. Spreading fescues have somewhat wider leaves, longer and thicker rhizomes, and better seedling vigor than other fine fescues. They are less tolerant of close mowing, have a lower turf density, and produce less thatch than the Creeping and Chewings types. In trials in New Jersey and Maryland the Spreading types have shown considerably less damage from *Fusarium* blight than the Chewings types. Improved selections of Spreading fescues would appear to be more compatible with Kentucky bluegrass and would have greater seedling vigor, better performance under low maintenance, and possibly better shade tolerance. Increased breeding efforts should be made to improve the Spreading fescues, especially in areas of severe summer stress.

The Hard fescues, *F. longifolia* Thuil., are receiving considerable attention since the development and release of 'Biljart' hard fescue (Scotts C-26) in Holland. The improved Hard fescues produce a turf comparable in texture and growth habit with the better varieties of the Chewings type fescue but with a somewhat slower rate of vertical growth, better resistance to some hot-weather diseases, and better adaptation to some poor soil conditions. Spring dormancy, slow recovery from injury, and costly seed production are problems that need improvement.

The Sheeps fescues, *F. ovina* L., collected from old turf areas of the Northeast look interesting in our turf evaluation plots. Most selections appear "grainy" under mowing but have shown excellent persistance under severe summer stress conditions. They have good shade tolerance and good adaptation to poor soils.

TALL FESCUE

Tall fescue, *Festuca arundinacea* Schreb., is used extensively for pasture, hay, general-purpose turf, and erosion control throughout the summer heat stress zone of the United States. It has the ability to tolerate summer heat and drought stress in areas where other cool season grasses perform poorly. There would appear to be considerable potential for the plant breeder to make substantial improvements in the appearance and turf performance of this interesting grass even though breeding efforts to date have met with only limited success. Dense, attractive, fine-textured lower growing types currently available in our breeding collection need further improvements in pest resistance and tolerance of temperature extremes. Recent work in central Alabama[1] show that nematodes can seriously limit rooting depth, drought tolerance, persistence, and productivity of tall fescue and other cool-season grasses. Well-organized and adequately supported team efforts by pathologists, nematologists, physiologists, and plant breeders might well produce tall fescue varieties of considerable value for areas where *Fusarium* blight is prevalent.

PERENNIAL RYEGRASS

The development of improved turf-type perennial ryegrass *(Lolium perenne* L.*)* varieties such as 'Manhattan,' 'Pennfine,' 'Citation,' 'NK200,' 'Eton,' 'Derby,' 'Yorktown,' 'Diplomat,' and 'Omega' has made this species of considerable usefulness to the turf industry. These improved ryegrasses are substantially superior to common perennial ryegrass for many turf purposes. Like all ryegrasses, the new

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[1] *Hoveland, C.S., R. Rodriguez-Kabana, and C.D. Berry. 1975. Phalaris and tall fescue forage production as affected by nematodes in the field. Agron. J. 67:714-717.*

turf-types are quick and easy to establish and are adapted to a wide range of soil types and uses. When properly managed in their area of adaptation, these ryegrasses can be durable, persistent, and attractive. Instances have been reported where turf-type ryegrasses have given good performance on turf areas where Kentucky bluegrass has been seriously damaged by *Fusarium* blight. The turf-type ryegrasses appear to produce much less thatch than bentgrass, Kentucky bluegrass, and the Chewings type fescues. A number of golf course superintendents in summer heat stress areas such as Washington, D. C., are having very promising success with overseeding established bermudagrass with blends of improved turf-type ryegrasses such as Manhattan, Pennfine, and Citation. Continued breeding efforts should lead to further improvements in mowing quality, summer performance, winter hardiness, and resistance to crown rust *(Puccinia coronata)*, brown patch *(Rhizoctonia solani)*, and leaf spot *(Helminthosporium siccans)*. Improved resistance to *Pythium* is also needed for good summer performance of ryegrass in the humid summer heat stress region.

TECHNIQUES FOR RAPID DETERMINATION OF *FUSARIUM* BLIGHT SUSCEPTIBILITY IN KENTUCKY BLUEGRASS SELECTIONS

William A. Meyer and Frank H. Berns

Fusarium blight is now recognized as a major disease problem of Kentucky bluegrasses and some other cool-season turfgrasses in the northeastern and midwestern sections of the United States (*1,6*)[1] and in California (*2*). *Fusarium roseum* and *F. tricinctum* are the two species of fungi found by Couch and Bedford (*1*) to be the incitants of this disease.

Disease symptoms seldom appear until a turf stand is two or more years old. Occasionally, symptoms may appear during the first year of turf establishment. The severity of this disease may vary greatly from year to year, depending upon such environmental factors as heat and moisture stress. It is usually very difficult to get a uniform distribution of *Fusarium* blight throughout a replicated turf plot area.

In the development of new Kentucky bluegrass varieties, it is important to establish their degree of susceptibility to *Fusarium* blight as well as other major diseases before they are released. Because of the time required for this disease to develop consistently in turf plots, rapid screening techniques are needed. The following paper will describe techniques which were developed to aid in the screening of Kentucky bluegrass cultivars for *Fusarium* blight susceptibility.

TILLER-PUNCTURE TECHNIQUE

With the tiller-puncture technique (*4*), 14 Kentucky bluegrass varieties were propagated from individual tillers and grown in 2-inch pots in the greenhouse for 50 to 75 days. They were then transferred to a growth chamber (14-hour day at 29° C, 24° C night; 4,000 foot candles; and 70 percent relative humidity) for three days prior to inoculation. A small wound (2 mm long) penetrating to the youngest enclosed leaf was made in each of two healthy tillers per pot between the crown area and third leaf. Mycelium pieces of *Fusarium trincinctum* isolate MSU1 or of *F. roseum* isolates UI2 or KC1 were then placed in the wounds. Wet sterile peat moss was used to cover the wounded area of each inoculated tiller. Other tillers were wounded but noninoculated to serve as controls. In all, 60 tillers of each variety were inoculated with the MSU1 isolate, 36 tillers with the UI2 isolate, and 12 tillers with the KC1 isolate. All pots were then returned to the growth chamber and the peat moss was kept moist.

Foliar lesions could be seen on the emerging leaf two to three days after inoculation. In many tillers the initial fungal infections in the new and old leaves would advance down into the crown area of the plant and eventually cause death. Some tillers were killed within seven days on the most susceptible varieties. After two weeks all pots were removed from the chamber and rated for severity of infection.

The MSU1 isolate was the most virulent isolate followed by UI2 and KC1. Leaf and crown lesions caused by the three isolates were similar on all of the varieties.

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[1]*Italicized numerals refer to entries in Literature Cited.*

The experimental variety WTN-I-13 had the smallest percentage of crown-rotted and dead plants. Eighteen percent of the WTN-I-13 tillers were crown rotted or dead with the MSU1 isolate, 8 percent with UI2, and none with KC1. WTN-I-2 and Belturf were ranked next with slightly higher percentages of dead or diseased plants. The varieties P104, WTN-J79, and Fylking were the most severely affected. Fylking had the highest percentage of dead or crown-rotted plants with 85, 68, and 42 percent, respectively, for the three isolates. The varieties A-20, WTN-H-7, A-34, Merion, and WTN-A-20-6 were intermediate in their reaction to the three isolates.

FIELD STUDIES

Field studies were developed in an attempt to determine the usefulness of laboratory tests such as the tiller-puncture technique for the determination of the susceptibility of Kentucky bluegrass varieties to *Fusarium* blight. One study was conducted on a golf course fairway in central Illinois that had a history of severe *Fusarium* blight. Eight-inch plugs of nine Kentucky bluegrass varieties were placed in a severely diseased portion of the fairway in November, 1973. Three healthy plugs were placed together in each of three replications for each variety. These were allowed to root down and were mowed and maintained like the rest of the fairway.

In the summer of 1974 *Fusarium* blight was not severe; all of the plugs were easily recognized and healthy except for Baron and Fykling, which were slightly thinned. During the summer of 1975 *Fusarium* blight was severe, and the varieties Fylking and Baron were severely damaged, as was the surrounding turf. The variety WTN-I-13 showed the least amount of damage with the varieties WTN-H-7, WTN-A-20-6, A-20, and WTN-I-2 ranking close behind. After two years the varieties WTN-I-13 and WTN-H-7 had grown laterally from the original 8-inch plugs, while the percentage of cover on the plugs of the other varieties had decreased in diameter. These changes, along with the difficulty in differentiating some of the plugs from the original fairway turf, made rating more difficult.

Another field study was initiated in the fall of 1974 in an area severely infested by *Fusarium* blight at the University of Illinois turf plots. In this test an 18-inch sod cutter was used to remove diseased sod to a depth of approximately 2 inches. Soil from a nearby field was used to fill these 18-inch strips back to the original grade and infested turf was left intact on both sides of the strips. Seed of 32 varieties, including most of the above-mentioned varieties, was then used to plant 3 replicated plots for each variety in plots 3 feet long in the 18-inch strips.

Fusarium blight was severe in the turf surrounding the 18-inch strips, but the new seedings remained free of *Fusarium* blight during the 1975 growing season.

DISCUSSION

The variation in the virulence of the three isolates in the tiller-puncture test is similar to the variation reported by other workers (3) with different *Fusarium* isolates. A limitation with the tiller-puncture test is that each inoculation is made with a single strain of the pathogen. Since the *F. roseum* and *tricinctum* species vary greatly in nature, a larger number of isolates need to be included in tests to increase their validity.

None of the varieties in the tiller-puncture test remained completely healthy. WTN-I-13 was the least severely affected variety in both the tiller-puncture and the field study. Other tests are needed in different locations with this variety to verify its degree of susceptibility to *Fusarium* blight. Some of the varieties that ranked intermediate in the laboratory tests also ranked intermediate in the field test. It should be noted that Merion was not the most susceptible variety in the test.

The high degree of susceptibility of Fylking to *Fusarium* blight has been reported in different locations (*5*). The susceptibility of the variety WTN-J-79 at a level similar to Fylking is an indication that this variety may perform poorly in areas where *Fusarium* blight is severe. The tiller-puncture test with a limited number of isolates may be most useful as a method to detect a high degree of susceptibility in a variety before it is released.

Many experimental and commercial Kentucky bluegrass varieties besides the 14 reported in this paper have been inoculated with the MSU1 isolate, using the tiller-puncture technique. To date, no variety has remained free of infection. It is hoped that this technique will at some time aid in detecting a source of germ plasm that has a high degree of physiological resistance to *Fusarium* blight.

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RESEARCH SESSION

TURFGRASS VARIETY EVALUATION RESULTS: 1975

A.J. Turgeon

The intraspecific variability of turfgrasses has allowed the development of many varieties and experimental selections that differ widely in their color, texture, density, environmental adaptation, disease susceptibility, and other factors. These differences are clarified through extensive testing at many sites from New England to Washington. The basis for these efforts is that improvements in the characteristics and adaptation of a turfgrass reduce its dependency on cultural practices that are designed to compensate for its weaknesses. Thus, turfgrass management is made simpler and higher turfgrass quality is obtainable with the use of improved varieties.

KENTUCKY BLUEGRASS VARIETY, BLEND, AND MIXTURE EVALUATION

There are 52 varieties plus 10 blends and 4 mixtures from an April, 1972, planting being tested at this station. Plots measure 6 by 8 feet and each variety is replicated three times. Fertilizer (10-6-4 analysis) is applied 4 times a year to supply a total of 4 pounds of nitrogen per 1,000 square feet. The turf is mowed 2 or 3 times a week at 1.5 inches. Irrigation is used as needed to prevent wilt.

The diseases of principal importance this year were *Helminthosporium* leaf spot, *Sclerotinia* dollar spot and *Fusarium* blight (Table 1). Varieties showing the least injury from these diseases were A-20, A-34, Adelphi, Baron, Bonnieblue, EVB-282, EVB-391, Galaxy, Glade, K1-131, K1-132, K1-143, K1-155, Majestic, MLM-18001, Monopoly, P-59, P-140, Parade, PSU-150, Sodco, Touchdown, Victa, and Windsor. The summer quality data reflect both disease incidence and summer stress tolerance. Thatch development varied from 0.71 to 1.91 centimeters thick, depending upon variety. There is reason to believe that thatch has an important effect on summer stress tolerance: Nugget typically declines as summer temperatures rise, but at the Belleville site in southern Illinois the absence of thatch in Nugget is associated with substantially better summer quality.

The blends reflect disease and quality levels that represent compromises between the two component varieties. Considering the fact that no variety is perfect, blending superior varieties allows for incorporating the desirable features of each component while reducing the impact of a specific weakness on general turfgrass quality. The mixtures of Kentucky bluegrass (Fylking) with fine fescue have not been good turfs because of the poor adaptation and high disease susceptibility of the fescues. The Fylking-Pennfine (perennial ryegrass) mixture is predominantly perennial ryegrass, and its quality through the season is similar to that of Pennfine alone.

FINE FESCUE VARIETY EVALUATION

Fine-leaf fescues (creeping red, Chewings, hard, and sheep) have traditionally been used in shaded or drouthy, sandy sites. Their performance in sunny locations on fine-textured Illinois soils has generally been less than satisfactory.

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Table 1. Performance of Kentucky Bluegrass Varieties, Blends, and Mixtures in 1975

Variety	Spring green-up[a]	Leaf spot disease[b]	Fusarium blight[b]	Dollar spot disease	Thatch depth, cm.	Quality[a] 7/11/75	8/15/75	10/9/75
A-20 (seeded)	3.3	2.0	1.0	1.0	1.39	2.7	2.0	3.7
A-20 (veg)	4.0	2.0	1.0	1.0	1.24	3.7	2.3	2.7
A-34	3.0	2.7	1.3	1.0	1.11	5.0	2.3	3.0
A-20-6	4.0	2.0	1.0	1.0	.99	2.7	2.0	2.0
Adelphi	2.7	2.0	1.0	1.0	1.25	4.0	2.3	3.0
Ba 61-91	4.3	2.7	2.0	1.3	1.05	3.7	3.7	4.7
Ba 62-55	4.0	2.3	1.3	2.0	1.50	3.3	3.3	3.3
Baron	5.3	2.7	1.3	1.0	1.37	3.7	3.0	3.0
Bonnieblue	3.0	2.3	1.3	1.0	1.01	3.7	2.3	3.3
Brunswick	2.0	3.0	2.3	1.7	1.54	2.3	3.7	4.7
Campina	2.3	7.0	1.0	1.3	1.06	4.0	3.3	3.3
Cheri	3.3	3.0	1.3	1.0	1.58	3.7	2.7	2.7
Delft	2.3	3.7	5.0	1.0	1.04	3.7	5.7	6.3
EVB-282	3.3	3.0	1.0	1.0	1.14	2.7	2.7	3.0
EVB-305	4.7	2.0	4.3	1.3	1.52	5.3	4.3	5.7
EVB-307	3.7	2.0	2.0	1.7	1.19	4.0	4.0	4.3
EVB-391	5.7	2.7	1.3	1.0	1.26	4.0	3.0	3.0
Fylking	4.3	2.3	2.3	1.3	1.30	3.3	3.3	4.7
Galaxy	3.7	2.0	1.3	1.0	1.17	3.7	2.3	3.3
Geronimo	3.0	3.3	2.0	2.0	1.25	3.3	4.0	4.3
Glade	3.7	2.7	1.0	1.7	1.54	3.7	3.3	3.0
K1-131	3.3	2.7	1.3	1.0	1.41	3.3	2.7	3.3
K1-132	3.3	3.0	1.0	1.0	1.27	3.3	3.0	3.0
K1-133	3.0	2.7	1.7	1.0	1.20	3.0	3.0	4.0
K1-138	3.0	4.0	5.7	1.0	1.21	3.7	6.3	5.7
K1-143	3.0	2.7	1.0	1.3	1.32	3.0	2.3	3.0
K1-155	2.7	2.0	1.3	1.0	1.21	4.0	2.7	3.3
K1-157	2.3	5.3	3.0	1.0	1.13	3.7	3.3	5.0
K1-158	2.0	5.3	1.7	1.0	1.22	3.0	1.7	2.7
K1-187	3.0	2.7	2.0	1.0	1.45	3.0	3.3	4.7
Kenblue	3.0	5.0	2.0	1.3	.96	3.7	3.3	4.0
1L-3817	4.3	2.3	2.7	1.3	1.13	4.3	4.3	4.3
Majestic	2.7	2.0	1.0	1.0	1.41	4.0	2.3	2.7
Merion	3.0	2.0	1.7	1.3	1.02	2.3	3.0	4.0
Monopoly	2.7	2.7	1.0	1.0	1.06	2.3	2.0	2.7
Nugget	7.7	1.0	2.7	3.3	1.52	4.7	5.3	5.3
P-59	2.0	2.3	1.0	1.0	1.33	4.7	2.7	2.7
P-140	2.3	2.7	1.0	1.7	1.76	2.3	2.3	2.7
Parade	2.3	2.3	1.3	1.7	1.01	4.3	3.0	2.7
Park	2.3	5.3	2.0	1.0	.71	2.7	3.3	5.0
Pennstar	4.0	2.0	2.0	1.0	1.22	3.3	3.3	4.0
Plush	3.7	3.0	1.7	1.0	1.33	2.3	2.3	3.7
PSU-150	3.3	2.0	1.0	1.0	1.17	3.0	3.3	3.7
PSU-169	3.0	2.3	1.7	1.0	1.13	4.3	3.3	4.0
PSU-190	3.7	2.7	1.7	1.0	1.29	3.0	3.3	4.0

[a]Spring green-up and quality ratings were made using a scale of 1 through 9 with 1 representing best quality and 9 representing poorest quality.
[b]Disease ratings were made using a scale of 1 through 9 with 1 representing no disease and 9 representing complete blighting of the turf.

Table 1. (cont.)

