DUTCH ELM DISEASE

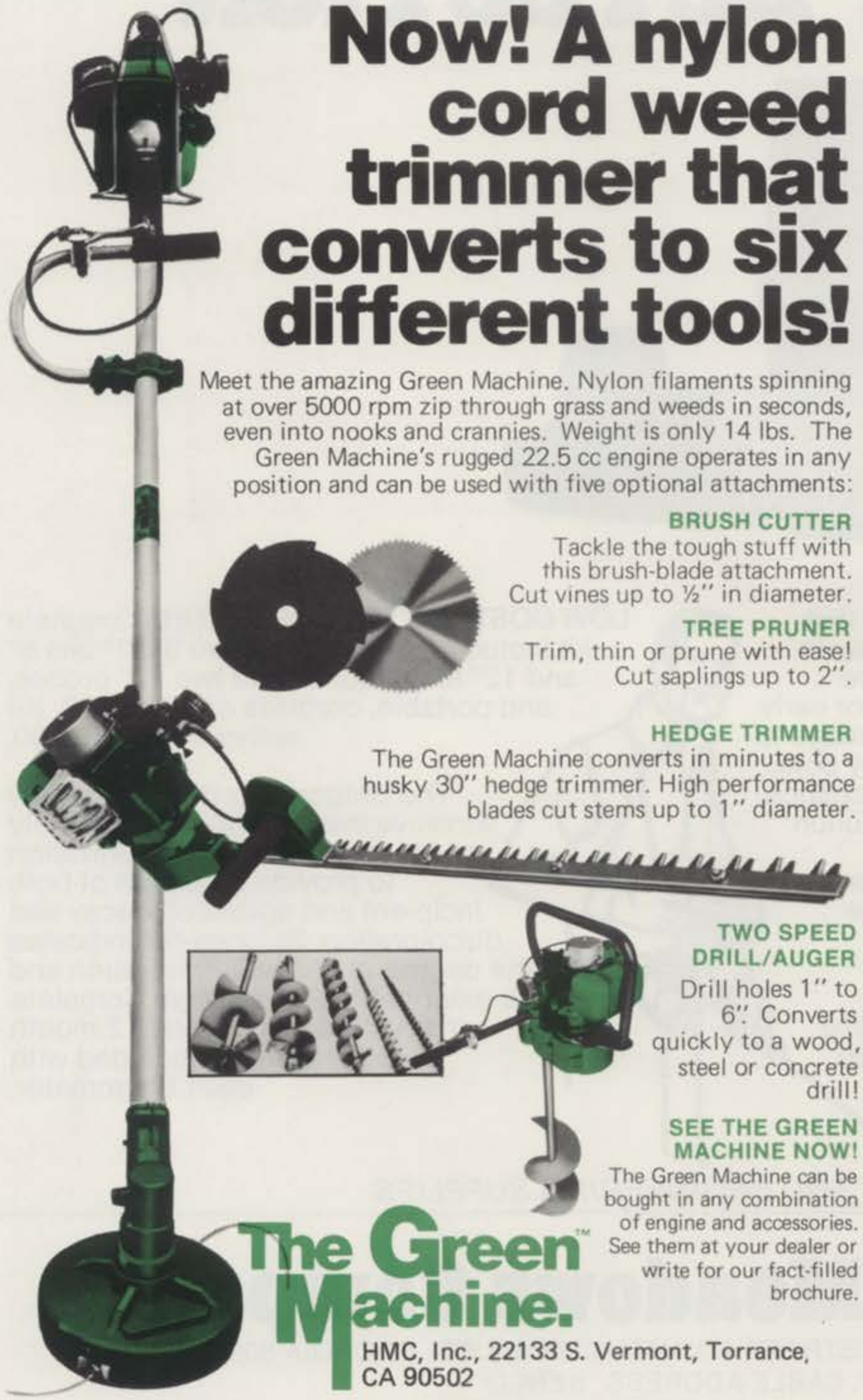
continued

diseased trees exhibiting less than 30 percent infection, are given a therapeutic trunk injection. (It is felt that trees exhibiting greater than 30 percent symptomology are well beyond the stage where systemic fungicide treatment would be effective and are therefore removed.) Injections are made at 70 psi with the tree injection apparatus developed by G. F. Gregory and T. W. Jones of the USDA Forest Service or with a conventional Spartan power sprayer, equipped with 13-gallon polyethylene carboys calibrated in liters per trunk diameter inch.

Injector heads are nailed to the trunk at six-inch intervals and connected to the pressure injectors with PVC nylon reinforced hose equipped with quick coupler connectors. With the aid of a skylift truck and a long delivery hose, diseased limbs are also injected near the main trunk. By injecting the diseased limb an effort is made to purge any infection at the limb's union with the main trunk. Diseased limbs are removed shortly after injection. For expediency, if DED is evident in several limbs, only the trunk is injected, and the diseased limbs removed promptly thereafter. Elms that are within 50 feet of diseased trees are given prophylactic trunk injections in an attempt to protect against root graft and beetle transmission of DED.

