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On

RELATIONSHIP OF ENVIRONMENT, MANAGEMENT AND PHYSIOLOGY TO BERMUDAGRASS DECLINE

Submitted by:

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2000 ANNUAL RESEARCH PROGRESS REPORT

RELATIONSHIP OF ENVIRONMENT, MANAGEMENT AND PHYSIOLOGY TO BERMUDAGRASS DECLINE

Executive Summary

Co-principle Investigators:	Richard H. White & Joseph P. Krausz
Graduate Research Assistant:	Mr. Roy Stanford
Research Associate:	Mr. Mark Hall
Ag. Research Technician:	Mr. Trent Hale
Research Period:	1 March 2000 through 1 November 2000

Bermudagrass decline is a recently described, devastating root disease of highly managed bermudagrass turf, especially turf used for golf greens in the southern United States. It is caused by an interaction of host-predisposing abiotic stresses and the soil-borne, ectotrophic, root-infecting fungus *Gaeumannomyces graminis* var. *graminis*. The objective of this research is to determine the relationship between several environmental, cultural, and physiological factors to the development and cure of bermudagrass decline. Summer fungicide applications did not control bermudagrass decline. The phototoxic effects of several fungicides, due in part to application when summer temperatures were high, may actually have been counter productive to recovery from bermudagrass decline. Mowing is extremely important in the maintenance of high quality putting surfaces. Decreasing mowing height did not increase bermudagrass decline symptoms. During 2000, symptoms were more severe at 0.188 than at 0.125 inch. Vertical mowing had a major impact on the expression of bermudagrass decline symptoms and frequent, light vertical mowing during late-summer was devastating to Champion, Floradwarf, and Miniverde bermudagrasses. Routine defoliation and mechanical stress caused by frequent, light vertical mowing increased bermudagrass decline symptoms. Nitrogen nutrition affected bermudagrass decline severity in a complex manner. Increasing N increased bermudagrass decline severity in Champion and Miniverde but decreased severity in Floradwarf bermudagrass. Nitrogen source may also be important in management of bermudagrass decline. An acidifying N source reduced and nearly eliminated symptoms of bermudagrass decline when applied to Floradwarf growing on a golf green with above neutral soil pH. Although we have not documented resistance of bermudagrass to *G. graminis* var. *graminis,* we did observe differences in expression of bermudagrass decline symptoms among 15 bermudagrass cultivars. Bermudagrass decline symptoms were less severe in Tifwarf than in several of the newer dwarf bermudagrass cultivars.

RELATIONSHIP OF ENVIRONMENT, MANAGEMENT, AND PHYSIOLOGY TO BERMUDAGRASS DECLINE

Richard H. White and J. P. Krausz

BACKGROUND

This program is a cooperative research project funded jointly by the Texas Agricultural Experiment Station (TAES) and the United States Golf Association (USGA). This project was initiated in March 2000. Annual progress reports are submitted 1 November each year and semi-annual progress reports are submitted in 1 May. This report constitutes the 2000 annual progress report for the project and highlights activities between 1 March 2000 and 1 November 2000.

PROFESSIONAL AND TECHNICAL SUPPORT

Mr. Roy Stanford joined the project in June 2000 as a graduate research assistant in Plant Pathology and Microbiology.

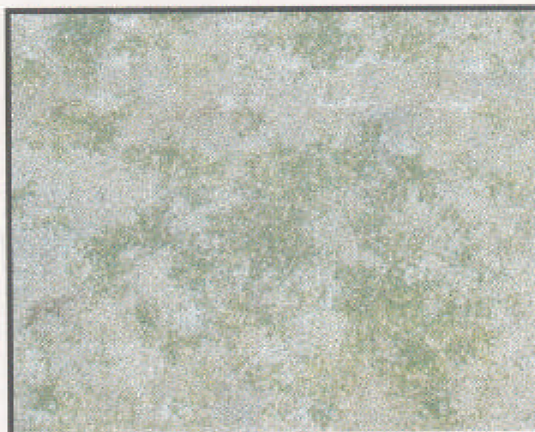
Mr. Mark Hall, Research Associate, provides day-to-day oversight for the experimental protocol associated with this project. Mr. Hall holds a Master of Science Degree in Agronomy from Texas A&M University. He has been employed by the Soil and Crop Science Department about 12 years.

Mr. Trent Hale, Agricultural Research Technician and Ph. D. candidate joined the project in March 2000. Mr. Hale holds a B.S. in Biology and Master of Science in Entomology from Auburn University.