Variety	Spring green-up[a]	Leaf spot disease[b]	Fusarium blight[b]	Dollar spot disease	Thatch depth, cm.	Quality[a] 7/11/75	8/15/75	10/9/75
PSU-197.	3.7	2.7	2.7	1.0	.97	3.0	4.0	5.3
RAM #1	4.3	2.7	1.3	2.7	1.68	3.7	3.7	3.7
RAM #2	3.0	2.7	3.0	1.3	1.37	3.7	4.3	4.3
Sodco.	3.0	3.0	1.0	1.0	1.37	3.0	2.7	2.3
Sydsport	4.0	2.0	1.7	1.0	1.22	5.0	3.0	3.0
Touchdown.	3.3	2.3	1.0	1.0	1.91	4.3	3.0	2.7
Vantage.	3.0	3.7	1.7	1.0	1.02	2.7	2.7	3.3
Victa.	5.0	2.7	1.0	1.0	1.47	3.0	3.0	3.3
Windsor.	3.0	3.0	1.0	1.0	1.22	2.7	2.0	3.0
Blends								
Blend 38	3.3	3.0	1.7	1.0	1.51	3.3	3.0	3.3
Merion + Kenblue	3.0	3.0	1.7	1.0	1.22	3.0	3.3	4.3
Merion + Pennstar.	2.3	2.0	1.0	1.0	1.19	2.3	3.0	4.0
Merion + Baron	3.3	2.3	2.0	1.0	1.30	3.7	3.3	4.0
Nugget + Pennstar.	7.0	1.3	2.0	1.0	1.28	4.3	4.0	4.3
Nugget + Park.	3.0	2.3	3.7	1.0	1.10	3.7	5.0	6.0
Nugget + Glade	4.7	2.0	1.3	1.0	1.42	3.7	2.7	3.7
Nugget + Adelphi	4.3	1.7	1.3	1.0	1.27	4.3	2.7	3.3
P-59 + Brunswick	2.3	2.7	3.3	1.0	1.41	3.3	4.3	5.3
Victa + Vantage	3.7	2.7	1.7	1.0	1.40	3.3	3.0	3.3
Mixtures								
Fylking + C-26 (HF)	3.7	2.0	3.3	1.3	1.31	3.7	4.3	5.7
Fylking + Jamestown (RF). .	4.0	2.3	5.0	1.0	1.36	4.7	4.3	6.0
Fylking + Pennfine (PR) . .	1.0	2.0	1.0	1.3	.72	2.7	3.3	2.7
Fylking + Pennlawn (RF) . .	3.3	2.3	5.3	1.0	1.24	3.7	5.7	6.0

The fine-leaf fescue varieties were planted in April, 1972. Plots measure 6 by 8 feet, and each is replicated three times. Fertilizer is applied twice yearly to supply a total of 2 pounds of nitrogen per 1,000 square feet.

None of the varieties provided high-quality turf under the experimental conditions (Table 2). Those least affected by disease and summer stress are Barfalla, Jade (formerly Horritine), Koket, Scaldis, and C-26. Dollar spot disease was evident in most of the plots, and definite symptoms of *Fusarium* blight were observed in many plots that were not weed-infested or substantially deteriorated.

Table 2. Performance of Fine-Leaf Fescue Varieties in 1975

Variety	Quality rating[a]				Dollar spot disease[b]
	4/16/75	6/27/75	8/15/75	10/9/75	
Barfalla	4.7	4.3	5.0	5.3	4.7
Barok	7.0	5.3	7.0	6.3	5.0
C-26	4.7	4.0	5.0	5.0	2.7
C-26 + Jamestown	5.7	5.0	6.0	6.0	3.3
CEBECO S70-2	7.0	6.3	7.0	7.0	5.0
CEBECO Hz71-4	7.0	6.7	6.7	7.3	3.7
Dawson	7.0	6.3	7.0	6.3	6.7
Durlawn	7.3	6.0	7.0	6.7	5.7
Encota	5.7	5.0	6.3	6.3	4.0
ERG-11	7.0	6.3	7.0	7.3	5.3
Flavo	6.0	5.0	6.3	6.7	4.7
HF-11	6.7	6.0	7.0	7.3	6.0
Highlight	7.0	6.0	7.3	8.0	3.3
Jade	3.7	5.0	4.0	4.3	2.7
Jamestown	5.3	4.3	5.0	6.0	3.0
Koket	4.0	4.7	5.0	4.3	3.3
Menuet	4.7	5.0	6.0	5.3	5.3
Novarubra	5.7	7.0	7.3	6.0	6.7
Oregon-K	4.7	4.7	5.0	6.3	4.3
Pennlawn	4.3	4.3	6.0	6.3	5.0
Polar	5.7	5.7	7.7	7.3	6.3
Roda	7.0	6.7	7.3	6.7	7.0
RU-45C	5.0	4.3	5.7	6.7	2.7
Scaldis	4.3	4.7	4.7	5.0	4.0
Scarlet	5.7	5.0	6.3	7.3	5.0
Waldorf	5.0	3.7	5.0	6.7	2.0

[a]Quality ratings were made using a scale of 1 through 9 with 1 representing best quality and 9 representing poorest quality.
[b]Disease ratings were made using a scale of 1 through 9 with 1 representing no disease and 9 representing complete necrosis of the turf.

CREEPING BENTGRASS VARIETY EVALUATION

Creeping bentgrass varieties were established in May, 1973, in plots measuring 6 by 8 feet with three replications of each variety. Mowing height is 0.25 inch and the plots receive a total of 4 pounds of nitrogen per 1,000 square feet annually. Irrigation is as needed to prevent wilting. Small sections of each plot were treated with 12 or 24 pounds of Tupersan 50 WP in May, 1975, to determine the tolerance of the bentgrasses to this herbicide.

The most outstanding variety was Penncross; Toronto was the poorest because of a severe incidence of red leaf spot disease followed by considerable crabgrass and annual bluegrass invasion (Table 3). In terms of color, density, and growth habit, Metropolitan was the least attractive variety.

Tupersan injury was evident in the following varieties: Washington, Old Orchard, Collins, Nimisilla, MSU-Ap-18, and MSU-Ap-38.

Table 3. Performance of Creeping Bentgrass Varieties in 1975

Variety	Quality ratings[a] 4/16/75	6/24/75	8/5/75	10/13/75	Tupersan phytotoxicity[b] 12 lb/A	24 lb/A
Arlington	5.3	3.0	5.7	4.7	1.0	1.0
Cohansey	3.7	3.3	4.0	4.0	1.0	1.0
Collins	5.3	3.0	5.3	4.3	1.7	2.0
Congressional	3.7	3.0	4.7	4.3	1.0	1.0
Emerald	4.0	3.0	3.7	3.7	1.0	1.0
Metropolitan	6.3	3.7	6.3	5.0	1.0	1.0
Morrissey	4.3	3.0	3.7	3.7	1.0	1.0
MSU-Ap-18	6.3	2.3	4.0	4.0	3.3	4.3
MSU-Ap-28	5.3	2.3	3.3	4.0	1.0	1.0
MSU-Ap-38	5.0	2.0	2.3	2.7	2.0	3.0
Nimisilla	5.7	2.7	4.0	4.0	1.7	2.0
Old Orchard	4.7	3.0	4.3	3.0	2.0	2.7
Penncross	3.3	2.7	3.3	3.7	1.0	1.0
Pennlu	6.0	3.3	5.7	5.0	1.0	1.0
Pennpar	4.0	2.0	3.3	3.0	1.0	1.0
Seaside	6.0	3.7	6.3	5.7	1.0	1.0
Toronto	7.7	5.3	7.3	7.3	1.0	1.0
Washington	4.3	3.0	4.7	3.3	2.3	3.0

[a]1 represents best quality and 9 represents poorest quality.
[b]1 represents no injury and 9 represents complete necrosis of the treated turf.

PERENNIAL RYEGRASS VARIETY EVALUATION

Perennial ryegrass is usually considered a temporary lawn grass or a nurse grass in seed mixtures. In Illinois, deterioration during the summer months has prevented perennial ryegrass from becoming an important permanent turfgrass. Improved varieties with better color, density, mowing quality, and disease resistance have challenged the traditional image of perennial ryegrass.

In early spring Manhattan was the best variety, while Pennfine, which had some winter injury, was one of the worst (Table 4). By early summer Pennfine was the outstanding variety and provided the best appearing turf throughout the summer. The seasonal performance of Pennfine and Manhattan suggests that a blend of these two ryegrass varieties may provide good turfgrass quality throughout the growing season.

Table 4. Performance of Perennial Ryegrass Varieties in 1975

Variety	Quality rating[a] 4/16/76	6/27/75	8/5/75	10/9/75
Common	7.7	6.7	5.0	5.3
K8-137	5.3	3.7	3.7	3.7
K8-142	4.7	5.3	4.3	4.3
Manhattan	2.7	4.3	4.3	4.0
NK-100	5.7	5.3	5.3	5.0
NK-101	5.0	5.7	6.3	5.3
NK-200	3.3	4.3	5.3	4.7
Pelo	5.0	4.7	6.0	4.7
Pennfine	6.7	2.0	2.3	2.7

[a]1 represents best quality and 9 represents poorest quality.

PESTICIDE EFFECTS ON SOIL PHYSICAL PROPERTIES

I.J. Jansen and A.J. Turgeon

Thatchy turfs are known to be more susceptible to drought, insects, and diseases than thatch-free turfs. A closer look at thatchy turfs reveals low infiltration rates and poor rooting of the grass into the soil. These undesirable effects have commonly been attributed to the thatch directly. Recent work indicates that some of these effects might be caused by physical conditions of the soil that are indirectly related to thatch development rather than by the thatch itself.

Turgeon, Freeborg, and Bruce (1975) observed that use of calcium arsenate or Bandane herbicides on Kentucky bluegrass turf induced thatch development and destroyed the earthworm population. They also observed that infiltration seemed slower on the treated plots than on untreated plots. The slower infiltration in this instance could not be due to the thatch since the thatch had been removed.

Earthworms, particularly surface-feeding species such as *Lumbricus terrestris*, pull organic debris down into the soil. Much of the debris is eventually passed through their digestive systems where it is fragmented and partially decomposed (Edwards and Lofty, 1972). Soil structure is also improved by earthworm activity. Dixon and Peterson (1971) observed that the infiltration rate of soils increased in plots where the earthworm population was increased, and decreased in plots where the existing earthworm population was killed by treating with chlordane.

The accumulation of thatch on soils treated with calcium arsenate or Bandane herbicides can be attributed to the absence of earthworms that, had they been present, would have fragmented and incorporated the fresh organic material into the soil. In the absence of earthworms the physical condition of the soil under the thatch should be expected to deteriorate over time. The objective of this study was to determine whether such physical changes had actually occurred.

The first step was to confirm the difference in infiltration rate. Infiltration rates in an untreated plot and in a plot treated with calcium arsenate were measured, using a variation of the falling head, double ring method. The infiltration rate was found to be significantly less for the soils treated with calcium arsenate than for the untreated soils.

Hydraulic conductivity of the surface soil was measured in the laboratory. When the thatch was removed, saturated hydraulic conductivity was much lower in soils from the plots treated with calcium arsenate than in soils from untreated plots. This indicates that there are fewer large pores in the treated soils, probably reflecting poorer structure and the absence of earthworm channels.

The control samples had a higher hydraulic conductivity when the top face of the sample was cut just below the soil surface than when the soil surface was left

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undisturbed. This indicates that some of the large soil pores in the control soils are closed at the soil surface, making them ineffective for conducting water. Cutting the soil just below the surface opened those pores so that water could move into them readily.

When a similar comparison was made using samples from the calcium arsenate treated plots, an opposite effect was observed. In this instance there was a layer of thatch about one inch thick on the soil surface. The "cut surface" samples were cut just below the soil surface, removing all of the thatch, so that the 3-inch-long core on which the test was made was all soil. For the "undisturbed surface" determination, the sample cores actually consisted of about 1 inch of thatch and only 2 inches of soil.

The observed conductivity was higher for the "undisturbed surface" (soil plus thatch) samples than for the "cut surface" (soil only) samples, indicating that water flows through the thatch more readily than through the soil.

The water retention characteristics of soil from the plots treated with calcium arsenate were compared to those of soil from untreated plots. The untreated soils released more water in the 0 to 1 bar tension range than did soils treated with calcium arsenate. This indicates that the calcium arsenate treatment had resulted in a change in the pore size distribution. The cessation of earthworm activity and subsequent deterioration of soil structure are apparently responsible for this observed difference.

The difference in soil structure and porosity is confirmed by the bulk density data, which indicate that soil from the plots treated with calcium arsenate is denser than that from the control plots. The treated soils also were lower in organic matter than the untreated soils. In the absence of earthworms, much of the fresh organic debris was left on the soil surface rather than being fragmented and incorporated by the worms.

There clearly are measurable changes in the physical properties of soils associated with thatch development upon treatment of bluegrass turf with calcium arsenate. The physical changes in the soil could be responsible for some of the undesirable effects that are commonly associated with thatch. Further work is needed to determine whether similar physical changes of the soil are associated with thatch development when the thatch has not been induced by use of a toxic chemical.

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PESTICIDE EFFECTS ON SOIL MICROFLORA

Michael A. Cole

Repeated annual applications of calcium arsenate and bandane have a variety of effects upon the physical and biological characteristics of soil underlying turfgrass. Prominent among the biological effects are the disappearance of earthworms and the accumulation of thatch.

The accumulation of thatch in the arsenate- and bandane-treated plots indicated that either the rate of thatch formation was increased or the rate of thatch decomposition by soil microorganisms was decreased in comparison to these processes in control plots. Since the amount of verdure was nearly equal in all plots, regardless of treatment, inhibition of microbial decomposition of grass residues seemed likely. This presentation is a preliminary description of microbial activity in the thatch and underlying soil in plots to which arsenate, bandane, or no herbicide was applied.

Microbial decomposition of plant residues requires a large number and variety of different microbes, and the habitat must be one in which the microbes present are active. Total numbers of bacteria and fungi and enzyme activity were examined as indicators of microbial activity in the samples.

Bacterial numbers in bandane-treated soil were higher than those in untreated soil, while there was no difference between arsenate-treated and untreated soils. The distribution of bacteria was substantially modified in both arsenate- and bandane-treated plots, with proportionately more bacteria in the thatch than in the soil, when compared to untreated plots; no change in fungal distribution or numbers was observed.

ENZYME ACTIVITY

Microbial numbers alone do not provide a complete picture of microbial activity in natural habitats because many of the organisms that grow when plated are not active *in situ*. For this reason, enzyme levels in thatch and soil were measured as indicators of *in situ* degradative activity and as a measure of biosynthetic capabilities in the samples. Amylase, cellulase, and invertase were selected because these enzymes are required for degradation of those carbohydrates that make up a large percentage of grass clippings. Enzyme levels in arsenate- and bandane-treated thatch were substantially higher than in the loose organic debris from untreated plots, but there was no difference in soil enzyme levels among the samples.

An indeterminate but possibly large fraction of the increased enzyme levels in thatch can be attributed to plant root enzymes, but the fact remains that herbicide treatment does not result in a decrease in total enzyme activity.

The abundance of bacteria that produce various degradative enzymes was examined in samples from all plots. There was no difference in abundance associated with

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herbicide application, with the exception of an increased abundance of amylase producers in the bandane-treated thatch.

On the basis of the data presented, there was no indication of a reduced ability of the microbes to degrade the major macromolecules in grass clippings. The total number of microorganisms was either increased or unchanged, the abundance of specific metabolic groups was largely unchanged, and enzyme activity determined *in situ* was much higher in thatch from the treated plots.

The one striking anomaly in the data is the equality of microbial numbers and enzyme activity in the soil underlying the thatch. In most cases the presence of more organic or inorganic nutrients is accompanied by increased microbial numbers and activity. The absence of this expected increase in thatchy soil suggests that soil organisms were unable to respond in a normal manner to the additional nutrients in undecomposed thatch.

Enzyme synthesis was used as a direct measure of the ability of organisms to respond to additional nutrients. Amylase was chosen as the test enzyme for these experiments because a high percentage of soil bacteria produce this enzyme. It is required at the beginning of the degradative pathway for starch in soil; if amylase cannot be made, the starch is not degraded, and all related processes will not occur. The synthesis of this enzyme is a complex process with a number of requirements, including the presence of metabolically active, live cells; abundant energy and precursors; availability of inorganic nutrients such as nitrogen and phosphorus from which precursors are made; and absence of toxic materials that would inhibit enzyme synthesis. If any one of these requirements is not met, the observed result would be a decrease in the rate of enzyme synthesis or a lower total quantity of enzyme synthesized over a period of time.

The following results for amylase synthesis in soil from arsenate-treated, bandane-treated, and untreated plots were observed. In the untreated soil, amylase activity increased steadily with time. There was also an increase in the arsenate-treated soil, but enzyme levels were lower than that of the control at all sample times except after 10 days. In bandane-treated soil the rate is identical to that of the control for the first 48 hours, then decreases; this pattern of synthesis indicates that in some manner bandane somewhat reduces the ability of soil organisms to synthesize enzymes but this limitation is not immediately expressed. The total quantity of enzyme present over the 10-day period was significantly less in the arsenate- and bandane-treated soils than in the untreated soil.

These results provide a possible explanation for the lack of difference in enzyme levels and microbial numbers in soil and a possible basis for thatch accumulation. The normal microbial response to additional carbon and energy sources, such as grass clippings and starch, is to increase microbial numbers and activity. The data strongly suggest that a major effect of both arsenate and bandane is to reduce this normal increase in soil microbial activity. Consequently, the rate of decomposition is not increased in proportion to an increase in nutrient availability, and the rate of disappearance of grass clippings thus becomes proportionately less than the rate of addition of clippings.

NITRIFICATION STUDIES

Most of the ammonia formed in soil from organic matter or added as ammonium or urea fertilizers is converted to nitrate by nitrifying bacteria. These bacteria, like other soil organisms, respond to increased supplies of energy sources by increasing cell numbers, cell activity, or both. When ammonium chloride was added to turfgrass soil, the initial rates (first two weeks) of nitrate formation were identical in all samples. However, the organisms in the bandane- and arsenate-treated soils did not respond as quickly to the additional energy source as the organisms in the untreated soil. The result of this slow response was an increasingly greater difference in nitrification rate among the samples with longer incubation times. Total nitrifying activity over a four-week period was 20 percent lower in bandane-treated plots and 25 percent lower in arsenate-treated plots than in the untreated plots.

The rates of nitrate utilization were nearly identical in all samples; therefore, the lower nitrate levels in arsenate- and bandane-treated plots can be attributed to a reduction in activity of nitrifying bacteria. Nitrite, the intermediate between ammonia and nitrate, was not present in significant quantities in any soil, indicating that the total activity of the ammonia-oxidizing bacteria was reduced but the nitrite-oxidizing organisms were unaffected. The result of this inhibition is that a larger percentage of ammonium fertilizer-nitrogen remains in the ammonium form in arsenate- and bandane-treated soils. In soils with a high ammonium-binding capacity, such as the soils used in this study, nitrogen availability may be reduced somewhat.

DISCUSSION

The comparative inability of soil organisms in arsenate- and bandane-treated soils to respond quickly to additional nutrients is shown in both the amylase synthesis studies and the nitrification studies by the relative response time of arsenate > bandane > untreated. This identical relationship obtained with two very different groups of soil organisms suggests a generalized effect of arsenate and bandane upon microbial biosynthesis. The mechanism by which two compounds of such different structure can have the same effect is unknown at this time but will be the subject of future investigations.

COMPARISON OF WASHED (SOILLESS) AND UNWASHED SOD

J.E. Renaud and A.J. Turgeon

Sodding has become widely used as a method of turfgrass propagation because of its ability to allow rapid establishment of high quality turf. A new approach to this conventional method was introduced by Warren's Turf Nursery with the development of soilless sod, obtained by using an automatic sod washing device.

Some obvious advantages of soilless sod include reduction in sod weight, which permits lower shipping cost and easier handling of sod at the transplant site; reclamation and reuse of soil that is removed from the sod in the washing process; and elimination of the potentially troublesome interface between the soil carried with the sod and the soil at the transplant site. This latter advantage may be especially important where sod is planted on a sand growing medium such as that utilized in the PAT system and often in the development of new greens.