During the summer of 1975, 60 elms contracted DED in the Federal Enclave which encompasses such notable areas as the White House, the Ellipse, Lafayette Park, the Jefferson and Lincoln Memorials, the Mall, West Potomac park and sections of Constitution and Independence Avenues. In the past, since little hope could be offered for a tree with DED, most diseased trees were removed. However, in 1975 half of the diseased trees were considered worthy of treatment and allowed to remain standing. The effectiveness of this injection and pruning program can only be evaluated as time goes on. It is hoped, however, that many of the treated trees will overcome the disease and continue to contribute to the Park landscape for many years.

Another vital aspect of our integrated program has been a continuing search for DED tolerant elms. Several European and American clones which exhibit high tolerance to DED have been selected from the diverse NCP elm population. These selections are currently being evaluated by the ESL for future use in the Park. ESL researchers are constantly searching for other plant materials from European, Asian, and American sources that might also be of use. Monoculture of the American elm has lead to the demise of many urban plantings. Incorporation of a diversity of elms tolerant to DED may reduce the possibility of extensive elm losses. Diversity may also prevent extensive losses from other elm problems such as phloem necrosis which, fortunately, has yet to be found in the Washington, D.C. area. □



Fusarium Blight

from page 9

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 enitire width of the leaf blade and may extend up to ½ inch long.

Root Rot State

Turfgrass plants affected primarily by the root rot phase of the disease are stunted, pale green in color, and

'Because of the predominant leaf-symptom pattern, we named the disease Fusarium blight' — Couch

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° 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 ½ 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 that 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

by 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 researcher has been done with seedlings. Our knowledge with other plants 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 predominate 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. 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 of 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 bluegrass will have problems with the disease if grown widely.

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Fusarium Blight

continued

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 micro-climatc 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.

'From the view of the golf superintendent with bluegrass fairways, it has become an impossible monster'—Cole

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 *Fusarium.* 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 strees 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 in 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 11 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.

REFERENCES

Bean, G. A. 1966. Observations on *Fusarium* blight of turfgrass. *Plant Dis. Reptr.* 50:942-945.

Bean, G. A. 1969. The role of moisture and crop debris in the development of *Fusarium* blight of Kentucky bluegrass. *Phytopathology* 59:479-481.

Cole, H., S. W. Braverman, and J. Duich. 1968. *Fusarium* and other fungi from seeds and seedlings of Merion and other turf-type bluegrass. *Phytopathology* 58: 1415-1419.

Cole, H., Jr., L. B. Forer, P. E. Nelson, J. R. Bloom, and M. H. Jodon, 1973. Stylet nematode genera and *Fusarium* species isolated from Pennsylvania turfgrass sod-production fields. *Plant Dis. Reptr.* 57:891-895.

Cook, R. J. 1968. *Fusarium* root and foot rot of cereals in the Pacific northwest. *Phytopathology* 58:127-131.

Cook, R. J., and R. I. Papendick. 1970. Effect of soil water on microbial growth, antagonism, and nutrient availability in relation to soil-borne fungal diseases of plants. Pp. 81-88 in *Root diseases and soil-borne pathogens*, Toussoun, Bega, and Nelson (Eds.). Univ. of Calif. Press.

Couch, H. B., and E. R. Bedford. 1966. *Fusarium* blight of turfgrasses. *Phytopathology* 56:781-786.

Cutwright, N. J., and M. B. Harrison. 1970. Chemical control of *Fusarium* blight of Merion Kentucky bluegrass turf. *Plant Dis. Reptr.* 54:771-773.

Cutwright, N. J., and M. B. Harrison. 1970. Some environmental factors affecting *Fusarium* blight of Merion Kentucky bluegrass. *Plant dis. Reptr.* 54:1018-1020.

Endo, R. M. 1961. Turfgrass disease in southern California. *Plant Dis. Reptr.* 45:869-873.

Fulton, D. E., H. Cole, Jr., and P. E. Nelson. 1974. *Fusarium* blight symptoms on seedling and mature Merion Kentucky bluegrass plants inoculated with *Fusarium roseum* and *Fusarium tricinctum*. *Phytopathology* 64:354-357.

Factors Affecting Fusarium Blight in Kentucky Bluegrass

by 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. 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

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Fusarium Blight

continued

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

by 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 lev-

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 No. 2**	**K1-131**	**RAM No. 1**	**K1-143**	**Victa**
			K1-133	**Sydsport**	**Majestic**	**Windsor**
			K1-155	**Vantage**		
			K1-158			

els 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.

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).

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 differenctial thatching tendency and *Fusarium* blightsusceptibility 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*

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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 No. 1, Touchdown**
1.50 - 1.25	**A-20, Ba62-55, Baron, EVB-391, Fylking, K1-131, K1-132, K1-143, K1-187, Majestic, P-59, Plush, PSU-190, RAM No. 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.

Fusarium Blight

continued

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 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 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 dessication of the plants. Although this practice is inconsistent with traditional principles of turfgrass culture, it may be necessary for the survival of a severely diseases turf.

In conclusion, there are two fundamental approaches to controlling *Fusarium* blight in Kentucky bluegrass. The "environmental-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.*

LITERATURE CITED

Funk, C. R. 1975. Personal communication.
Turgeon, A. J., and W. R. Meyer. 1974. Effects of mowing height and fertilization level on disease incidence in five Kentucky bluegrasses, *Plant Dis. Reporter* 58:514-516.

The Role of Nematodes in the Development of Fusarium Blight

by 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 *Tylen-chorhynchus dubius* and *Creconemoides* spp., occured 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 system, 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 and 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 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. Light, frequently 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