INTRODUCTION

Bermudagrass decline is a recently described, devastating root disease of highly managed bermudagrass turf, especially turf used for golf greens in the southern United States (Elliott, 1991). It is caused by an interaction of host-predisposing abiotic stresses and the soil-borne, ectotrophic, root-infecting fungus *Gaeumannomyces graminis* var. *graminis*, which also causes a serious root rot disease of St. Augustinegrass and zoysiagrass (Krausz, 1992; Elliott et al., 1993).

Bermudagrass declinde is characterized by large areas of affected turf with poor, abbreviated, brown-to-black root systems and an absence of feeder roots and root hairs. Infected turf usually has few rhizomes and stolons. Gross symptoms include foliar chlorosis, a thinning stand, poor response to fertilizer and irrigation, and premature plant death (Photograph 1). The pathogen causes root, rhizome, and stolon rotting. Symptoms, however, are often not

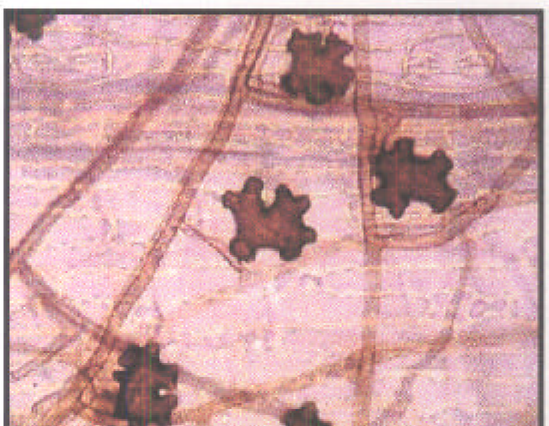


Photograph 1. Characteristic thinning and chlorosis of Bermudagrass decline caused by *Gaeumannomyces graminis* var. *graminis* in Champion bermudagrass.

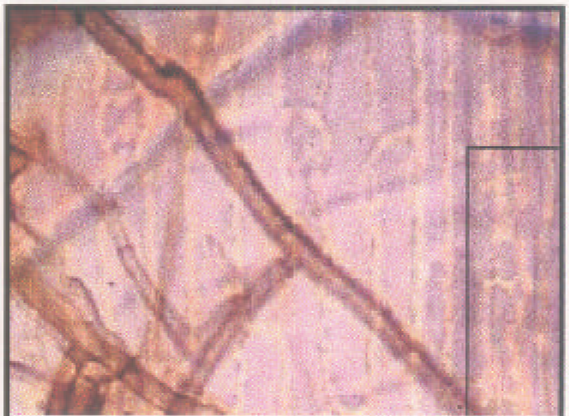
expressed until late spring or summer when high temperature and drought cause sufficient additional stress to impact bermudagrass growth and development. Large areas of greens usually become chlorotic and thin. Nutrient and irrigation management is difficult because of diminished root systems.

Bermudagrass decline is more widespread and devastating than previously imagined. In Texas alone, at the Texas Plant Disease Diagnostic Laboratory at Texas A&M University, 38% of a total 130 golf green bermudgrass samples received for diagnosis in the past 30 months were diagnosed as having bermudagrass decline. Bermudagrass golf greens infected by *Gaeumannomyces graminis* var. *graminis* are often devastated. After seeing symptoms, golf course superintendents often apply fungicides frequently and abundantly with little turf response. A common golf course situation is similar to a case in Beaumont, Texas, where recently $16,000 worth of fungicides were used ineffectively in an attempt to manage the disease on golf course greens.

Fungicidal control of bermudagrass decline is difficult because pathogen activity and disease symptom expression do not always coincide. Also, predisposition to infection by the pathogen and expression of disease damage appear to be influenced by other abiotic and biotic stresses. Cultural factors such as mowing height, type and level of nitrogen fertility, and soil pH, appear to have an effect on the incidence and severity of bermudagrass decline (Dernoeden, 1993). However, the interaction among several environmental, cultural, physiological, and chemical factors relative to the development and management of the disease has not been adequately defined.



Photograph 2. Characteristic hyphopodia (infection pads) of *G. graminis* var. *graminis*. J. P. Krausz, TAEX, 1996.



Photograph 3. Ectotrophic hyphae on turfgrass root surface. J. P. Krausz, TAEX, 1996.

The fact that bermudagrass decline rarely occurs in the absence of biotic and abiotic stresses, indicates that *G. graminis* var. *graminis* is an opportunistic pathogen. Infection and colonization by this pathogen appears to be dependent on host plants with a low energy balance and concomitant low vigor.