Washed (soilless) and unwashed sod sections measuring 9 by 11 inches were planted in root observation boxes. Both sod types were planted on soil and sand growing media, and each treatment was replicated three times. Thirteen days after planting, root development was measured at three soil depths. This experiment was conducted in late May and again in late July.

The results indicated that the root development of washed sod was substantially better than that observed from unwashed sod when planted in the spring. Both sod types showed a greater response when planted on a sand medium than on a soil medium. The results were reversed when the same experiment was conducted in the summer under much higher temperatures. It appears that the absence of soil reduces the stress tolerance of the washed sod and, therefore, results in poor root development under conditions of climatic stress. When climatic stress is not a major factor, the elimination of the soil interface under the planted washed sod allows for better root development.

To determine sod rooting strength, washed and unwashed sod sections measuring 12 by 12 inches were placed on top of rooting screens that were then planted on both soil and sand growing media. Muck-grown sod was used, and each treatment was replicated six times. After three weeks hooks were attached to the screens and the force required to extract the sod sections from the underlying growing media was measured. The results indicated that the rooting strength of the washed sod was generally higher than that of the unwashed sod.

The effects of sod moisture on the weight and surface area of the sod were studied by saturating 12 by 12 inch sections of washed and unwashed sod and determining the weight and area losses after air-drying the sod sections for several days. Results showed that moisture loss and shrinkage were greatest in the washed sod. Since sod shrinkage at the planting site does not favorably affect

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the establishment and appearance of new grass, irrigation becomes more critical where soilless sod is planted.

A sod-washing apparatus designed and constructed by Warren's Turf Nursery was used to study the effects of automated washing on sod weight and sod strength. Sod sections measuring 1.5 by 6 feet were run through the washing apparatus 1, 2, 3, 4, or 5 times; each section was then immediately weighed and tested for sod strength, using a sod stretching device. For comparison, unwashed sod sections were saturated with water by careful soaking to avoid soil loss, and these were also weighed and tested for sod strength. Results showed a significant loss of sod strength after one washing but no significant loss of sod strength from successive washings. Saturating unwashed sod also resulted in a substantial loss of sod strength. Hence, the loss of sod strength from washing was not due to soil removal but rather from the addition of moisture to the sod. It appears that the addition of water has a lubricating effect on the intermingled roots and rhizomes that provide sod strength.

Washing the sod sections did result in a reduction in sod weight; however, the weight loss was partially offset by the weight of the water added to the sod from washing. Thus, a more effective means of reducing sod weight after washing would be desirable in order to optimize the advantage of reduced sod weight when using soilless sod.

PROTEIN AND XANTHOPHYLL CONTENT OF TURFGRASS CLIPPINGS

A.J. Turgeon

Mowing is one of the primary cultural practices necessary for sustaining turf. The clippings from regular mowing are either picked up and discarded or returned to the turf, where they decompose. In view of the traditional use of grasses for forage, it is likely that processed turfgrass clippings could be successfully used for feeding livestock and other animals. Because turfgrass cultivars and cultural practices are substantially different from those of forage production, investigations were initiated in 1975 to determine the relationships of turfgrass species and cultivars, mowing, and fertilization to the nutritive value of clippings from turfs.

Lutein, a nonepoxide xanthophyll important as a pigmenting agent in poultry feeds, was found to occur in large quantities in Kentucky bluegrass clippings from sod farms in California. Clippings were collected from 20 Kentucky bluegrasses, 4 perennial ryegrasses, and K-31 tall fescue in May, 1975, and analyzed for lutein using an acetone extraction and thin-layer chromatographic (TLC) separation of the pigments. Colorimetric determination of lutein was made from extracts from the TLC plates. Lutein levels ranged from a low of 72 mg/kg fresh weight in Vantage Kentucky bluegrass to a high of 358 mg/kg in Adelphi Kentucky bluegrass. The average lutein level of all 20 bluegrasses was 240 mg/kg. The perennial ryegrass varieties varied from a high of 347 mg/kg in Pennfine to a low of 241 mg/kg in NK-200; the average level of the four varieties was 275 mg/kg. Thus, selection of a particular turfgrass cultivar substantially affects the lutein yield from the clippings. Clippings were also collected from Kentucky bluegrass fertilized with 0, 0.5, 1.0, or 2.0 pounds of nitrogen per 1,000 square feet per month. Results showed that lutein increased significantly with increasing fertilization, but the increases were of a relatively low magnitude. Fertilization with 0.5 pound of nitrogen resulted in a 10 percent increase in lutein over the unfertilized turf, while 1 and 2 pounds of nitrogen yielded lutein increases of 4 and 7 percent, respectively.

Turfgrass clippings offer a potentially important source of protein in animal feeds, especially for ruminants (sheep, cattle), which can digest the cellulose and other constituents of the plant tissue. Protein levels were determined in dried clippings by Kjeldahl analysis for total nitrogen (X 6.25 for conversion of total nitrogen to crude protein) in 53 Kentucky bluegrasses and 8 perennial ryegrasses. Within the Kentucky bluegrasses, crude protein levels ranged from 22 percent to nearly 33 percent, depending upon cultivar, while the perennial ryegrasses ranged from 26.3 to 30.2 percent crude protein.

The effects of mowing height, mowing frequency, and nitrogen fertilization on the crude protein level in Kentucky bluegrass clippings were also determined. Results showed a range of crude protein levels from 20.3 to 36.8 percent with the higher levels occurring in plots maintained under close mowing (0.75 inch) and high rates of nitrogen fertilization (2 pounds of nitrogen per 1,000 square feet per month); there was no significant effect from mowing frequency. In a similar study on tall

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fescue, closer mowing and high nitrogen fertilization also yielded the highest crude protein levels in clippings.

The timing of nitrogen fertilization substantially affected the crude protein levels in clippings from Kentucky bluegrass. Clippings harvested in late May from plots receiving 2 pounds of nitrogen per 1,000 square feet in April and again in May were higher in crude protein (33.9 percent) than plots receiving nitrogen at other times during the growing season. Also, late season applications of nitrogen (October or December) resulted in high crude protein levels the following May.

The nitrogen carrier used in fertilizing Kentucky bluegrass significantly affected the crude protein level in clippings. Urea, the only soluble form of nitrogen used, yielded the highest level of crude protein, while UF and IBDU applications resulted in the lowest crude protein yield.

Additional studies with turfgrass clippings are currently underway in the Animal Science Department under the supervision of Frank Hinds. Dehydrated clipping pellets are being fed to sheep to determine the digestibility of the pellets in ruminants. Dr. Hinds is also evaluating clippings from Kentucky bluegrass and tall fescue turfs for their digestibility through laboratory analyses.

VEGETATIVE ESTABLISHMENT OF COOL-SEASON TURF FROM PLUGS

A.J. Turgeon and E.G. Solon

Research at the University of Illinois has shown that vegetative establishment of weed-free A-20 Kentucky bluegrass turf can be accomplished by using closely-spaced plugs of sod in conjunction with oxadiazon (Ronstar 2G) herbicide application to a prepared soil (Solon and Turgeon, 1975, 1975a). A study was undertaken in May, 1975, to determine the effects of mowing height and fertilization level on the rate of coverage by a planting of A-20 plugs subsequently treated with Ronstar 2G at 3 pounds of active ingredient (a.i.) per acre. Mowing heights were 0.75, 1.5, and 3.0 inches and no mowing; fertilization rates were 0, 0.5, 1, and 2 pounds of nitrogen per 1,000 square feet per month. Plots measured 12 by 6 feet, and each treatment combination was replicated three times.

The fastest rate of coverage by A-20 occurred in the unmowed plots, or under a 3-inch mowing height and a minimum of 1 pound of nitrogen per 1,000 square feet per month. Unacceptably slow lateral growth of the plugs occurred under the 0.75-inch mowing height regardless of fertilization level. At the 1.5-inch cutting height, 0.5 pound of nitrogen per 1,000 square feet per month was adequate to provide optimum lateral growth from the plugs. Since the smoothness of the turf decreased with increasing mowing height, it was concluded that a mowing height between 1.5 and 3.0 inches and monthly fertilization between 0.5 and 1.0 pound of nitrogen per 1,000 square feet constitute a reasonable compromise for achieving rapid establishment of a smooth turf.

Since all previous studies were performed with A-20 Kentucky bluegrass, a study was undertaken in May, 1975, to determine the adaptability of other varieties to this method of establishment. Three replications of 2 by 2 feet plots were planted with four 2-inch plugs each of 48 Kentucky bluegrass varieties. Ronstar 2G was then applied at 3 lb.a.i./acre.

The condition of plugs of the Kentucky bluegrasses treated with Ronstar ranged from no injury to complete necrosis, depending upon variety (Table 1). Thus, plugging in conjunction with Ronstar application is not a feasible establishment method for all varieties, and careful attention should be paid to the type of sod used. Furthermore, these results suggest that Ronstar should not be used on those turfs composed of varieties shown to be highly injured on Table 1.

Plugs of three creeping bentgrass varieties (Toronto, Pennpar, and Cohansey) were machine-planted and treated with several preemergence herbicides in June to determine the feasibility of this establishment method for bentgrass. Herbicide treatments included bensulide (Betasan 3.6G) at 10 and 20 lb.a.i./acre, oxadiazon (Ronstar 2G) at 2 and 4 lb.a.i./acre, benefin (Balan 2.5G) at 3 lb.a.i./acre, and DCPA (Dacthal 5G) at 12 and 24 lb.a.i./acre. Plots measured 5 by 6 feet, and each treatment was replicated three times.

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Table 1. Phytotoxic Effect of Ronstar Applied to Field-Planted Plugs of Kentucky Bluegrass Varieties

Phytotoxicity rating	Kentucky bluegrass varieties
High	Campina, EVB-305, K1-157, Merion, P-59, Parade, Park, Pennstar
Moderate	Adelphi, Ba 61-91, Bonnieblue, Cheri, EVB-391, Fylking, K1-138, K1-155, Kenblue, Monopoly, Nugget, P-140, PSU-190, Sydsport, Touchdown
Low	A-20, Ba 62-55, Baron, Edmundi, EVB-307, Galaxy, Geronimo, K1-131, K1-132, K1-133, K1-143, Majestic, Plush, PSU-197, RAM #1, RAM #2, Sodco, Vantage, Victa
None	A-34, Brunswick, Glade, PSU-150, PSU-169, Windsor

The results from the bentgrass study indicate that Ronstar and Balan are too injurious to be practical for this use and that Betasan offers the best potential for controlling weeds during vegetative establishment of creeping bentgrass turf from plugs. Dacthal, although not injurious to bentgrass, was ineffective in controlling the weeds.

Conclusions from these studies are tentative and may be modified by subsequent observations of the plots.

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TURFGRASS RENOVATION WITH GLYPHOSATE

K.A. Hurto, A.J. Turgeon, and J.A. Tweedy

Maintenance of quality turf involves sustaining a uniform plant community free of undesired weedy species. Selection of adapted turfgrass species and proper cultural practices help achieve this goal. Most of the weedy species that infest established turfgrass communities can be effectively controlled without adversely affecting the desired plant community. The use of selective herbicides has allowed for removal of unwanted annual grasses and broadleaf weeds. However, there is no herbicide presently on the market that will selectively remove unwanted perennial grasses. To remove these weedy types, the infested area must be renovated. An effective turfgrass renovation program consists of two steps:

1. Effective control of the existing vegetative cover.

2. Immediate reestablishment of the treated area.

Control of existing vegetation usually requires applications of herbicides. Amitrole and dalapon have been recommended in the past for controlling rhizomatous perennial grasses. Although these herbicides are translocated throughout the plant, they are generally not completely effective in controlling regrowth from the rhizomes. An additional reason for ineffectiveness of these herbicides in a renovation program has been their soil-residual activity, which can delay reestablishment of the treated area for up to six weeks.

Over the past few years glyphosate, a nonselective translocative herbicide, has been evaluated for its ability to control perennial rhizomatous grasses. Control has been superior to that with currently recommended herbicides *(7, 8, 9)*. However, complete control has not been achieved from single applications. It appears that translocation of glyphosate into the plant's rhizomes is not in sufficient quantities to completely suppress regrowth from rhizomes. Rates of glyphosate as high as 6 pounds per acre were ineffective in controlling rhizomatous perennial grasses *(3, 4)*. Several researchers have reported that time of application *(1, 2, 3, 5)* and foliage height at time of treatment affect control of perennial grassy weeds *(1, 3, 6)*.

Studies were initiated in 1974 at Southern Illinois University to evaluate methods for enhancing the control of glyphosate-treated bermudagrass. In field studies, glyphosate was applied at rates of 2, 4, and 6 pounds per acre. Two separate studies were initiated--in late August on an actively growing stand and in late September on a slower growing stand--to determine if applications of one pound of paraquat 7 to 14 days after treatment with glyphosate would enhance bermudagrass control.

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Results from these studies showed that bermudagrass was not completely suppressed at any of the applied rates. Applications of paraquat to glyphosate-treated bermudagrass did enhance control but failed to give consistent supression throughout the study. It appears that mobility and accumulation of glyphosate in rhizomes are affected by another factor besides rate. Time of year or metabolic activity of the plant seems to affect glyphosate efficacy. Studies are currently being conducted at Southern Illinois University to further explore these possibilities.

Studies conducted this fall at the University of Illinois have shown glyphosate to have no adverse affects on reestablishment of Kentucky bluegrass or perennial ryegrass by seed. Applications of glyphosate at rates up to 16 pounds per acre, applied either preplant incorporated or preemergent to a prepared seedbed, had no significant effects on stand density or clipping yield. A study of methods of reestablishment in a glyphosate-treated tall fescue sod showed differences in turfgrass coverage. Best coverage was obtained where core cultivation was followed by broadcast seeding and vertical mowing. Results were comparable from disc seeding or broadcast seeding followed by vertical mowing. Broadcast seeding alone resulted in poor stand coverage. Disc seeding was the most efficient in terms of labor and seed required. It should be noted, however, that when reseeding with a disc seeder a time lag is required between glyphosate treatment and reseeding. This allows for adequate translocation of the herbicide within the rhizome system prior to possible severence of the rhizomes by the disc seeder.

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TURFGRASSES RESEARCH FOR THE TRANSITION ZONE

H.L. Portz

Turfgrass research underway and planned at Southern Illinois University and outlying locations emphasizes the particular problems and needs of the transition zone. As determined by the USDA Plant Hardiness Map, southern Illinois is mostly in Zone 6 but is bordered by Zone 5 on the north and Zone 7 on the south. This entails a range of conditions often too hot and humid for cool-season turfgrasses and too cold for warm-season turfgrasses during parts of a year or in certain years. Besides the Carbondale locations there are other turfgrass research locations within this transitional area (or "Crabgrass Belt"), cooperative with the University of Illinois, the University of Missouri, and the Old Warson Country Club. Note locations in the concluding outline.

Research in adapting turfgrasses for the transition zone includes various cool-season and warm-season species and cultivars and many blends and mixtures. Kentucky bluegrass and perennial ryegrass cultivars have been tested for several years at the Belleville Research Center, and new seedings have been made at three locations. In 1975, 17 bermudagrass cultivars and 9 zoysiagrass cultivars were sprigged at Carbondale, 12 bermudagrasses and 10 zoysiagrasses at Old Warson Country Club, and 6 cultivars of the two species in large blocks at the Belleville Research Center. Sources of these grasses were R.A. Keen, Kansas State University; Bill Lobenstein, University of Missouri; Northrup, King and Co.; and the USDA.

Management studies in establishment and maintenance of turfgrasses are underway with initial emphasis on low-maintenance programs and late fall nitrogen fertilization. Work with herbicides and growth retardants continues with major inputs by Drs. J. Tweedy and D. Elkins of Southern Illinois University. New perennial ryegrass and tall fescue cultivars and various combinations with Kentucky bluegrass are being tested for athletic fields and lawn use.

Low-temperature studies with new cultivars of bermudagrass, zoysiagrass, and perennial ryegrass will include testing for cold hardiness and winter damage. An especially important area to be researched involves increased utilization of warm-season grasses for golf courses, athletic fields, and lawns in the transition zone. Fall-color retentions by means of fertilizers, fungicides, and colorants show promise. Mixtures of warm-season and cool-season turfgrasses such as bermudagrass and perennial ryegrass or Kentucky bluegrass are being tested along with timely cultural, fertilizer, and other practices to maintain an acceptable year-round turf in the area. Overseeding to mask the dormant warm-season grass or to periodically reestablish and strengthen the mixture is also being tested. What is really needed is for someone to breed a WS 10-30 turfgrass that can handle all our variable winter/summer conditions, much as we have an all-season motor oil. An

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outline of the turfgrass research program at Southern Illinois University follows. Results will be reported in succeeding years.

FIELD RESEARCH FACILITIES AND STUDIES

Carbondale	Horticulture Research Center
	P.L.S.S. Research Greenhouses
	Illinois Horticulture Experiment Station
Belleville[1]	Belleville Research Center
	Scott Air Force Base
St. Louis[2]	Old Warson Country Club
Southern Illinois	Campus and area athletic fields
	Area golf courses
	Local parks and lawns

Adaptation Studies

Emphasis is on selection of adapted Kentucky bluegrass cultivars and alternative species for lawns, parks, athletic fields, and golf course fairways and tees for the transition zone:

Kentucky bluegrass cultivars and blends.
Perennial ryegrass cultivars and mixtures with Kentucky bluegrass.
Tall fescue and meadow fescue cultivars and mixtures with Kentucky bluegrass.
Fine-leaf fescues--species, cultivars, and mixtures.
Warm-season grasses--bermudagrass and zoysiagrass cultivars.

Management Studies

Mowing, fertilization, irrigation--combinations and levels of maintenance (especially including low-maintenance programs).
Herbicides (with J. Tweedy)--annual and perennial weeds, weedy grass elimination, and renovation.
Growth retardants (with D. Elkins)--low-maintenance turf areas.
Lawn establishment, renovation, and cultivation procedures.
Disease and insect control--combination of cultural and chemical methods.
Fertilization--N sources, amounts, timing (especially fall fertilization).
Golf courses--green, fairway, and tee improvement.
Athletic fields--improve drainage and test new perennial ryegrasses, tall fescues, and maintenance practices.

Low-Temperature Studies (Field, Greenhouse, and Cold Cabinets)

Dormancy and cold hardiness--genetic, chemical, cultural, fertilization, and other treatments.
Frost-heaving and other winter-damage problems.
Cold-testing new cultivars of bermudagrass, zoysiagrass, and perennial ryegrass.
Winter overseeding of warm-season grasses in the transition zone.
Color retention in warm-season grasses, use of colorants, and warm-season/cool-season turfgrass mixtures.

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[1] *Cooperative with University of Illinois.*
[2] *Cooperative with University of Illinois, University of Missouri, and Old Warson Country Club.*

GOLF TURF SESSION

A NEW KIND OF *PYTHIUM*

Kenneth L. Quandt

The summer of 1975 was perhaps the worst we have experienced in many years. The spring was extremely wet and cold, and the summer was brutally hot and even wetter. We recorded 43 days (far more than average) of 90° F. or higher temperatures, beginning as early as mid-May and lasting until late August.

With weather like that, almost anything could happen; as it turned out, almost everything did happen to some of my greens. It was almost as if I had fooled Mother Nature in some way and she was punishing me for my indiscretion.

For instance, on Tuesday, June 24th, I noticed that some of my greens were going off-color even though the fertility level was quite high. I thought that they might be coming down with red leaf spot. At the time the temperatures were in the 70's and 80's by day and in the low 60's at night.

On Wednesday, June 25th, we sprayed with 8 ounces of Daconil and 2 ounces of Actidione TGF per 1,000 square feet. The next day the greens hadn't really improved, but they didn't look any worse either. I thought that I might have stopped whatever it was that was causing the discoloration.

By Friday, however, it was obvious that I had not stopped the disease at all. Some of my greens turned almost completely yellow that day, and some areas began to die. This yellowing began at the leaf tips and progressed downward toward the crowns. It looked very similar to the symptoms caused by red leaf spot. There was no mycelial growth visible on the turf.

Unable to come up with a reason for the damage being done, I called Dr. Turgeon at the University of Illinois and described the symptoms to him. He said it sounded like *Pythium graminicolum*, which he had seen in other parts of the state. He recommended Tersan SP as a control.

On Friday evening we applied 6 ounces of Tersan SP per 1,000 square feet; by Sunday morning the turf that was still alive was regaining its color. Unfortunately, however, much of the turf had already been killed. Some of the greens were more than half destroyed.

The disease was not, however, through with us yet. It attacked three more times during the rest of the summer. The next attacks came on July 16, August 20, and finally on September 10th. The last outbreak of *Pythium* came when night temperatures were in the low 50's and day temperatures were in the upper 60's and low 70's. I discovered later that anytime I left Tersan SP out of my spray program for more than 14 to 16 days the disease returned.

The disease didn't seem to have a preference for any particular kind of grass. It seemed equally happy chewing on C-15, Penncross, Washington, or *Poa annua*. The

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only consistent factor seemed to be wet, poorly drained soil. The greens that were most severely affected by the disease were those most poorly drained.

Once we felt that we had the disease under control, we began trying to get the greens to recover. We first aerated, topdressed, overseeded, and fertilized them. In about six days we began to see green fuzz and within ten days the dead areas were turning green. However, a few days later, much to my dismay, the seedlings began to shrivel and die. No amount of syringing or anything else seemed to help them.

In disgust we ripped out the dead areas and resodded them with some nice healthy Penncross sod that had just a little bit of crabgrass in it. The sod looked healthy for a few days and then began to slowly decline. The only thing that seemed to thrive was the crabgrass. Eventually, approximately half of the new sod died, especially in the low, wet areas.

Of course, the fact that we got 6 inches of rain in July and 6 1/2 inches in August, coupled with blazing heat, probably didn't do very much to help matters either.

Furthermore, despite all the fertilizer and fungicides we had applied, we just couldn't seem to get any growth out of the greens. Not only were the new seedlings and the new sod not growing, but also the grass that had survived the initial *Pythium* attack was not growing. We were mowing some of the greens only once or twice a week and still not getting very many clippings from them. In addition, much of the turf, especially the *Poa annua*, developed a severe discoloration of the leaf tips; some even turned white.

Well, as you might guess, by this time a number of baffling questions were bothering me. Why was *Pythium graminicolum*, which is normally a saprophytic organism, suddenly becoming such a powerful parasite of my turf? Why was the recovery rate of the diseased greens so slow? Why didn't the turf respond to fertilizer and other treatments?

When we first began to have problems with our greens, we shipped soil and plant samples to the University of Illinois. It was from these samples that they confirmed that the culprit was indeed *Pythium graminicolum*. That, I expected; but about the middle of August they came up with something I had not expected. They found that my soils were infested with unbelievably high populations of nematodes.

We found that we had three different kinds of parasitic nematodes in our greens: stunt nematodes, spiral nematodes, and root-knot nematodes. The spiral and the stunt nematodes were the most numerous. The root-knot nematodes were the least numerous but the most pathogenic of the three. Interestingly enough, the greens that were the most severely damaged by the *Pythium* also had the highest nematode counts.

This nematode thing fascinated me so I looked up some information on nematodes and how they might affect turf. I found that the symptoms of nematode infested turf include the following:

1. Poor plant growth, especially during the summer.
2. Turf that thins out and does not respond to fertilizer or water applications.
3. Shallow root systems, with individual roots usually brownish in color.
4. A slow decline in the plants, with the parts above ground being stunted and yellowish and exhibiting food deficiency symptoms.
5. A discoloration or even death of the leaf tips.

6. Weeds thriving where the turf does not.
7. An increased susceptibility to fungus diseases due to the open wounds on the roots caused by the feeding nematodes and by the weakened conditions of the plants.

Suddenly, everything began to fall into place and make sense. What had been totally baffling before made sense when nematodes were injected into the equation. The presence of nematodes would account for the susceptibility of the turf to *Pythium graminicolum*, for the lack of response to fertilizer, and for the slow recovery rates.

Putting everything together, then, into what we will have to call "Quandt's Theory," we can explain what happened to my turf. Prior to the attack of *Pythium graminicolum*, we had high nematode populations but there was enough turf to feed all of them. However, the feeding nematodes weakened the turf and left open wounds on the roots that served as ports of entry for the fungi. After much of the turf had been killed by the *Pythium*, there wasn't enough left to feed the entire nematode population. The nematodes then ganged up on the surviving turf, which completely sapped its strength and kept it from growing. They were also responsible for the demise of the sod and seedlings because they kept the plants from establishing healthy roots.

Upon learning of the high nematode levels, we immediately ordered a nematicide called Nemacur. However, this nematicide was in short supply and we were unable to get any until September. We applied Nemacur to five of our greens in September; six weeks later we had some soil samples from them analyzed for nematodes. Unfortunately, we could not draw any conclusions as to the effectiveness of the chemical because the nematode populations were already declining due to the cool fall weather; even the check plots where no nematicide had been applied showed a reduction in nematode levels. In the spring of 1976 we will have more soil samples analyzed for nematodes before we apply any nematicides. After the nematicides are applied we will wait six to eight weeks and then have more samples tested to determine how effective the nematicide has been.

ZOYSIA ESTABLISHMENT AND CULTURE IN THE TRANSITION ZONE

Jim Manka

Meyer zoysia Z-52, an individual plant selection made at the Arlington Farms of the U.S. Department of Agriculture in 1940, is a grass plant that spreads by an intergradation of stolons and rhizomes to form a tight, vigorous, upright, tough, prostrate-type turf. This growth habit produces an almost weed-free turf. Its outstanding characteristics are drought resistance and heat hardiness, but survival of Meyers in solid shade is very poor. The plant tolerates a wide range of soil types and pH ranges. However, it does best on a well-drained sandy soil. Propagation is by vegetative material in the form of sprigs, plugs, or sod. This material may be planted by several methods. Hydromulching and sodding have met with great success. Since a minimum temperature of 60° F. is required for shoot growth, sprig planting must be accomplished in a limited growing season.

Mowing practices will greatly determine your success of zoysia management. A 3/4" cutting height will produce a desirable golf turf and yet reduce excess thatch buildup. Reel-type mowers are a must in maintaining good zoysia turf. At Old Warson we cut fairways every other day; every third cut is crossways to the fairway. We alternate seven- and nine-gang sets of fairway units to prevent tracking and wear problems. Constant mowing in the same pattern will establish a wear pattern within 5 to 6 weeks even during the growing season. Again, a cut of more than 3/4" will create many problems.

Meyer zoysia exhibits a high resistance to drought. Yet frequent irrigation of established zoysia sod will stimulate growth. It is very important to keep sprigs and plugs moist during early growth stages. A combination of fertilizer and daily watering may produce playable turf from sprigs in a year.

Proper or necessary levels of nitrogen are still subject to review. After sprigs have formed a sod-type turf, I believe 2 pounds of nitrogen per 1,000 square feet per year will maintain a good playable turf. A split application of 1 pound nitrogen applied during spring greenup time followed by a final 1 pound application of nitrogen no later than August 10 has proved successful. This will allow for early frost conditions, which can happen in our area. Excessive fertilization only promotes a heavy thatch buildup.

The tight nature of growth of zoysia inhibits many weeds from germinating. Still, the darlings of the weeds in our area, goosegrass and *Poa annua*, exist. In controlling these weed problems, we have observed temporary discolorations, that last 5 to 7 days after applications of 2,4-D, AMA, and Daconate (MSMA). Zoysia grass is tolerant of simazine and atrazine, but the rates of application are affected by temperature and sunlight. Keep in mind the undesirable side effects these chemicals produce. Improper timing of paraquat to control *Poa annua* can cause disaster.

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As with other warm-season grasses, verticut operations are very important, Sufficient and efficient equipment is necessary for this operation. Spring greenup and warm temperatures serve as a proven timing guide for verticutting. After a heavy dethatching program, the golfer should be able to play summer rules within 4 to 5 weeks. A *severe* verticutting may be necessary no more than every three or four years if other good management practices are adhered to. The biggest problem we presently have is the disposal of the dethatched material. Again: Verticutting is necessary to maintain good zoysia turf.

Another problem of zoysia turf in the transition zone is that of injury during the dormancy period. Golf cart traffic at clubs with heavy winter play has caused damage to zoysia approaches and channels of concentrated traffic. In Japan many golf clubs have alternate greens of cool-season grass that are played when their zoysia greens are subject to injury. For those who object to the brown wintertime color, the use of colorants may be a solution. This will not change the playability of the turf, and the axiom that you play golf off grass and not on color remains valid. The practice of overseeding to obtain a green turf is debatable.

SOIL MOISTURE—ITS IMPORTANCE IN TURFGRASS CULTURE

P.E. Rieke

Water is said to be the single most important compound in nature. Its use is certainly one of the very important keys to wise turfgrass management. The healthy, actively growing turfgrass plant is 75 to 85 percent water, depending on the type of grass and the environmental conditions. On a molecular basis, over 99 percent of all molecules in the turfgrass plant are water molecules. A reduction by as little as 10 percent could lead to death of the plant (Beard, 1973).

Water in a plant has many functions. It is a necessary component of photosynthesis, participates in hydrolytic and numerous metabolic processes, and is a transport medium for nutrients and various metabolic compounds in the plant. Besides maintaining turgidity and plant shape of nonwoody species such as turf, water also has a key role on plant growth and seed germination. Because of water's high heat of vaporization (450 calories to evaporate 1 gram of water), transpiration serves as an ideal cooling mechanism for plants, preventing plant tissue from overheating on hot sunny days, which could cause injury or death.

Most of the transpirational water loss occurs through unique cells on the leaf surface called stomates. These cells also provide for entry of CO_2, which is also required for the photosynthesis process. When the stomates are open, CO_2 diffuses into the leaf, and water in the leaf can diffuse out into the atmosphere; when the stomates close, both processes are greatly reduced.

If the plant wilts because of a limited rate of water uptake, the stomates close in an attempt to reduce water loss and potential injury. This in turn, however, reduces CO_2 entry and the photosynthesis rate, so plant growth is slowed not only by water stress but also by the decreased amount of photosynthesized compounds needed for further growth.

The primary means of water uptake is through the root hairs near the root tips. Water is transported upward through the roots and stems to the leaves, where most of it is used.

WATER STRESS

Turfgrasses suffer from both excesses and deficiencies of water. Excess water can be caused by too much rainfall, excessive irrigation rate or frequency, or poor drainage. Among the results of excess water can be a shallow root system; reduced turf vigor and quality, including poor color; increased thatch accumulation; increased susceptibility to disease and certain other pests; decreased wear tolerance; decreased tolerance to temperature and moisture stress; increased weed problems; especially from *Poa annua* and crabgrass; slower warming of the soil in the spring; nutrient losses through leaching or denitrification; and inefficient water use. These are strong arguments against excessive water use and merit a carefully planned irrigation program.

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On the other hand, the lack of water can result in serious injury or even death of the susceptible turf. If the turf is allowed to be subjected to moisture stress gradually, the plant will tend to develop increased rooting with a noticeable increase in root:shoot ratio; increased tillering, leaf numbers, and leaf area; decreased growth, particularly as a result of decreased photosynthesis; thinner leaves with smaller intercellular spaces; thicker cell walls and cuticle; physiological changes; and changes in disease and wear susceptibility.

Obviously, the ideal moisture condition falls somewhere between excessive and deficient moisture levels. The objective is to provide adequate water so that the plant can carry on its normal metabolic functions without the problems of excessive water.

WATER-USE RATE

The amount of water a turf uses is called water-use rate and is dependent on evapotranspiration, growth rate of the plant, species and cultivar, intensity of cultural management, traffic, wear on the turf, rooting, type of soil, soil moisture level, and effects of pests on turf.

An adquate root system is essential for the plants to provide a healthy, actively growing turf that does not require extensive management during moisture- and heat-stress periods. Rooting depth of grass is affected by species and cultivar, mowing practices, nitrogen fertilization, watering practices, soil compaction, soil acidity, drainage and aeration in the soil, soil temperature, and injury from diseases, insects, nematodes, soluble salts, and certain pesticides. Highly intensive turfgrass management (short infrequent mowing; high nitrogen rates, especially in the summer; heavy thatch conditions; and frequent watering) results in short root systems that cannot use soil moisture effectively.

Some typical values for the amount of available water that soils could hold for turfgrass use are shown in Table 1. Most literature gives the percentage of

Table 1. Some Typical Values for Soil Moisture Available to Turf as Affected by Soil Texture and Rooting Depth

	Soil texture		
	Silt loam	Sandy loam	Sand
Field capacity, %	29.7	17.8	8.5
Permanent wilt point, %	11.8	6.3	4.5
Available water, %	17.9	11.5	4.0
Inches H_2O to 12 inches	2.1	1.4	.5
Inches H_2O to 3 inches	.53	.35	.12

water available to plants on the dry weight basis of the soil. Converting this to inches of water per foot of soil makes the data more readily evaluated to determine how much water is available to the turf when the rooting depth is taken into consideration. If, for example, during July or August the turf has a 3-inch rooting depth in a sand soil, 0.1 to 0.15 inch of water would be available for the turf for use during that day.

During a typical summer day in central Illinois the evapotranspiration rate (water lost from plant leaves through transpiration and water loss from the soil through evaporation) might be 0.2 inch with an upper limit of about 0.3 inch during a very hot windy day. Is it apparent under these conditions that soil moisture stress will occur. This will necessitate syringing during the day as a minimum procedure to hold the turf. This is one reason that rooting depth is a most important factor in helping a turf survive summer stress periods.

The most effective water uptake occurs through the root hairs, as has been mentioned. These root hairs are effective for only a limited time before the root matures, and the development of new root hairs is dependent upon root extension (new root growth). Because of soil temperatures and the intensity of culture and use of many turfs, there is little new root development (no new root hairs) during the heat-stress periods of summer. Thus the roots then available are not only limited in depth and contact with the soil but also no longer as effective in water uptake as they were at one time.

To encourage turf tolerance to soil moisture stress, practices and conditions that result in limited rooting should be avoided. Moderate to low rates of nitrogen, especially in the summer, are very important to encourage good rooting. This means careful fertilizing in the spring as well. Too many turfs are fertilized for top growth, not for root growth. Adequate to high potassium levels are necessary to achieve good moisture-stress tolerance. Shading turf tends to limit rooting. Intensive traffic injures the turf, decreasing moisture-stress tolerance. Careful and modest irrigation can help maintain a desirable turf without seriously shortening the root systems. The objectives for turf use may cause a natural conflict here, however, especially on golf courses. For example, many greens are overwatered to keep the soil moist so the turf will hold a good approach shot. As might be expected, such turf becomes less stress tolerant. Then the decision must be made whether the turf maintenance, including irrigation, is being done for the convenience of the turf manager or the turf user.

Many recreational turfs are watered too intensively, which is one of the reasons *Poa annua* is so common on many turfs. In an irrigation study at the University of California-Davis, Madison (1971) used five different bases for determining when to irrigate turf (see Table 2). Where 1/2 inch of water was applied to the turf

Table 2. University of California Irrigation Study (Madison, 1971)

Water stress treatment	Water use during growing season
	Inches
1/2 inch applied on alternate nights	64
1 inch applied when 1 inch lost from open evaporation pan	30
Water applied when tensiometer reached 15 centibars	22
Water applied when tensiometer reached 40 centibars	19
Water applied when tensiometer reached 65 centibars	15

on alternate nights, 64 inches of water were applied during the growing season. When water was applied every time 1 inch of water was lost from an open evaporation pan, only 30 inches of water were used during the season. Water use was further reduced from 22 inches, when the tensiometer was set to have the irrigation systems turn on when the moisture stress reached a 15 centibar reading (very wet), to a low of 15 inches of water during the season when the tensiometer was set at 65 centibars (moderately dry soil moisture for turf). There was no apparent difference in turfgrass quality among the plots, indicating that "normal" irrigation practices are probably using too much water.

The tensiometer has potential as an aid in reducing irrigation amount or frequency. However, the problems of upkeep of the tensiometer, the fact that it must be installed permanently during the growing season and removed during the winter, the difficulty of variability of soil and turf and environmental conditions (which increases the number of tensiometers needed), and the importance of very careful placement of the tensiometer are arguments against such use. Still, in most cases, reduced irrigation rates and frequencies could be practiced on intensively managed turfs without serious injury to the turf. Turf so treated may be able to withstand stress conditions better.

For the turf to survive environmental stress, it must becomes "hardened." This means the plants must have slowly growing or nongrowing tissue with small cells, a high carbohydrate content, and a relatively low water content. The nature of this hardening varies somewhat between summer and winter, but the hardened plant can better survive both high temperature and moisture stress in the summer and low temperature stress in the winter. The crown tissue (or growing point of the plant) for both top growth and root growth must be hardened for stress tolerance. Proper drainage is essential for good hardening of the turf in the fall. Beard (1973) has shown that highly hydrated crown tissue is quite susceptible to winter injury.

Proper water management through irrigation and drainage is one of the very important aspects of turfgrass maintenance. The successful turf manager knows his turf and soil conditions and his irrigation system and will keep a careful eye on the weather. Understanding the importance of water in the plant and how it functions should be a further aid in his water management program. For a more comprehensive review of this topic the reader is referred to the three textbooks listed below.

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ROLE OF ACTIVATED CHARCOAL IN TURFGRASS MANAGEMENT

K.E. Clapp

A primary reason activated charcoal is useful in agriculture is its ability to attract and hold a wide range of organic molecules on its surface (adsorption). The ability to adsorb is related to surface area, and activated charcoal has its surface area vastly increased over conventional charcoal by an additional manufacturing step that honeycombs the charcoal with tunnels called pores. This process increases the surface area to such an extent that one ounce of activated charcoal has more surface area than an entire football field.