G. graminis var. *graminis* is a soilborne fungus which is an opportunistic pathogen of several warm-season turfgrasses. It easily exploits the turfgrass ecosystem and is able to persist on turfgrass root surfaces or in root cortical cells for long periods of time without causing visible injury to the host grass. However, when certain conditions favorable for disease development occur, this fungus can invade the vascular tissue of host roots, resulting in root dysfunction and eventual death of root tissue and the entire plant (Photgraph 2).

The ecology and epidemiology of *G. graminis* var. *graminis* presently is poorly understood. This fungus characteristically has an ectotrophic growth habit which describes an extended, external (ectotrophic) growth of fungal hyphae over the root surfaces that occur prior to penetration of the root cortical tissues (Photograph 3). Ectotrophic growth and disease development have been shown to increase following a decline in plant vigor. It is speculated that an interactive relationship exists between the defense mechanisms of the host and the ectotrophic fungal growth (Garrett, 1970). If host defense mechanisms weaken due to plant stress, infection may proceed with little obstruction.

The pathogen is not known to produce any truly durable, dormant resting structures used in saprophytic survival. Most evidence suggests that *G. graminis* var. *graminis* survives in the soil primarily in previously parasitized dead plant tissue or on the surface of live plant hosts. It is a weak competitor for organic matter compared with other soil micro-organisms. In the absence of a living host, the pathogen remains viable in the soil for relatively short periods of time (Landschoot et al. 1993). The most likely means of dissemination of the fungus appears to be through movement of infested root, crown, and stem tissue.

The ideal conditions for fungal growth appears to be during the moderate temperatures of the autumn and spring when adequate moisture is available. Fermanian et al. (1997) suggest that *G. graminis* var. *graminis* is most active during cool, moist weather when night temperatures are below 70°F, and during moist rather than dry weather. The pathogen is likely more active during fall, winter, and early-spring in the southern United States. However, the organism can be observed and isolated from affected bermudagrass greens during hot, dry conditions. Above-ground symptoms of infection often become evident anywhere from spring green-up through the spring and summer months when heat and moisture stress challenge the weakened root systems of affected plants. Winter overseeding grasses often mask any damage prior to spring and early-summer transistion and overseeding grass competition with bermudagrass may be another abiotic stress that predisposes bermudagrass to infection by the pathogen.

Previous work in Florida suggested that there was no significant difference in response of 28 bermudagrass accessions to root rot caused by *G. graminis* var. *graminis* (Elliott, 1995). However, this work was a greenhouse study in which the plants were grown in small tapered plastic containers (2.5 x 18 cm) and inoculated with as high as a 2-cm depth of inoculum. The greenhouse study did not take into account the cultural interactions or stress factors that may play an important role in varietal response in a field situation. There is often an inconsistency between field and greenhouse test results in evaluating bermudagrass for disease response to root rotting ectotrophic fungi (Crahay et al.,1988) Preliminary observations in a field test at College Station, Texas, designed to evaluate various cultural interactions on five bermudagrass cultivars indicated definite differences in reaction to the incidence and severity of bermudagrass decline. The management study at College Station, Texas includes Champion, Floradwarf, Miniverde, Tifeagle, and Tifdwarf bermudagrasses. Champion and Floradwarf appear to be highly susceptible, Tifeagle and Tifdwarf, moderately susceptible, and Miniverde had not developed symptoms of bermudagrass decline prior to 2000. Tifdwarf only exhibited slight symptoms at nitrogen application rates of 6 pounds per 1000 ft^{-2} annually. Floradwarf primarily exhibited symptoms at 10 pounds N per 1000 ft^{-2} or less annually, although symptoms were exhibited in Floradwarf at almost all N application levels. Conversely, Champion primarily exhibited symptoms at 14 and 18 pounds of N per 1000 ft^{-2} annually in conjunction with frequent, light vertical mowing. Symptoms of bermudagrass decline, particularly chlorosis, are evident in Champion at low N application levels but a major reduction in stand density has not occurred. Bermudagrass decline symptoms developed in Floradwarf in the second growing season and in Champion in the third growing season.

The data from Texas A&M University trials at College Station are of interest because Tifdwarf from actual golf greens has previously and often been diagnosed with bermudagrass decline. The soil pH at the Texas A&M University site prior to 2000 was 8.5 and above during summer months, irrigation water is high in sodium, and the previous years of the study have been hot and dry. Mowing heights are 0.157 inch during fall, winter, and spring and lowered to 0.125 inch during summer. Tifdwarf is not considered to be adapted to continuous mowing below 0.157 inch whereas, Champion in particular is recommended by some for greens mowed at 0.125 down to 0.100 inch. The relative response of Tifdwarf and Champion to N during the second (1998) and third (1999) growing seasons provide evidence that nutrition as well as cultivar susceptibility impact the development of bermudagrass decline. Although the turf quality response of both grasses in 1998 and for Tifdwarf in 1999 are considered typical responses to N, Tifdwarf exhibited minor symptoms of bermudagrass decline in 1999 at the lowest N level. Champion exhibited chlorosis at all N levels in 1999 with severe thinning and death at higher N levels in early-summer 2000. Increasing N caused increased thatch with subsequent scalping injury in Champion in late 1998 and 1999. The resultant abiotic stress caused by mechanical injury likely reduced photosynthetic capacity, reduced vigor, and predisposed Champion to more serious bermudagrass decline.