Tests show activated charcoal effectively reduces unwanted herbicidal activity from spills, over- or misapplications, and even normal applications. Activated charcoal will adsorb many toxins and most organic pesticides; however, it will not effectively adsorb the most water-soluble pesticides, including Paraquat, Diquat, Amitrole, and the methyl arsenates. Fortunately, it will also not adsorb such solubles as fertilizer compositions. It is important to use an activated charcoal designed specifically for agricultural purposes because conventional charcoals exhibit a wide range of properties, depending upon raw materials and manufacturing conditions.

APPLICATIONS OF ACTIVATED CHARCOAL

Water-Slurry Application

One of the most convenient ways of working with activated charcoal is in the water-slurry form. Agricultural-grade activated charcoal wets readily and requires no additional wetting agent. (Any wetting agent added would be absorbed by the charcoal, using up valuable surface area.)

After slurrying, a broadcast application of activated charcoal can be made with equipment as simple as the normal sprinkling can. A home garden sprayer is also a convenient piece of equipment for this method of application. Before spraying from a garden sprayer, however, the activated charcoal should be slurried in a separate bucket and poured through a screen into the sprayer. This is necessitated by the low amount of agitation available in the normal home sprayer. Using power equipment with conventional nozzles is another convenient way to make broadcast applications with activated charcoal. A spray gun can also be used.

When spraying activated charcoal, handle it much the same as a concentrated wettable powder mixture. The sprayer should be filled approximately halfway with water and the agitator started. The activated charcoal and the rest of the water should be added simultaneously. Choice of pump is very important since the abrasive nature of activated charcoal will cause premature failure of a paddle or roller pump. The best pump to use is either a centrifugal or piston pump with ceramic cylinders. Nozzles with large orifices should be used to prevent plugging.

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Slurry concentrations of 1 pound per gallon of agricultural-grade activated charcoal can be applied using conventional nozzle flow data without viscosity corrections.[1] Screens should be removed unless foreign matter is present in the spraying system, in which case slotted screens should be used. Mechanical agitation is preferable, but an efficient bypass agitator is sufficient. Nozzles should be close to the ground to limit spray drift.

Dry Application

Powdered activated charcoal can be dispensed directly with properly designed equipment. The best results are usually obtained when the charcoal is not allowed to stand in the spreader prior to application. Standing in the spreader may result in compaction and cause bridging of the spreader's outlets. For obvious reasons, spreaders should not be used on windy days. Direct use of dry powdered charcoal has achieved acceptance on golf courses, where it is applied to herbicide or hydraulic spills and is followed by a thorough watering.

INCORPORATION OF ACTIVATED CHARCOAL

After a broadcast application of activated charcoal, it should be incorporated into the area in which it is expected to tie-up the herbicide or other organic compounds. This can be done by simply using a rake, rotor tiller, hoe, disc, plow, aeroblade, or other such equipment. When working with established turf, about the only practical means of incorporating activated charcoal without seriously damaging the turf is with a thorough watering.

USES OF ACTIVATED CHARCOAL

Pesticide and Hydraulic Spills and Misapplications

Experiments at the University of Rhode Island proved watering can be an effective means of incorporating the activated charcoal. A simulated spill was applied by spraying a 3 pounds per acre rate of simazine on established turf. One part of the turf was treated 24 hours later with a 500 pounds per acre rate of activated charcoal. No precipitation or watering was allowed in the area in the intervening time. After the application of the activated charcoal, both areas were thoroughly watered. One month later the portion with no charcoal treatment was completely dead, while the part treated with activated charcoal was growing vigorously.

At the University of Delaware an experimental herbicide killed the grass and produced areas in the turf that were sterile to the establishment of grass seed. These barren areas were sprayed with a 300 pounds per acre rate of activated charcoal, followed by incorporation and reseeding. Six weeks later an excellent stand of grass had been established in this previously barren and sterile area.

As a result of these and other tests, activated charcoal has found widespread commercial use in curing spills and misapplications. Although each spill must be considered as an individual problem, the following procedure will effectively treat most spills: Apply 100 pounds of activated charcoal for each pound of herbicide residue present, with a minimum of 600 pounds per acre. Incorporate the activated charcoal and reseed if necessary. As previously stated, these treatments have been successful at many golf courses.

Terminating the Action of Turf Herbicides

Jagschitz, at the University of Rhode Island, was one of the earliest turf researchers to conduct and publish research on using activated charcoal on turf.

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[1]This figure applies to GRO-SAFE® activated charcoal.

A 300 pounds per acre broadcast application of activated charcoal incorporated into the top inch was sufficient to inactivate a wide range of turf herbicides and permit immediate seeding of grass in previously sterile ground. Basic manufacturers of herbicides frequently recommend the use of activated charcoal for this purpose. For example, the Betasan label recommends the use of activated charcoal when, due to unforeseen circumstances, seeding is required in less than four months after Betasan is applied. An example where this is frequently useful is when a heavier than expected stand of *Poa annua* dies from summer heat on ground treated with Betasan for preemergence crabgrass control. A 300 pounds per acre application of activated charcoal permits an immediate reseeding.

Meyers, at the University of Florida, has shown both Kerb and Balan used for *Poa annua* control on bermudagrass can be inactivated by a 100 pounds per acre application of activated charcoal to permit an immediate and timely overseeding for winter cover. The only incorporation required was a thorough watering. It is interesting to note that in Meyer's greenhouse and field studies the presence of the charcoal in no way interfered with the action of a Koban seed treatment.

Enhancing Germination and Early Growth of Grass

Even in the absence of known herbicide residues, activated charcoal can frequently assist in establishing grass. In 5 out of 7 tests, grass coverage was achieved in approximately one half the time when using 100 to 300 pounds of activated charcoal per acre. The possible mechanism involved includes tying up natural toxins, removing germination inhibitors from the seed, and aiding uptake of nutrients into the plant.

Sodding

Mitchell, at the University of Delaware, ran tests on transplanting bluegrass sod onto soil with residues of various turf herbicides. The plots were split, and activated charcoal was applied to one half of each plot prior to laying the sod. Even with Tupersan, which doesn't affect growth of bluegrass, twice the knitting strength was achieved in one month by adding activated charcoal. Since sodding can cost as much as $5,000 to $10,000 an acre, it is a good investment to insure the best possible results with an inexpensive application of activated charcoal. A normally recommended application would be 300 pounds per acre of charcoal incorporated into the top soil prior to laying the sod.

Activated Charcoal as an Aid to Transplanting

Tests at numerous locations show activated charcoal frequently protects transplants from herbicides or, even in the absence of herbicides produces increased growth. Applications can be made by either dipping the roots in a 1 pound per gallon slurry or adding the charcoal to the transplant water.

CONCLUSIONS

Activated charcoal is an ideal plant protection agent. It is easy to work with, effective, and, since it is classified as a *soil amendment*, it can be applied without EPA approval. However, it should not be used to violate a herbicide label.

The various application techniques discussed should be sufficient to cover most situations. If you desire additional information, consult available literature; ICI United States, Inc., publications; or the author.

ANTHRACNOSE

J.M. Vargas, Jr.

This summer a new disease problem attacking "Poa" (*Poa annua:* annual bluegrass) was identified on golf courses. That is not to say anthracnose *(Collectotrichum graminicola)* is a previously unidentified problem, for it is reported in the literature. Although the disease has been reported before, however, its importance has been overlooked, or more correctly stated, the damage done to Poa by anthracnose has been blamed on other factors:*Pythium, Helminthosporium,* and high temperature. It was not uncommon to go to a golf course this summer and hear a superintendent say, "*Pythium* has wiped out my fairways," or "*Helminthosporium* has wiped out my fairways," and "I treated it with this or that and it didn't help." Nor was it uncommon to walk onto a golf course and hear someone say, "Look, I can't apply any more water--the fairways are saturated and they're still wilting" or "I've even syringed in the middle of the day and they are still wilting." The reason the *Pythium* and *Helminthosporium* fungicides didn't work was that neither fungus was the problem. The reason excess water and syringing didn't work was that the grass was not wilting. If anything, the excess water contributed to the anthracnose problem.

The one characteristic symptom of Poa infected with anthracnose is its yellow appearance. When Poa or any grass wilts, it turns dark blue to purple in color; yet this summer, superintendents were talking about their Poa turning yellow and wilting.

What is anthracnose? It is a weak pathogen that can attack Poa, Kentucky blue, and red fescue under stress. It appears to attack during cool as well as warm weather. The yellowing is present under cool or warm weather, but death of the grass plant occurs in hot, humid weather conditions.

Most of the stress on Poa came from the high temperatures this summer. The disease was worse in heavy soil, compacted areas, and heavy traffic areas or hillsides. In one case excess nitrogen fertility was also implicated in symptom development. In Kentucky bluegrass, shade and short root systems contributed to the severity of the disease.

How can the disease be properly identified in the field? By the presence of black fruiting bodies (acervulus, acervuli pl.) of the fungus, with spines (setae) protruding from them, in the infected tissue. The black bodies can be found in the green or chlorotic tissue (yellow) when the disease is moving rapidly during warm weather, but they are more commonly found in the dead tissue.

CONTROL

Only eradication experiments were conducted, since the studies were not initiated until after the disease had been discovered. The benzimidazole systemic fungicides

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(Tersan 1991, Fungo 50, Cleary's 3336, Scotts DSB & Fertilizer) at the 2-ounce rate gave the best control. Rates of 1 ounce per 1,000 square feet, while effective, did not give as good control as the 2-ounce rate. Rates of 4 and 8 ounces per 1,000 square feet also gave excellent control, but the cost is prohibitive. One or two applications of the contact fungicides at two-week intervals were not very effective. Tersan 75, Tersan LSR, Fore, and Daconil 2787 at a 6- or 8-ounce rate were the best of those tested. Perhaps shorter intervals would work better, but this becomes very expensive in both material and labor.

Many fairways had lost 50 to 75 percent of their turf prior to treatment. Ten days to two weeks after treatment they had recovered, indicating that the crowns of the plants had not been killed by the anthracnose fungus. The roots of these treated annual bluegrass plants were up to 2 inches long in spite of the fact that daytime temperatures were in the high 80's and low 90's. In the untreated controls the annual bluegrass roots remained shallow to the point where the turf could be easily torn out. Preliminary evidence would indicate that much of what has been previously called high-temperature killing of Poa, *Helminthosporium*, and *Pythium* was in fact due to anthracnose.

If next summer is hot and humid, or if you are in an area that always has hot, humid summers, I would suggest you apply 1 ounce of a systemic fungicide per 1,000 square feet when the weather starts to go above 85° F. This should last for four weeks. Then I would apply Tersan 75, Tersan LSR, Fore, or Daconil 2787 at a 6- to 8-ounce rate, followed a week later by an additional ounce of a systemic fungicide. Applied as a preventative, one ounce should be sufficient.

Why use the contact fungicide if the systemics are so effective? Because resistance to the systemic fungicides has developed for every major pathogen on which it was used. This includes *Colletotrichum* spp. on other crops. There is no reason to believe it won't happen here; if it does happen on your course, you will have to spray every 3 to 7 days with 6 to 8 ounces of a contact from July through August to prevent anthracnose.

GOOD GROOMING IS GOOD SPENDING

Mike Bavier

Golf course superintendents wearing tuxedos...green fees of $75 per round...golf carts renting for $50--does this sound a little far-fetched? Gentlemen, fortunately we have not arrived at this era, and, I hope, we will not see the day in our lifetime. However, we *are* in the era of maintenance budgets of $100,000 to $200,000 and up, which are very commonplace and acceptable.

The grooming I refer to is the landscaping that strikes the golfer's eyes when he or she enters the clubhouse drive--those beautifully trimmed bushes, the nice weed-free green grass, and just possibly that rose garden off to the side. This, of course, is just the first glance of a beautifully groomed course. You surely would want to carry this out to the first tee and on to the course, never forgetting the object of our position--to provide our golfers with the best playing conditions possible and a pleasant atmosphere for recreation.

Many of you, I am sure, have read in the *Golf Course Superintendent* magazine what the assistant vice-president of golf at Sea Pines Plantation, William D. Carlson, said about their golf operations: After trying to cut corners and costs, they soon found out the people were not satisfied with inferior course conditions and their hotel occupancy dropped off. They then realized that people came to play on well-groomed courses and not just to eat at their restaurants, for there were many good eating places close to home. This point, of course, has been mentioned by many people, such as Mr. Bengeyfield of the U.S.G.A.; Paul Voykin, golf course superintendent; and others. The golf course is, and always will be, the drawing card. The barnyard pasture golf of yesterday has passed. We are now in the Space Age, when the sky may be the limit, but the sky should not be the height of the grass.

Many people refer to the British courses and comment on the height of the grass and the long, shabby-looking sand traps. When the first British courses were being designed, the thought was to utilize the constant strong wind in making a difficult playing course. Therefore, few trees were planted so as not to interfere with this wind. However, it was soon found that this was not all that was needed for a tough golf course--thus came the idea for long roughs to put a real premium on shot making. The ball had to be hit on the fairway to be found at all. The longer grass was also more practical in the early years since machines were not available to keep the grass maintained constantly.

The inventions of recent years have made the cutting of the grass and the edging of sand traps possible when the need arises. How often might that be? Well, let's just say, enough to make our courses enjoyable to play and not to have conditions that will interfere with play. That shabby, unkempt look on you or me is not any more impressive to our members than an untidy golf course.

"What about the cost?" you are saying. "Sure, this guy works for a club that has money." Actually, I work for a club of modest means. The members appreciate a

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well-groomed course but also believe in spending wisely. Money saved in purchases of chemicals, fertilizers, and labor disbursement is what they want and expect. They also want the grass cut at a respectable height in all playing areas--in *all* playing areas--and they want the sand traps trimmed. That does not mean cutting playing areas every day or constant trap maintenance, but enough so people can find their balls without spending a lot of time looking. The game of golf takes long enough now--we need not do anything to further delay the game.

Suppose we analyze just what we might save by not cutting certain areas on the course. Actually, many of the clubs are so designed that there is relatively little area between fairways to let the grass grow long. But let's just say there is an acre or two that we might let grow wild--I'm the first to agree to letting the birds and the bees have a place to live, too. But we really would be stretching the point to say we might save $500 to $1,000 in the maintenance of these areas.

How about the sand traps? My first suggestion would be to eliminate all traps that are out of play areas and, gentlemen, there are a lot of them--like those 100 yards off the tee, which catch only the ladies, or those at 290 yards, which few golfers reach, or those behind the greens, in which a golfer may land a shot only once a week. I have removed a few traps at my club.

Now, how much can be saved if we cut out some of the raking and edging of our sand traps--a thousand or two? Certainly not enough to cut a man off our staff, which means he would just be doing some other work on the course. To cut down on good grooming, therefore, does not necessarily mean you will cut costs in labor.

The next place we might realize a saving would possibly be in machines not used or not replaced--savings again of a thousand or two. I would be surprised if we totaled these figures and found we had saved $4,000 or $5,000. You can easily figure out that this will save each member of a club of 250 only about $1.50 to $1.75 a month. A drink costs more than that at many clubs.

Yes, the economy has gone up--costs and expenditures have gone up. But thanks to many cost-conscious superintendents, the club maintenance budgets have risen only moderately. Why cut back on good grooming when it saves so little, but means so much to our members? I have always been under the impression that we were in this business to give our members, whether at public or private courses, the best possible playing conditions. We can do just that with good grooming and good spending.

LAWN TURF SESSION

A FERTILIZATION PROGRAM FOR SOD PRODUCTION

John R. Hall

Modern sod production methods of harvesting and installation require increased sod shear strength. The new automatic cutting and installation systems such as the Nunes harvester, the Beck Big Roll system, and the Brower harvesting system all require high quality sod with good shear strength. In addition, the increased demand for more efficient utilization of labor requires sod that can be handled easily with minimum breakage.

The importance of growing varieties recommended by the Cooperative Extension Service of each state cannot be overemphasized. In Maryland our recommendation for cool-season sod production includes both Kentucky bluegrass and tall fescue mixtures. The Kentucky bluegrass general purpose sod-production blend is approximately 30-percent certified Merion Kentucky bluegrass; 30-percent certified Kenblue or South Dakota certified Kentucky bluegrass; 30-percent certified Adelphi, Baron, Birka, Fylking, Pennstar, or Sydsport; and 10-percent Pennlawn or Jamestown fine fescue. The tall fescue sod recommendation is 90-percent certified Kentucky 31 tall fescue and 10-percent certified Kenblue or South Dakota certified Kentucky bluegrass. These varieties have performed most reliably in Maryland.

The advantages of mixing cultivars of bluegrass include increased disease resistance and a greater ability to provide quality turf over a wider range of climatic and management conditions. Adding fine fescue in sod produced in Maryland provides increased rooting over a greater period of time, and creeping red fescue has been very important in sod installations in shady, drought-prone areas with low soil pH. The tall fescue mixture has been particularly popular in multi-use areas that have minimal maintenance--along highways, on airport grounds, and in park and recreational areas.

In choosing the proper fertilizer for cool-season sod production there are several important factors. Fast-release fertilizers are generally the cheapest per pound of applied nitrogen. The immediately soluble fertilizers are very popular on cool-season grasses.

The efficiency of nitrogen utilization is also important. Studies indicate that immediately soluble, fast-release fertilizers are most efficiently utilized by the turfgrass plant. Transition zone experiments with late fall fertilization have been a very successful means of producing high quality sod; fertilizers are applied from November 15 to December 15 when soil temperatures are below 55° F. Fertilizers that are immediately available are the most efficiently utilized by the turfgrass plant during periods of low temperature.

Commercial availability of fertilizers is very important. In late 1973 and early 1974 the sod industry was made aware that nitrogen availability was not unlimited, particularly on ornamental and nonfood crops. The ratio of nitrogen to phosphorus to potassium in the fertilizer you select is important and should be chosen on the basis of soil tests taken from the fields in sod production.

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Storage characteristics of some materials are important. Selecting a 30-percent nitrogen source instead of a 6-percent nitrogen source would obviously require 1/5 the storage space for the total amount of fertilizer. Other storage characteristics, such as hygroscopicity, must be considered; ammonium nitrate is known for its ability to absorb water if bags are not properly sealed.

Regardless of the source of nitrogen, all forms will be utilized by the plant in the nitrate (NO_3^-) form. Whether we select an organic slow-release or an inorganic fast-release source of nitrogen, the plant will still utilize the nitrate form. Several reactions in the soil--mineralization, immobilization, volatilization, and denitrification--affect nitrogen and can influence the efficiency of nitrogen utilization by the turfgrass plant. Mineralization is simply the breakdown of soil organic matter to ammonium (NH_4^+). Nitrification is the conversion of ammonium to nitrate through microbial activity and is most efficient above 55° F. Immobilization is the conversion of nitrate back to soil organic matter by microbes and includes the tying up of NH_4^+ by fixation in clay minerals. Denitrification is the conversion of nitrate to nitrogen gas in either a N_2 or N_2O form. Volatilization is the conversion of ammonium to gaseous ammonia (NH_3). All of these nitrogen reactions in the soil can influence the efficiency of nitrogen fertilization and should be given serious consideration in developing a fertilization program.

For instance, it is apparent that in the coming year many of the more popular types of soluble fertilizers will contain urea as their primary source of nitrogen. It is important that sod producers be aware of the volatilization reactions of urea in the soil. Volatilization will occur very rapidly on alkaline soils. Research has shown that, 10 days after an application of 100 pounds of nitrogen per acre as urea on a Dixon silt loam with a pH of 7.0, approximately 35 percent of the applied nitrogen can be volatilized into the air as ammonia gas. This could possibly occur in situations where urea was being applied at the same time as corrective lime application.[1] Other factors that affect ammonium volatilization are soil incorporation and soil temperature. Surface applications of urea on soils of pH 6.5 have been shown to volatilize as much as 15 percent of the applied urea nitrogen. Surface applications of urea to 90° F. Dixon silt loam soil of pH 7.5 at the rate of 100 pounds of nitrogen per acre have been shown to volatilize over 20 percent of the applied nitrogen. The application of lime to correct acid soil pH should not be discouraged by this, however, because practically all of the 16 essential elements are favorably affected by the correction of acid pH. Soil incorporation of nitrogen will minimize the pH effect.

The timing of fertilization in sod production can be influenced by several factors, including type of grass, soil type, and kind of fertilizer used. Cool-season grasses are generally fertilized in fall and late fall in Maryland; bermudagrass and zoysia sods are summer fertilized. Heavy soils with high clay content will retain moisture longer and perhaps require longer drying periods; sandy soils will have longer periods when heavy equipment can traverse the field. Slow-release urea-formaldehyde fertilizers are generally most effective if utilized when soil temperatures are above 55° F. Labor availability on each farm will also have an impact on the timing of fertilization.

Consider also the benefits to be derived from late fall fertilization of cool-season grasses. The general theory of late fall fertilization is based on the fact that photosynthesis is rather insensitive to temperature and respiration is very temperature sensitive. Photosynthesis, or the production of food, can occur even

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[1]J.W. Ernst and H.F. Massey. 1960. The Effects of Several Factors on Volatilization of Ammonia Formed From Urea in the Soil. Soil Sci. Soc. Amer. Proc. 24:87-90.

when air temperatures are approaching freezing. Respiratory processes, whereby the food is burned up to produce growth or stored foods, are very temperature sensitive, however, and food breakdown will occur most rapidly under high temperatures. Therefore, fertilization of Kentucky bluegrasses during hot weather leads to high respiratory processes, which tend to burn up food reserves in leaf production. Late fall fertilization stimulates the plant to grow during the period when shoot growth is minimal, photosynthesis is maximum, and respiration is minimal. This creates a situation whereby the food being produced is shunted into storage in the crown, rhizome, and stem tissue and is not utilized for shoot growth, which simply requires mowing. The food reserves made during this late fall fertilization period can be called upon during the stress months of June, July, and August. Practical observations in Maryland lead us to believe that late fall fertilization is a very beneficial program for sod production.

The amount of nitrogen needed in any sod production program will be influenced by several factors. Geographic location will have an influence on the total amount of nitrogen used. Areas in northern parts of the state will have shorter growing seasons and may thus require slightly lower levels of nitrogen fertilization than areas in southern parts of the state. The type of grass being grown will help determine the amount of nitrogen necessary for high quality sod production; tall fescue can generally persist with less nitrogen than Kentucky bluegrass. Soil texture will have an influence in that applied nitrogen will tend to leach more readily through sandy soils than through heavy clay soils. And keep in mind the tendency of nitrate to leach through soil profiles in areas where heavy rainfall patterns persist.

But be aware of the effects of excessive nitrogen. Excessive nitrogen tends to create disease-prone tissue, which exhibits decreased drought tolerance and decreased heat and cold tolerance. Excessive nitrogen in sod production can cause sod heating on the pallet, which can destroy sod in transit. Excessive nitrogen will also decrease the root and rhizome activity of Kentucky bluegrass and other cool-season grasses. Minimal amounts of nitrogen are most beneficial in sod production. A general sod fertilization program in Maryland would follow the outline below.

A General Sod Production Fertilization Program for the Transition Zone

Time	Sod age (months)	Amount per acre	Comments
Fall seeding	0	400 lb. 10-10-10 40-60 lb. nitrogen	Disk in Topdress
Late November-early December or February	2-3 5	40-50 lb. nitrogen	Only if needed
September	12	40-50 lb. nitrogen	After Labor day
October	13	40-50 lb. nitrogen	Late October
Late November-early December	14	40 lb. nitrogen	Late November
30-60 days before spring harvest	15+	30 lb. nitrogen	If needed to market

There have been much data generated to show that long day lengths and high light intensity are two primary factors that influence rhizome growth in Kentucky bluegrass. Sod producers have no control over the day length or the light intensity, however, and must concentrate on a third factor involved in influencing rhizome growth--nitrogen level. Low nitrogen levels have been shown to significantly increase rhizome growth in Kentucky bluegrass. This increased rhizome growth will lead to increased shear strength and higher quality sod.

In Maryland we are experimenting with new sources of nitrogen. We have successfully established sod with liquid sludge sources of nitrogen. The demand for sod is generally greatest in metropolitan areas, and metropolitan sanitary commissions are currently looking for means of disposing of liquid and solid sludge. Our preliminary research indicates that liquid sludge might be successfully utilized in sod production. Chelated iron might also possibly increase sod rooting and quality. We have found that late November applications of chelated iron (4 ounces per 1,000 square feet) plus 1 pound of nitrogen per 1,000 square feet will improve sod color and quality the following spring. Some increases in rooting have been observed with late November chelated iron treatments in conjunction with nitrogen.

The demand for high quality sod will increase in the coming years. The likelihood that nitrogen fertilizers will become more available in the coming years is small. The need to investigate alternate sources of nitrogen is essential, as is the importance of efficiently utilizing available nitrogen sources. Because of rapidly increasing fertilizer costs, every sod producer should become aware of the most efficient means of utilizing valuable nitrogen fertilizer. It is also important that sod producers realize a happy medium in regard to sod fertilization and attempt to achieve a high quality product that is not excessively green but green enough to market. Do not ignore the disadvantages of excessive nitrogen and the problems involved in trying to achieve excessive green color for marketing purposes. Excessive nitrogen does not lead to good root and rhizome production in Kentucky bluegrass sod. We have found in Maryland that avoiding the spring application of nitrogen fertilizer is important. Late fall fertilization programs do decrease *Fusarium* activity and sod heating and increase carbohydrate food reserves, drought tolerance, and root rhizome growth.

MAJOR DISEASES IN SOD PRODUCTION

J.M. Vargas, Jr.

When we are talking about major disease in sod production, we are talking primarily about three diseases: *Helminthosporium* (melting out or leaf spot), *Fusarium* blight, and stripe smut.

If you were asked which was the most devastating disease, I think most of you would answer *Fusarium* blight, and some might say stripe smut, but really the most devastating disease in Kentucky bluegrass is *Helminthosporium* or the *Helminthosporium* diseases. Fortunately, there are many varieties or cultivars of Kentucky bluegrass that are resistant to the *Helminthosporium* diseases and, therefore, we tend to overlook it as a major disease problem. The reason Merion has been so widely grown and is so popular is that it was the first and for many years the only variety of Kentucky bluegrass that had excellent resistance to the *Helminthosporium* diseases. Since then other cultivars with excellent *Helminthosporium* resistance have come along: Fylking, Pennstar, Adelphi, Parade, Baron, Galaxy, Touchdown, and others.

With *Helminthosporium* eliminated as a problem through resistant cultivars, *Fusarium* blight and stripe smut have become the major problems in Kentucky bluegrass sod. *Fusarium* blight is the more important of the two because of its more conspicuous symptoms and because of the lack of a permanent solution to the problem. Stripe smut is more devastating in the long run and can destroy an entire turf area, but because it is a slow process that allows weedy grass to fill in the thinned areas it often goes unnoticed until large areas have been affected. Blending *Helminthosporium*-resistant Kentucky bluegrass cultivars appears to be a satisfactory solution to these problems.

If the cultivars did not have excellent *Helminthosporium* resistance, you would not have to worry about diseases like *Fusarium* blight, because the Kentucky bluegrass stands would not be around long enough for *Fusarium* blight to be a problem.

Fusarium blight can be a problem in sod production, but it usually is not, especially in good years when the fields are being turned over in less than a year and a half. *Fusarium* blight is more of a problem where sod is not harvested for two or three years. But whether it is your problem initially on the sod farm or the homeowner's problem on his lawn, it is really always your problem because dissatisfied customers can't do anything but hurt business.

Stripe smut is likewise not usually an important problem on the sod farm where the sod is being turned over rapidly. However, it can be a problem in older Merion and Windsor fields where these cultivars have been grown year after year. New infection tends to take place very rapidly because of the large number of spores present in the soil. Stripe smut is a systemic perennial disease; once a plant

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is infected, it will remain so for life. Moreover, all plants arising from that plant through tillering will also be infected. All that is needed for the grass plant to be destroyed is adverse environmental conditions.

If the sod industry's only concerns were disease problems on the sod farms, they could be solved by using *Helminthosporium*-resistant cultivars. By blending three or more of these cultivars the stripe smut problem could be solved, and by proper planning and planting so the fields were harvested before they were a year and a half old the *Fusarium* blight problem could be solved.

However, your concerns cannot end here; they must go to the customer. If he is unhappy with the product, then eventually your business will suffer. The question is what can be done to keep the customer satisfied? Solutions come under two categories: proper public relations and using the best available cultivars in blends and mixtures.

First, public relations: you as a sod industry have oversold your product. You have inadvertantly implied it can do something it cannot. You have promised them a lawn that will last forever. Yet every appliance is built and sold with planned obsolescence; no one expects the car to last forever, and even your house needs paint, new roofing, new carpeting, and possibly even new siding after a while. I believe sod should be sold the same way, with 10 years as a target date for replacement.

How do we produce a sod that will last 10 years?

The answer is simple--we must start with the proper cultivars. The proper cultivars means avoiding three diseases: *Helminthosporium*, *Fusarium* blight, and stripe smut. It would appear that Warren's A-20, Adelphi, Glade, Majestic, Touchdown, Parade, and Baron Kentucky bluegrasses offer the best solution for the future. There are, of course, many other cultivars resistant to *Helminthosporium*, which could solve that problem, but *Fusarium* blight must also be taken into consideration, and the above-mentioned varieties offer the best tolerance, at least at this time. Blending three or four of these Kentucky bluegrass cultivars should solve the stripe smut problem.

Now that you have the best possible cultivars, you must insist on proper soil preparation prior to the laying of the sod. There is nothing sadder than to see good quality sod laid on ground with the consistency of asphalt. And yet time and time again, contractors or developers will remove the top soil and smooth off and compact the "gumbo" underneath with heavy equipment, then lay sod on top of this and expect it to grow. No one in his right mind would seed into soil in that condition, but somehow sodding over it is supposed to work.

Finally, the best cultivars in the world will not grow if they are not properly maintained. The Kentucky bluegrass blend needs to be mowed at a minimum 2" height and given about 4 pounds per 1,000 square feet of actual nitrogen a season with most of this being applied in the fall. Potassium (K) and phosphorus (P_2O_5) should be applied once a year in amounts determined from results of a soil test. Proper watering is also very important--there is nothing more frustrating than trying to explain to a homeowner he cannot properly water his 20,000-square foot lawn with one sprinkler that covers only 200 square feet at a setting.

I believe it would be worth the time, effort, and money for your sod growers' association to draw up a one-page fact sheet explaining some of the points I have made and either hand them out to your customers, if they buy directly from you, or give them to the landscaper, if you sell through him.

NEW IDEAS IN SOD PRODUCTION

Ben Warren

In the past several years there have been several innovations in handling and producing sod. Three of these--soilless sod, vegetative planting of bluegrass, and utilization of clippings--will be discussed here, and others will be mentioned briefly.

SOILLESS SOD

The introduction of the Prescription Athletic Turf (PAT) system revived an idea we had worked with more than 10 years ago. The soil layer associated with sod handled in the conventional manner would retain enough moisture to cause damage from football traffic. In the fall of 1974 a machine was developed to wash 80 to 90 percent of the soil from the sod. Experimental plantings were made comparing washed and unwashed sod in outdoor plots, and one landscape job of 400 yards was laid half and half. During the following winter months a series of transplantings was made in the greenhouse using root observation boxes. These tests indicated that at those times the soilless sod rooted significantly faster than sod with soil.

On the basis of this evidence the PAT people made the decision to plant the Mile High Stadium at Denver with Warren's A-34 bluegrass handled in this manner. About two weeks after planting, baseball season started, followed by football in the fall. Midway through the football season it was standing up better than any of the other PAT fields.

VEGETATIVE PLANTING OF BLUEGRASS

Vegetative planting of turfgrasses is not new, being common practice with bents and many of the southern grasses, but it has not been used in establishing bluegrasses other than sodding. Most bluegrasses from seed produce a high percentage of maternal-type progeny by a process called apomixis. Others produce such a high percentage of offtypes through sexually formed seed that it is not possible to reproduce the parent truly from seed. These latter types must be planted vegetatively to retain the parental traits.

Because of the superior qualities of A-20, which produces a rather high percentage of sexually formed seed, we elected to increase it vegetatively. Several methods of planting were tried before settling on the Beck plugger, which had been developed to plant southern grasses.

An additional advantage of vegetative propagation is that preemergence herbicides can be used at planting time, allowing one to control *Poa annua* and other weeds in the soils.

UTILIZATION OF CLIPPINGS

There are different approaches to utilizing clippings. We have chosen to go the dehydrating route. One plant in California has completed its first year of

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production. After an indifferent start it ended the year with reasonably good production. Construction of a second plant in Wisconsin was completed just at the end of the past season and will be ready to go next spring.

A ready market seems to exist for the dehydrated pellets, particularly in the poultry industry. Prices are variable, depending upon the location. We have much to learn about optimum mowing height and frequency, fertility management, and general handling. Probably the major problem we have encountered is gathering the clippings and getting them to the dryer. To solve this, we have developed a unit in which hydraulic-powered reel mowers discharge into cross conveyors.

OTHER NEW IDEAS

Several ideas, some not exactly new and untried, should be mentioned. The Harvestors have come along through Ryan, Daymon, and Ryder rollers to the complete harvesters with three still on the market: Princeton, Nunes, and Brouwer machines. Of these the Brouwer seems to have achieved the most popularity.

The Beck sod-laying system is one of a kind. The idea of cutting sod into a roll of 4 by 50 or 60 feet and laying this as one unit is catching on in some parts of the country.

The plastic netting offered as a means of speeding up sod production has been tested across the country, but I know of only one nursery that has used it extensively.

From West Virginia and England have come several ideas in speeding up sod development. One uses flats arranged on a Ferris wheel apparatus in a greenhouse and uses a prescription soil. Another uses a foam-type medium floating on water, and the third utilizes an impermeable film, a layer of netting, and a layer of growing medium. All claim a very short development period, five to six weeks, but none seems to be very practical.

CONTEMPORARY CUSTOM LAWN CARE

William R. Fischer

The custom lawn-care business has proved itself to be a very viable segment of the turf industry in the last decade. Professionalism, showmanship, business savvy, and horticultural expertise are all important tools of the trade.

Originally, custom lawn care was an extension of the golf course maintenance business, directed primarily at the owners of large estates and millionaires in general. Since then, and especially during the last decade, the demand for lawn care has grown tremendously, and from this demand has evolved a separate entity that has very little in common with golf course maintenance.

Increased leisure time, emphasis on beautification, increased cost of do-it-yourself materials, and, to a certain extent, the EPA regulations of some chemicals have all added to the vigorous growth of the custom lawn-care business. Not to be overlooked is the amount of first-class advertising and promotion work done by the sophisticated businessmen who are the leaders in this business. In fact, it is the "result-producing" advertising campaigns and follow-up that have as much to do with the growth of this business as any other factor. A good advertising package combined with good-looking equipment and the ability to at least semiaccurately measure a lawn is all you need to go out and get 500 to 1,000 customers your first year in business! Sounds like a no-risk, success-guaranteed business, doesn't it? Those adjectives usually describe disaster and many amateurs have met with disastrous results in the lawn-care business.

Undoubtedly, the most common reasons for failure in this business are the same as in any other business--the lack of business experience, the inability to manage yourself and your business, and undercapitalization. Basic business principles must be followed and management skills tuned to produce results if you are going to compete in today's lawn-care market.

Horticultural knowledge, of course, is a must in the lawn-care business. With the incidence of fungus diseases and insect pests increasing every year, one must be willing and able to continuously update his knowledge. Pesticides that were quite effective two or three years ago may be essentially ineffective today because the pest has built up an immunity to that particular chemical. There are also environmental factors to be considered when using pesticides. Discriminate use of pesticides is not only the law but also essential for the applicator's health and the effects desired on the customer's lawn.

The custom lawn-care marketplace today is much different from 10 years ago. Today's customers are better educated than ever before and are rapidly beginning to understand and cherish the value of a dollar. The economic pressures put on all consumers lately makes them very demanding about getting their money's worth in service and results. Your success in retaining customers is predicated upon your ability to explain to your customer why certain results are not attainable under certain cultural and climatic conditions.

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Contemporary custom lawn care has developed into a very professional business. It is also an ever changing and quite challenging business. Combine controllable factors such as sufficient capitalization, good business habits, and good management skills with uncontrollable factors like the weather, economy, and people, and you have a pretty good idea of what the contemporary custom lawn-care business is all about.

INSTITUTIONAL GROUNDS MAINTENANCE

A.C. Herbster

The University of Chicago, located on the south side of Chicago, has an enrollment of 8,000 students and some 9,500 employees. Included in the complex is a 700-bed teaching medical center. The campus covers 132 acres, with 23 miles of walks, 4 acres of flowerbeds and ground cover beds, 24 acres of parking lots, 39 1/2 acres of grass with sprinklers, and another 20 acres of grass without spinklers.

In 1974-75 my total budget was some $275,000, or a maintenance cost of $2,100 per acre. The work staff is composed of a superintendent, an assistant superintendent, and 14 men. In the summer I may employ one or two students. The men are unionized and the current pay rate for my grounds personnel ranges from $4.80 an hour for Gardener I to $6.17 an hour for Gardener III.

A large piece of the Chicago Park District divides the campus on the southern border. Called the Midway Plaisance, it is a one-block wide, one-mile long green strip lined with trees and grass areas. Many of these areas are used as athletic fields by University personnel.