The preceding discussion is strong evidence that additional research is needed to define cultivar susceptibility to bermudagrass decline and to elucidate the relationship between specific cultural practices, abiotic stresses, and development of bermudagrass decline. The objective of this research is to determine the relationship between several environmental, cultural, and physiological factors to the development and cure of bermudagrass decline

APPROACH AND METHODS

Three issues need to be addressed. The first issue is the determination of cultural variables that provide the best prevention. The second is the determination of cultural variables that provide the most rapid cure. A third issue is cultivar susceptibility to *Gaeumannomyces graminis* var. *graminis.* A determination of the cultural variables that provide the best prevention should be linked to physiological parameters, such as crop growth rate (CGR), net assimilation rate (NAR) and critical or optimum leaf area index (LAI). The CGR, NAR, and LAI are genetically controlled but are influenced by environment and culture. These growth characteristics are indirect measures of distinct physiological processes in plants. The NAR is a measure of the average photosynthetic efficiency of leaves in a plant community.

With some modification in sampling methodology, these plant growth concepts may be adaptable for use in golf course monitoring of bermudagrass golf greens and as indicators to be used in altering cultural strategies as environments (seasons or weather patterns) change. Carbohydrate balance in plants has long been implicated in the performance and persistence of most turfgrass plants. High levels of non-structural carbohydrates in storage organs such as rhizomes and stolons are important for survival during winter dormancy and drought, and recovery growth following dormancy periods and injury. Maintenance of a critical or optimum LAI is paramount to maintaining an adequate carbohydrate balance in plants. Little information is available on CGR, NAR, LAI, and carbohydrate balance in golf greens and the relationship of these factors to performance and disease resistance because of the difficulty in measuring leaf surface area of plants growing on golf greens. However, determination of the relationships between cultural practices, environment, and specific physiological growth characteristics, will provide useful information on which to base recommendations for the prevention and most efficient cure.

Investigations of a Preventative System for Bermudagrass Decline. Our current research and previous work indicate an advantage of using acidifying fertilizers in the suppression of *Gaeumannomyces graminis* var. *graminis* and bermudagrass decline. We have identified in current USGA-Green Section supported work, new dwarf cultivars that are very susceptible and cultivars that are more tolerant or resistant to *G. graminis* var. *graminis* in our environment along with cultural practices that appear to promote or suppress disease activity. We propose research to more clearly delineate cultural practices that suppress or prevent development of bermudagrass decline and to quantify physiological parameters, such as CGR, NAR, critical or optimum LAI, and carbohydrate status that may be used to elucidate the relationship between environment, physiology, culture and bermudagrass decline development.

A susceptible and moderately susceptible cultivar will be established at the Texas A&M University Turfgrass Field Laboratory in College Station, Texas on a USGA-Green Section Specification Method for Green Construction golf green. Grasses will be main blocks. Mowing heights will be sub-plots and consist of bed knife bench settings of 0.125, 0.156, and 0.188 inch. Nitrogen treatments will consist of ammonium sulfate and polymer coated sources applied at 4, 8, and 12 total pounds of N per 1000 sq. ft. per year. Grooming, topdressing, and aerification will be uniformly applied and consistent with sound putting green management. Irrigation will be uniformly applied and closely equated to Class A Weather Pan evaporation.