The grounds of the University are broken into many sections. They range from the large 7.4-acre athletic field to grass areas of only 100 square feet. Because these plots are broken up into so many small areas, maintenance is very costly. In order to meet a shrinking budget, the result of lack of University funds and inflation, I have been forced to use as much time-saving equipment as possible.

For mowing, one 5-gang mower is used in many of the larger areas, traveling from section to section and cutting the large areas as it goes. Two hydrostatically driven rotary mowers--in this case, Hustlers--travel in conjunction with this machine. The Hustlers can pick up a lot of smaller areas and do a tremendous job of trimming, which cuts the use of the hand-trimming mower considerably.

In other instances we use a combination of mechanical devices and chemicals to control unwanted vegetation, such as along the athletic field fence. The area is cleaned out with a weed eater, then sprayed with Hyvar-XL. The spray didn't give as tight a band as I would have liked, but it did keep the area clear for an entire season and saved many man-hours trying to keep it clear.

Our central quadrangle area has many miles of walks, so a special mower was adjusted for trimming along the sidewalks. The mower is offset, and it's painted a special color so that the operator knows he is using an offset machine. When mowing, the men are taught to throw off of the sidewalks and into the grass area. We have an even cut along the sidewalk area while two wheels are on the walks.

For years our ground cover beds were trimmed with electrically driven hedge shears powered by a portable generator. Then we decided to build a special frame for one of our rotary mowers and use this unit to trim the ground cover beds. This is much

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faster and does away with having to pick out the sheared pieces of the vines. I estimate that this has saved enough time in trimming to allow an extra trimming with no increase in man-hours. This machine must be used carefully, however, because it is so elevated, and we are constantly watching out for people and objects so that no one is injured.

Most of our fertilizer is applied from an electrically driven Cyclone spreader mounted on the back of a Jacobsen-Rogers truck. This way, a man can handle the application and carry the material along with him as well. Fertilizer is piled at various strategic sites so that he can load his vehicle without having to return to the warehouse. About 85 percent of our lawn areas are fertilized this way, with the rest being fertilized by walk-behind Cyclone spreaders.

One of my biggest pet peeves is the cost of removing leaves from the campus. When I started working at the University of Chicago, the leaves were picked up with a 3-gang-mower pulling Parker sweepers, dumped onto the street, and then hand-loaded into trucks and hauled to the rubbish pile. Now we sweep the campus with Rogers 154 sweepers. Using a Jacobsen-Rogers sweeper, one man does in one day the work it took 3 men to do in 3 days in earlier years. The leaves are loaded into a special body built on the back of a dump pickup truck with a giant vac loader and dumped into a compost pile. The following year this is shredded into usable compost. The compost is added to planting beds, used as an organic addition in tree planting, and used to mulch new plantings. The soil here tends to need as much organic material as possible, since we have 12 inches of topsoil and 60 feet of sand underneath it. Even with all the machinery, there is still much hand raking.

Speaking of mulch, I have been fortunate to be able to pick up large quantities of pecan shells at a very good price. We have been mulching more and more of our ground cover and shrub beds with this material. We have been applying it at a depth of 6 to 8 inches and find that it gives us tremendous weed control for as much as two years. After that we add 2 or 3 inches a year. This is probably one of the greatest labor-saving devices I have found, one that also has benefited the plant materials through increased moisture retention and reduced competition from weeds.

For snow removal we use the standard equipment, for example, a Hustler with a broom and a Ford tractor with a broom. I have ordered snow blowers for the Hustlers; they should work well because the drive on the blower operates independently of that on the tractor. We found that this equipment did not work with a plow. Many of our trucks have plows and salt spreaders. Rock salt, calcium chloride, and sand are used to fight ice.

We do most of our weed spraying ourselves, although I occasionally contract for this service. I have to admit I do very little control of diseases on our lawns, and this year *Fusarium* blight in one area killed 20 percent of the grass.

There are areas of grounds maintenance other than lawns--one that's a real problem is walks. Much of our walk area is gray Amherst sandstone, 2 1/2" thick, laid in random patterns. While this makes a beautiful walk, it is very subject to breakage and frost heave and really should be reset every 10 years. This is a very expensive proposition; in fact, the cost of the material alone now is almost equal to the cost of concrete walks installed. Weed growth in the joints also is a maintenance problem; we spray with Hyvar-XL.

Five years ago we adopted a new standard for concrete sidewalks. We specify a 2 course pour. The base is 3 1/4" thick, 6-bag mix concrete. The topping is 3/4" thick and composed of 8-bag mix concrete with trap rock sand and stone as an aggregate. This gives us a very pleasing appearance in a couple of years and it wears like iron. In 8 years I have not had one sidewalk failure using this method.

We have also installed some asphalt sidewalks and find them satisfactory, provided that they are edged with steel curbing and that they are wide enough for a big roller to be brought in to compact them when they are put in place. No matter what the material is, though, you have to have a wide enough radius on your sidewalks or the people are going to create the radius, and it will become necessary to install it.

This brings us to the problem of keeping people walking where you want them to. One method we have used with moderate success is the installation of the black plastic chain. We weren't able to use the plastic post because there was no way to permanently anchor the chain to it, but we did take 2 x 4's, painted them black, drilled and ran the chain through them, and then fastened with lag screws at frequent intervals. This system has worked in areas where we feel we have to use a rather permanent form of barrier.

As a temporary barrier around our football field we use the green manmade snow fence (Easy Fencin' by Burlington Industrial Fabrics Co.). It works very well on a temporary basis. This year we are also going to try using it as snow fence control because it is much easier to install and doesn't seem to get knocked down quite as readily.

We still have a very good use for wood snow fence. By laying it down over the tulip beds, it keeps the squirrels and dogs from digging in the soil, and it spreads the foot traffic out so that there isn't too much compaction. You just want to be sure to remove the fence early enough so that the plants won't get caught when they start growing.

Snow fence and burlap are also placed around some plantings in the winter. This has been effective in keeping the salt spray from auto traffic off the evergreens.

Where possible, the best solution for paths is the installation of plantings that blend in with the landscape. I have two examples. This first path was not stopped by installing three Washington hawthorns, so we went up to five and completely filled the area, and the path is no longer existent. In another instance we installed a combination of hawthorn and dwarf pfitzer junipers in an area to completely cut off a path, and the landscape actually was improved by this installation. There are times, though, when the only answer is to install a walk. No matter what we do, people are going to continue to use this path because it is a definite walk-oriented area and pavement of some sort should be installed.

Another task which takes up considerable time is that of removal of trash. Each of my men spends from one to four hours a day dive-bombing for paper. We have found no replacement for the man with the stick with a nail in the end of it, walking his area and cleaning up the trash.

Trash baskets strategically placed reduce the litter problem. The containers we use are lined with a plastic bag so that one man can pull out the liner and insert a new one, throw the bag on the truck, and haul it to the trash pile. The round, expanded metal basket is the best one for our use. When people see trash in it, they will throw their waste in it. This basket is not very easily used for a billboard, and its maintenance cost is low. There is a move by the administration to use nicer looking trash baskets, but I am fighting this. I feel that if the trash basket looks like a nice piece of sculpture it's not going to be used as a garbage can.

One of my major nemeses, and probably that of all people in the horticultural industry, is bindweed, or wild morning glory, two of the nicer names it is known by. We tried an experiment on one hedge this year; the timing was kind of late, but I will continue to test next year. I had the men very carefully pull the bindweed out of the hedge and lay it along the wall. Then it was sprayed with Hyvar-XL and allowed to hang there for about 4 or 5 days before we cut if off. We hope the chemical was trans-located down into the roots and killed the plant completely. Other herbicides could also be used.

One of the problems that we all face in institutional maintenance is the fact that we forget that the institution is for the use of the people; while the people do cause the problems, if we can get them thinking about the landscape, our job will be easier. I have done a few things I consider in the area of public relations. I have met with a group of students and asked them what they thought we might be able to do to help people stay on the hard pavement and off of the grass areas when weather conditions are such that the lawns are destroyed. One student came up with an idea for a little publicity campaign centered around the University seal. The University seal is a crest with a phoenix on it, and above it is written in Latin, "Through education life is enriched." They changed the seal so it has a squirrel on it and above it in Latin it says, "Let the grass grow so that life may be enriched." I had this made up into buttons and signs. We posted the signs in a few areas where there is cutting across the lawns, and the buttons were passed out free to anybody who wanted them. I have now passed out about 3,000 buttons, and this particular piece of publicity has made two or three of the Chicago newspapers, since we are the only university in the country that asks the people to keep off the grass in Latin. It has worked a little bit, and I am hoping that it will work much more in March when we get our major damage.

Another thing I do concerns some of the flower beds on campus. The center one has been shown here--it is planted with geraniums throughout the summer and fall. Each year when it is time to clean these beds out and prepare them for the fall bulbs, I put an advertisement in the campus newspaper stating that the geraniums will be removed at 8:00 on such and such a day. By about a quarter to eight, people are lined up to pick up the geraniums. We pull the plants out of the ground and lay them aside, and the people can pick up as many as they want. This year we started removing at 8:10, and 2,200 geraniums were gone before 9:00.

A third project, undertaken through the donation of a member of the Board of Trustees, was the identification of a number of trees on the campus by installing signs. I wasn't crazy about this idea because I felt there would be vandalism. So far I have not witnessed any vandalism, but I have received numerous phone calls and heard other comments where people have really enjoyed the fact that many of the plants and trees on the campus are identified. I think this is an undertaking any institution might want to consider.

I have had some problems with architects who construct areas that are very difficult to maintain. While I have quite a bit of input into the landscaping, frequently a building is built at various levels where slopes are not easily mowed. Or the architect insists on certain features in a playground such that either we can't keep the grass on it, or if grass grows on it we should have sheep to mow it. Just once I would like architects to have to mow this sort of thing, and perhaps you wouldn't see too much of it in the future.

FERTILIZATION SYMPOSIUM

TURFGRASS FERTILIZATION—NITROGEN

P.E. Rieke

Fertilization of turfgrasses is only one of the important management tools the turfgrass manager must manipulate, but it is one of the very important ones. The effect of fertilization on turf and the turf's susceptibility to stress, the potential effect of fertilizers on the environment, the new fertilizers on the market, and the cost of fertilizer as a part of the total budget in the turf management program should all be considered.

This discussion will concentrate on nitrogen fertilization. Although all of the essential elements are necessary in the appropriate amounts for good quality turf, nitrogen is the nutrient to which the turf is most responsive. It is also the nutrient that is probably the most difficult to manage.

Consider, for example, all the different ways that nitrogen can be added to or lost from the turf. Additions include water-soluble fertilizers, water-insoluble fertilizers, clipping return, nitrogen fixation in the soil by various soil organisms, atmospheric addition through rainfall, and various other sources such as top-dressing material. Additional nitrogen can come from soil organic matter being decomposed. Organic soils have a particularly large reservoir of nitrogen tied up in the organic matter, which can provide nitrogen to the turf over a period of time.

On the other hand, the primary means of nitrogen loss from the soil are leaching with water passing through the soil, removal with clippings or other plant debris, gaseous return to the atmosphere, removal of coarse fertilizer particles with clippings from closely mowed turfs, and the possibility of nitrogen fixation as ammonium in certain clay minerals. The important variables over which the turf manager has some degree of control are fertilizer additions, clipping removal, and leaching losses.

Not only must the potential gains and losses of nitrogen from the turf/soil environment be considered but also the effects of nitrogen on the turf (Beard, 1973). For example, the use of very high nitrogen rates on turf influences the green color of the turf, increases shoot growth, therefore increasing mowing frequency needs, and increases shoot density, especially as compared to very low nitrogen levels. Very high nitrogen rates also decrease root growth, thus increasing susceptibility to stress tolerance; decrease low temperature tolerance if the turf has remained in a vegetative succulent condition going into the winter; decrease high temperature tolerance if turf is overfertilized with nitrogen during summer stress periods; decrease moisture-stress tolerance; decrease wear tolerance if the turf is very succulent; increase thatch accumulation, which, however, tends to increase the wear tolerance of the turf; increase the turf's recuperative potential after thinning due to various stress or pest conditions has occurred; and decrease seed head formation of certain grasses. The level of nitrogen has a dramatic effect on the type of grass that predominates and on the tendency for invasion of certain weedy species of turf,

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depending upon the species involved. Water-soluble sources of nitrogen on turf can cause a foliar burning; any water-soluble fertilizer can cause this type of injury, however.

Using higher nitrogen rates, according to the literature, should increase the susceptibility of the turf to *Helminthosporium* leafspot, brown patch, *Fusarium* patch, *Ophiobolus* patch, *Fusarium* blight, gray leafspot, and stripe smut. On the other hand, higher nitrogen rates will tend to decrease the susceptibility of certain turfs to dollarspot, rust, and red thread (Beard, 1973).

One of the very important areas in turfgrass management that can ultimately influence the turf is the effect of nitrogen fertilization on the kinds of plants that tend to be present. On many turfs, weeds will tend to be more prevalent at very low nitrogen levels because the turf is not competitive enough to crowd out and prevent weed encroachment. For example, at Michigan State University several years ago, applying high rates of water-soluble nitrogen such as ammonium nitrate in April and May tended to keep the number of dandelions at a very low level. In contrast, splitting that nitrogen into three applications a year resulted in considerable encroachment of dandelions into the turf. Using slow-release nitrogen carriers also resulted in higher rates of dandelion encroachment, even when all of the nitrogen was applied in the spring. The slow-release carrier did not provide enough nitrogen early in the season, allowing dandelion seeds to germinate in the open spaces before the turf had filled in.

In a polystand of Merion Kentucky bluegrass and Pennlawn red fescue at Traverse City, the use of high rates of nitrogen encouraged the Kentucky bluegrass to predominate. The use of an organic (slow-release) carrier, Milorganite, also resulted in an increase in the percentage of Kentucky bluegrass present in the turf. This result reflects greater efficiency in utilization of the nitrogen in the slow-release carrier because of the leaching tendency of soluble sources on this heavily irrigated sandy soil. In addition, using heavier rates of nitrogen in the summer (compared to spring and fall treatments) resulted in more Kentucky bluegrass in the stand.

Also at Traverse City, where Pennlawn red fescue has been mowed at 3/4 inch over a period of years, *Poa annua* has tended to encroach much more on the plots receiving higher nitrogen rates, indicating that at higher nitrogen rates the competitive ability of *Poa annua* is greater than that of Pennlawn red fescue. Milorganite treatments have also tended to increase the amount of *Poa annua* encroaching upon these plots, more than have ammonium nitrate and ureaformaldehyde treatments.

Crabgrass encroachment into red fescue turf has been reduced by using higher nitrogen rates and heavy nitrogen applications of water-soluble carriers in the spring. When slow-release nitrogen carriers are applied in the spring, the encroachment of crabgrass has tended to be somewhat greater than where no nitrogen was used on the plots. Apparently, the slow-release carriers are not providing for the early spring growth of the turf until after the crabgrass has germinated. As the nitrogen is released during the late spring and early summer, the crabgrass is being fertilized as well as the desired species.

In a study at East Lansing in plots to which heavier nitrogen rates were applied *Poa annua* has tended to increase compared to the percentage of Merion Kentucky bluegrass in the turf. Early spring applications of nitrogen apparently have increased the competitive ability of *Poa annua* in this mixed turf as well.

Table 1 illustrates various effects of nitrogen rates on turf. These data are taken from a study of sod production on organic soil, which provided a considerable amount of nitrogen to the turf (English, 1971). As would be expected the higher nitrogen rates caused an increase in clipping weight and in nitrogen content in the clippings. As a result the total nitrogen removal with the clippings from these plots increased as well. In contrast, however, the higher nitrogen rates tended to cause a decrease in sod strength, a much weaker root system, and many fewer rhizomes. On this organic soil, the treatment that seemed to provide the best response was about 15 pounds of nitrogen per acre per month during the growing season. Note that the soil did provide some nitrogen to the sod in that in July the sod strength for the untreated plot was 109 pounds, while in mid-October it was 146. The sod had become stronger during this period, indicating a response to the nitrogen released from the soil. Some nitrogen, of course, is needed, but too much nitrogen will weaken the turf. This is true not only in sod production but for all turfs.

As you review the effects of nitrogen on turf and the potential gains and losses from the soil, remember that all the factors must be weighed. In some cases, higher nitrogen gives a desirable response; in other cases, a less desirable response. These factors must be weighed in determining what nitrogen fertilization program and what nitrogen rate should be used for the turf. The fertilizer program should be designed to provide the nutrients according to the needs of the turf, not just according to the color of the plant or the growth rate. One must consider, for example, not only the potential encroachment of weeds when fertilizer is not applied in the spring, but also the potential increased susceptibility to other problems like *Fusarium* blight, as has been pointed out so well during this conference. Thus, it is not really possible to design one fertilization program that will fit all turfs or will fit a given turf for every season.

As a turf nitrogen fertilization program is planned, one must consider a number of factors: the condition of the turf at the time of evaluation, whether clippings are to be removed or returned, soil texture, amount of irrigation water and rainfall the turf receives, type and use of grass, cost of the nitrogen per pound, cost of labor for application, ease of application of that particular fertilizer, environmental conditions at the time the fertilizer is to be applied, the intensity of the use of the turf, and the quality of turf desired. As various programs are evaluated, the cheapest program may not necessarily be the best.

Table 1. Nitrogen Treatment Effects on Merion Kentucky Bluegrass Sod Grown on Houghton Muck at East Lansing; Seeded August,1 1970 (English, 1971)

Nitrogen rate	Annual clipping yield, dry wt.	Average N in clippings	Total N removal	Sod strength 7/22	Sod strength 10/15	Rhizomes 7/22
lb/A/month	*lb/A*	*%*	*lb/A*	*lb to tear*		*grams*
0	463	3.0	14	109	146	99
15	1,807	3.3	59	148	188	89
30	2,555	3.6	92	123	130	120
60	5,676	4.5	255	105	97	43
120	8,447	5.4	460	68	67	14

When clippings are removed, nitrogen and other nutrients are also removed, increasing the need for supplemental nitrogen and other nutrients. At Michigan State we have found that using high rates of nitrogen and removing the clippings result in a "mining" of other nutrients out of the soil. This has meant a severe potassium deficiency on Kentucky bluegrass in one of the studies; where clippings are removed, higher potassium rates are needed than we have generally been recommending.

Another factor to consider is the tendency of the fertilizer to cause acidification of the soil. Because nitrogen fertilizer is only placed on the surface and not incorporated into the soil, over a period of years the surface layer of the soil may become quite acid. In fact, the thatch layer could become very acid, contributing to further thatch accumulation. The rate at which this acidity moves down into the soil to lower layers is very slow. As a result it is very important to sample soils carefully to the same depth all the time so that pH changes over a period of years can be followed. Ammonium sulfate is the most acidifying nitrogen fertilizer, but we also know that ammonium nitrate, urea, and ureaformaldehyde also cause acidification.

Counteracting this acidification effect could be the water being applied in irrigation. Many wells in the Midwest come from limestone aquifers; each watering should thus contain a small amount of dissolved calcium carbonate and therefore cause a small liming. On turfs so treated the pH may tend to stay well above 7.0 and even approach 8.0.

When soil pH reaches this alkaline level, we begin to get concerned about iron deficiency, especially on bentgrass and *Poa annua*. An application of nitrogen might not give the color response that an application of iron could. It is my opinion that we should be using less nitrogen on many of our turfs in the Midwest and perhaps should use iron to improve the color of the turf for key or important periods.

Not only are we faced with various possibilities of gains and losses of nitrogen from the soil and the varying effects of nitrogen on the turf, but also we must consider the various types of nitrogen fertilizers available on the market. The standard water-soluble sources, of course, have been available for many years. Most people would say the most desirable fertilization program would use very frequent applications of very light rates of *water-soluble nitrogen* carriers (ammonium nitrate, urea, ammonium sulfate). In this way one could increase or decrease nitrogen rate very easily. Still, the labor cost of frequent applications, as well as conflicts with use of the turf during application and potential injury to the turf, prevents most turf managers from utilizing this practice.

Organic fertilizers, such as *sewage sludge* and *ureaformaldehyde*, have also been researched and used for many years. The release of nitrogen from these carriers is dependent upon warm soil temperatures, so that the release rate is slow in the spring and higher during the summer. Ureaformaldehyde is normally mixed with water-soluble nitrogen to provide a more balanced response to soil temperature. We have found that the release of nitrogen from Milorganite tends to be somewhat faster than from straight ureaformaldehyde.

A number of other slow-release nitrogen fertilizers are or will soon be available on the market. *Isobutylidenediurea* (IBDU) is one of the recently available materials. The finer the soil particles, the faster the nitrogen is released. And, the lower the soil pH, the faster the nitrogen tends to be released. Mixing

IBDU and water-soluble nitrogen has provided a good uniform response over the season. Using IBDU alone has often resulted in a slow response during the spring season.

Sulfur-coated urea, a fertilizer developed by the Tennessee Valley Authority, has been researched for a number of years. This appears to be one of the best fertilizers we have evaluated in Michigan for providing both relatively short-term response and some degree of slow release.

Plastic-coated fertilizers have also looked promising but require very careful quality control in the fertilizer plant in maintaining the uniformity of the plastic coating. As water diffuses into the fertilizer particle through small openings in the coating, the fertilizer is dissolved and diffuses out into the soil where the turf plant can use it. The cost of this material is apparently high enough at this time that it has not become competitive on the turfgrass market.

A number of other nitrogen sources have been considered as well as a number of byproducts that contain nitrogen. To date, it appears that none of these has sufficient promise or is available at an appropriate cost to be a significant factor in turfgrass fertilization. We can be sure, however, that the search for a new and possibly better turfgrass nitrogen fertilizer will continue. As new information becomes available on these materials, the turfgrass manager will have to evaluate the possible application in his program.

In any event, it is essential that the turfgrass manager knows his soil conditions, his turf, the susceptibility of that turf to various stress conditions, and the kind of response he can expect from the nitrogen fertilizer he has applied. In evaluating these factors he then will have to decide which kind of nitrogen carrier to select, how much to apply, and when to apply it. In setting up a turf fertilization program, he should consider the resources at his disposal as well as his objectives for the turf area. One normally continues to make adjustments until satisfied with the program in use.

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SOIL TEST RESULTS FROM ILLINOIS TURF

T.R. Peck

Producing and maintaining desirable and appealing turf involves many management factors. Of course, adequate soil acidity and fertility are major manageable variables. This paper is a discussion of the contribution of soil tests in ascertaining soil acidity and fertility factors.

To provide a background for discussion of soil test of turf areas on Illinois golf courses, the results from four golf courses will be reviewed. Two of the courses are in the Chicago area, one is in McLean County in central Illinois, and one is in Marion County in south-central Illinois. Separate composite soil samples were collected from each separate green, fairway, and tee area, except that the tee areas of the Marion County course were not sampled. Routine soil tests of pH (a measure of soil acidity), the Bray P-1 test (a measure of plant-available soil phosphorus), and exchangeable potassium (a measure of plant-available soil potassium) were made. Average test data are shown in Table 1.

A desirable pH level is in the range of 6.0 to 6.5 for turfgrass. A pH below 6.0 indicates an acidity condition, and the use of lime to neutralize the acidity is a recommended practice. A pH above 7 is higher than desirable because of reduced plant availability of nutrients in the soil. In particular, iron, which is of major significance to turf, is reduced, as are the minor turf nutrients manganese and zinc.

Average pH's for all of the greens tested are 7 or above. Typically, it is common for greens to have a pH above 7, as the result of an accumulation of basic-reacting nutrients in the irrigation water. While reducing the pH to below 7 may seem desirable (and it can be done by acidulating amendments such as sulfur or acids), in practice the problems of excessive soluble salts produced in the acidulating process may be more serious than living with the pH above 7. Slow acidulation of soil

Table 1. Average Values of Soil Tests Results

Golf course		pH	P, ppm	K, ppm
Chicago 1	Greens	7.7	39	231
	Fairways	7.0	20	348
	Tees	7.6	42	374
Chicago 2	Greens	7.2	72	91
	Fairways	6.9	58	247
	Tees	7.2	60	121
McLean	Greens	7.0	69	124
	Fairways	6.5	28	195
	Tees	6.8	35	265
Marion	Greens	7.0	58	101
	Fairways	5.8	16	129

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with nitrogen carriers can be expected at the rate of 2 to 4 pounds of lime for each pound of nitrogen applied as ammonia urea or ammonium nitrate. The acidulating rate is more rapid with ammonium sulfate as the nitrogen carrier, approaching 6 to 8 pounds of lime for each pound of nitrogen. However, the tendency for a soil to acidify or neutralize depends upon the base status of the irrigation water, that is, the levels of calcium, magnesium, sodium, and potassium.

The pH in the tee areas is higher than soil acidity levels of fairways. Undoubtedly, irrigation is an influencing factor, but the relatively high player traffic and associated tabacco wastes would also tend to decrease soil acidity.

Levels of pH exceeding 8.3 are indicative of high sodium levels. Such conditions might develop where poor quality irrigation water high in sodium and bicarbonate is used. Living with soil pH levels above 7 requires more attention given to supplying iron. Chelated forms and periodic foliar sprays will assure a greener turf. Lime, which has been so beneficial to agricultural soils, should be used with caution on turf soils in Illinois.

Phosphorus levels in the range of 25 to 35 ppm are desirable. How low a level is adequate for a desirable turf depends upon the nature of the soil. A loamy soil with good aeration will produce a good turf with lower available soil phosphorus than will a coarse sand soil or a clayey soil with poor drainage. Noticeably, the greens areas generally have the highest soil test levels, followed by the tee areas. Quite likely, this a reflection of two things: more phosphorus fertilizer is added to these areas, and the green areas often are amended with sand, so that the coarse material tends to build up phosphorus soil test values faster than small soil particles. However, because of the intensity of player traffic in the green and tee areas relative to fairways, compaction is a factor detrimental to good turf. Maintaining a higher available soil phosphorus level helps offset some of the effects of compaction and will yield a better turf.

How high a soil phosphorus level should be before additional phosphorus is uneconomical and makes no improvement in appearance is not well defined, but certainly at 50 ppm extensive use of phosphorus fertilizers is not prudent. However, at 30 ppm small applications in early sping or late fall will stimulate and provide a more favorable turf earlier in the spring, particularly in cold and wet spring seasons.

Potassium soil test levels should be in the range of 75 to 100 ppm. Generally, the greens areas have lower soil test potassium levels than fairway and tee areas. This is probably because greens amended with sand to enhance drainage have a lower capacity to hold potassium, and removal of clippings removes large amounts of potassium. Care must be exercised with potassium fertilizers to preclude soluble salt problems. Thus, maintaining potassium test levels in the desirable range can be more critical for good turf than hitting the desirable range with pH and phosphorus.

Soil test values for phosphorus and potassium may or may not be reported in units of ppm. Commonly, units of pounds per acre are used. To convert pounds per acre to ppm, simply divide by 2 (lb./acre ÷ 2 = ppm).

When sampling soil send at least a cupful of soil to the laboratory to perform the tests. Sample each green, tee, and fairway separately. Greater variation in test results can be expected among fairways because of greater variation in soil type than among greens. Soil tests for micronutrients are not as valid as soil tests for acidity, phosphorus, and potassium--the micronutrient soil tests may predict a need for treatment when it is not needed, and vice versa. Information about micronutrient needs is best obtained from knowledge of the soil type, plant tissue analysis, and appearance of the turf.

TISSUE TESTING AS A GUIDE TO TURFGRASS FERTILIZATION

John R. Hall

Knowledge about foliar analysis of turfgrass is very limited at present. With more research, however, turfgrass foliar analysis could be as important in diagnosing plant problems as blood analysis is in diagnosing the state of human health. The concept of testing the soil the plant grows in for available nutrients has been extremely valuable. But if a plant or a man is in a poor state of health from problems other than nutritional ones, neither is likely to feed on available food. Therefore, it is valid to question which system can more accurately determine the state of health of the plant itself. It is my opinion that foliar analysis has a great potential for providing the necessary information.

When using soil testing as a diagnostic tool, the questions of where the roots are feeding and to what depth a soil sample should be taken are difficult to answer. On many golf greens grass may feed heavily from different depths at different times of the year. On heavily thatched greens it is suspected that considerable feeding takes place in the thatch layer. And on many of our compacted athletic fields the area of active root feeding is very limited. In contrast, the answer to where the sample for foliar analysis should be taken is obvious. The plant tissue is the most accurate indicator of the health of the turfgrass plant. The limiting factor for foliar analysis at this time is the ability to utilize and understand the analysis of the turfgrass plant.

Even with the limited knowledge available, foliar analysis provides several capabilities. Nutrient deficiency diagnosis or confirmation is routinely accomplished with foliar analysis on sugar beets, rubber trees, sugar cane, and other high value crops. Nutrient deficiency in turfgrass, however, does not generally manifest itself in an immediately apparent way as it does in other crops such as tomato or corn. Symptoms of potassium deficiency, which appear as a purple falming from the tip of the grass, have been seen on bentgrass golf greens, and nitrogen deficiency symptoms, which appear as chlorosis, are also periodically noted on golf greens. However, the ability to determine other nutrient deficiencies by visual observation is extremely limited and of no practical value. Foliar analysis can expose these hidden or incipient deficiencies in turfgrass. It is essential that more adequate means of determining the nutrient needs of turfgrass plants be developed.

Foliar analysis can be used to verify nutrient uptake. Occasionally, a nutrient is added to turfgrass without improving color or quality. A turfgrass manager will want to know whether the nutrient was absorbed and had no effect or whether it failed to move into the plant. In many instances excessive amounts of one element can be applied and cause a deficiency of another element. The classic interaction occurs between phosphorus and zinc--golf greens with high phosphorus levels may exhibit diminishing levels of zinc availability. Such interaction effects between elements can be easily traced with foliar analysis. Foliar analysis can also monitor nutrient balance very cheaply. As shown by a great deal of data, the healthiest plants are those with a good balance of nutrients available to them.

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Foliar analysis has the capability of solving many problems facing the turfgrass manager today. It is a cheap means of troubleshooting in an attempt to determine which nutrient deficiencies are limiting in turfgrass management. Foliar analysis also has a potential as a research tool to provide insight into the growth mechanisms of the turfgrass plant.

The system is not without problems. Tissue samples removed for analysis must be cleaned with water before drying to avoid soil contamination with iron, manganese, and aluminum. Moreover, the questions of what plant parts to remove and at what time of the year they should be removed need to be standardized. Our work has shown that general clippings are most reliable in terms of providing meaningful information about nutrient concentrations. Clippings taken 10 to 14 days after the last mowing are more reliable than clippings removed from more frequent mowings. Young tissue is most likely to be variable and can provide the least meaningful information in foliar analysis.

Our data also show that there is a great seasonal fluctuation in some of the elements--phosphorus, for example. If one is concerned about the availability of a particular nutrient that exhibits seasonal fluctuation, the analysis must be interpreted in light of the influence of seasonal variations, as well as the effect of the method of sampling. Nutrient composition also varies with cultivar. Work conducted at Ohio State University, for example, has shown that Merion Kentucky bluegrass accumulates higher amounts of phosphorus than Windsor or Fylking. Finally, sampling generally must be done over at least two time periods to determine if nutrient concentrations are decreasing or increasing.

Foliar analysis has no predictive value in helping determine the future nutrient availability to the plant; it indicates only the availability at the time of sampling. And there is the weakness that foliar analysis may reveal only a single nutrient deficiency at a time. Keep in mind that nutrient availability in the plant is much like a chain; the nutrient appearing to be deficient will be the weakest link in the chain. Once the nutrient deficiency is corrected, however, another nutrient element may become deficient and become the weakest link in the chain. Therefore, continuous foliar sampling may be necessary following the correction of a single nutrient deficiency. In areas with layering, or heavy root feeding in thatch, or in trouble-shooting for nutrient deficiencies, foliar analysis can be particularly helpful in determining the problem.

Foliar analysis is limited at present, but we have hopes that a total plant analysis system will be developed, providing us with a reading of elemental availability and protein, amino acid, and carbohydrate content of the turfgrass plant. It is obvious that there will always be a need to integrate both foliar analysis and soil testing to develop a diagnostic tool with predictive value. Foliar analysis alone cannot provide the necessary information to determine what nutrients will be available to the plant 30 days from now, nor can it indicate the nutrient-holding capability of the soil in which the turfgrass plant is growing. Therefore, both foliar analysis and soil testing must be used to give turfgrass managers a complete picture of the nutritional status of the turfgrass plant.

TURFGRASS DISEASE-NITROGEN RELATIONSHIP

J.M. Vargas, Jr.

When we talk about turfgrass disease-nitrogen relationship, we are talking about two types of relationships: those diseases that nitrogen makes more severe and those that nitrogen makes less severe. The major turfgrass diseases are broken down into these two categories below.

Severity Increased by Nitrogen		Severity Decreased by Nitrogen
Pythium	*Fusarium* patch	Rust
Brown patch	*Typhula* blight	Red thread
Fusarium blight	*Helminthosporium* diseases	Dollar spot
Stripe smut		

Once the relationship of nitrogen to disease development is known, timing becomes the important aspect. Applying excess nitrogen in the spring is not going to solve a stem rust problem in the fall; likewise, 2 to 3 pounds of nitrogen in the late summer and fall will not affect *Fusarium* blight. But the same 2 to 3 pounds of nitrogen applied in the spring would increase the *Fusarium* blight severity.

Reducing the severity of a single disease by timing of nitrogen application is not a simple matter; many other diseases occur on the same turfgrass species throughout a growing season, and all the diseases must be taken into consideration. It would be nice if each turfgrass species only had one disease, for then a nitrogen fertility program could be developed for it specifically, but unfortunately that's not the case. Many diseases occur on the same turfgrass species throughout the growing season and sometimes at the same time. So a nitrogen fertility practice that may reduce one disease may increase another. With this in mind, the following figure was developed to show the wrong times of year to fertilize with nitrogen or the times of year when fertilizing with nitrogen will increase the severity of each disease. The figure shows that nitrogen applications in the spring encourage

April	May	June	July	August	September	October	November	December
-*Fusarium* blight--					-*Helminthosporium*--			
--*Helminth.*--								
		-----Stripe smut------						
		-----*Pythium*--------						
		-----Brown patch------						
					--------*Typhula* blight------------			
					--------*Fusarium* patch------------			

Figure 1. Time of year that nitrogen applications will increase severity of individual diseases.

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Fusarium blight development; nitrogen applications in the summer encourage stripe smut, *Pythium,* and brown patch; and nitrogen applications in the fall encourage *Typhula* blight and *Fusarium* patch.

Obviously, what is needed is a nitrogen application schedule to obtain maximum disease reduction with a functional program. The grass plant needs nitrogen, and you can't simply eliminate all nitrogen fast to obtain disease control. So you must try to apply nitrogen at the times it will benefit your disease-control program. With this objective in mind, the bentgrass and annual bluegrass turfs have to be considered separately from the Kentucky bluegrass turfs.

The table below shows a nitrogen fertilizer schedule that could be used in most of the Midwest. The program would start with a dormant application in the late fall after the final mowing. In my experience, this gives the turf an early gradual start in the spring and eliminates the problem of how to get on a wet golf course in the spring; this also prevents a surge of lush growth that often accompanies spring nitrogen applications. This gradual growth instead of a surge will help reduce the severity of *Helminthosporium* on the bentgrass. A pound of nitrogen around the middle of May will aid in reducing the severity of any early dollar spot, and the light 1/2-pound applications in June, July, and August should give the turf enough nitrogen to grow but not increase the severity of *Pythium* and brown patch. A pound of nitrogen in late August or early September, depending on your area, should help reduce the severity of fall dollar spot and *Corticium* red thread. Not fertilizing in the fall (after early September) should allow the turf to harden off and be less susceptible to attacks by *Typhula* blight (gray snow mold) and *Fusarium* patch (pink snow mold) and to *Helminthosporium,* which often develops on bentgrass in cool, wet falls. The only possible problem in not fertilizing with nitrogen after early September is that *Corticium* red thread can be a problem. However, it is better to have a little *Corticium* red thread than to encourage a more serious problem like the snow molds by overfertilizing. Since *Fusarium* blight and stripe smut are not usually problems on annual bluegrass or bentgrass, they were not considered in this schedule.

The schedule for Kentucky bluegrass turfs on fairways, park areas, industrial sites, or home lawns assumes use of a cultivar of Kentucky bluegrass that is resistant to *Helminthosporium.* Thus, the two main concerns are going to be *Fusarium* blight and stripe smut. By limiting nitrogen fertility in the spring, the severity of *Fusarium* blight should be reduced; by limiting nitrogen fertility in the summer, the amount of turf lost to stripe smut should also be reduced. Not fertilizing late in the fall will reduce the severity of *Typhula* blight and *Fusarium* patch. As with annual bluegrass and bentgrass, the dormant application of nitrogen should give a slow, steady greenup in spring and avoid the surge of lush growth that can lead to *Fusarium* blight problems later on or to a severe problem later in the spring if you have a *Helminthosporium*-susceptible Kentucky bluegrass turf.

Schedule of Nitrogen Fertilizer Application Rate (per 1,000 square feet) to Help Retard Disease Development

	May 15	June 15	July 1	July 15	August 1	September 1	...	December (Dormant)
Annual bluegrass, creeping bentgrass	1 lb.	½ lb.	½ lb.		½ lb.	1 lb.		1 lb.
Kentucky bluegrass	½ lb.	½ lb.		½ lb.	½ lb.	½ lb.		1 lb.

The home-owner nitrogen fertility schedule will be the toughest one to implement, because of human nature. Most people are tired of their lawns by Labor Day, and it is very difficult to get them to apply a dormant application of nitrogen in the fall. Likewise, it is just as difficult to get them not to apply large amounts of nitrogen in the spring when they have been "dormant" all winter.

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