After establishment of grasses and treatment structure, physiological growth parameters such as CGR, NAR, LAI, and non-structural carbohydrate status will be assessed to establish baseline information and monitored routinely during logically delineated seasons, such as late-spring, early-summer, mid-summer, etc. The growth parameters will be assessed as physiological markers or predictors for development of susceptibility to *G. graminis* var. *graminis*. Modifications in the measurement of these variables could make them applicable for use as specific indicators of bermudagrass growth, development, and physiological vulnerability to infection. Visual symptoms and microscopy will be used to determine presence and prevalence of However, there appears to be a substantial difference in expression of bermudagrass decline symptoms among bermudagrass cultivars.. Sampling for *G. graminis* var. *graminis* will be initiated at an early stage, probably at full establishment, and continue throughout the study on a regular basis in conjunction with measurements such as CGR, NAR, LAI, and non-structural carbohydrates. *G. graminis* var. *graminis* presence will be assessed by extracting 1-inch diameter cores of turf at random from each treatment. The cores will be gently washed to remove the soil from the roots. The roots will be evaluated microscopically for the presence of root discoloration and rotting and the presence of dark-pigmented fungal hyphae and lobed hyphopodia characteristic of *G. graminis* var. *graminis* associated with the discolored root tissue. Using surface disinfestation and a semi-selective media developed for isolation of *Gaeumannomyces*-like fungi (Elliott, 1991 b), the fungus in infected roots will be isolated, cultured on potato dextrose agar, and identified following production of its reproductive structures. After confirmation of the presence of *G. graminis* var. *graminis* in association with the rotting root symptoms, further disease evaluation will be based on above ground symptoms, since *G. graminis* var. *graminis* previously has been confirmed as a causal agent of bernudagrass decline (Elliott, 1991).

Meterological data will be recorded by a weather station located within 100 feet of the experimental site. Fungicides will not be applied. Information generated from this work will be used to determine the relationship between environment, culture, physiology, and disease development. Additional controlled environment research may be used to provide further clarification of plant response as needed.

Investigations of a Curative System for Bermudagrass Decline. Recommendations for recovery from bermudagrass decline include raising the mowing height and applying acidifying fertilizers or foliar feeding. Currently no published information is available on which to base recommendations for alleviating bermudagrass decline. An experimental bermudagrass green severely affected by bermudagrass decline is currently available to explore cultural and chemical approaches for alleviating the problem. The green is currently maintained at 0.125 inch, has a soil pH of 9.1, and is fertilized with a polymer coated nitrogen fertilizer. A series of treatments on this area to include nitrogen regimes, mowing heights, and fungicides will be applied to this area in a split plot design and recovery from decline will be evaluated. Nitrogen regimes will include weekly applications of ammonium sulfate applied at 0.5 lb N per 1000 sq. ft. as a granular and ammonium sulfate applied at 0.25 lb per 1000 sq. ft. as a foliar spray. Nitrogen regimes will be supplemented with potassium, phosphorus, and micronutrients based on soil tests. Fungicide treatments will include none, Heritage or Eagle. Treatment timing will include Fall, Spring, and Summer, and Fall + Spring. Crop growth rate, NAR, and/ or LAI will be assessed to determine their relationship to elimination of decline symptoms. Total non-structural carbohydrates in stolons will be determined before treatments are applied and every 8 weeks thereafter or more often if deemed necessary to assess treatment effects on plant energy status. Visual evaluations of turfgrass quality and disease incidence will be taken every 2 weeks. Microscopy will be used to assess presence and prevalence of *G. graminis* var. *graminis*. Additional on-site locations will be identified to pursue further testing of specific management strategies to aid recovery from bermudagrass decline.

Investigations of Bermudagrass Germplasm Disease Reaction to G. graminis var. graminis. Fifteen bermudagrass cultivars and experimental selections at the Texas A&M University Turfgrass field laboratory that currently exhibit no symptoms of bermudagrass decline will be used to determine field susceptibility to this devastating disease. Plots will be assayed to determine presence of *G. graminis* var. *graminis* by methods described above. Currently, these plots are fertilized with ammonium sulfate to supply about 10 lb N 1000 ft^{-2} annually. Nitrogen fertilization will be altered to include a non-acidifying fertilizer on one-half of each plot and ammonium sulfate to the other half. Mowing height will be maintained at 0.125 inch or below. Inoculation of plots with *G. graminis* var. *graminis* will be accomplished if bermudagrass decline symptoms do not develop naturally.

RESULTS & PROGRESS

Investigations of a Preventative System for Bermudagrass Decline was initiated in late-August 2000. Floradwarf and Tifdwarf bermudagrass were established in 25 feet by 25 feet randomized main blocks replicated four times using 12 bushels of sprigs per 1000 ft^{-2}. Floradwarf was chosen as the more susceptible and Tifdwarf as the more resistant cultivar based on previous observations. Currently the experimental area is about 90 percent established. Treatments as previously described will be imposed in spring 2001.

Investigations of a Curative System for Bermudagrass Decline. A Tifeagle bermudagrass golf green severely affected by bermudagrass decline was treated during August 2000 with a number of fungicides that have demonstrated activity on *G. graminis* var. *graminis* in laboratory tests. None of the fungicides tested proved effective in the field tests and almost all were phototoxic to bermudagrass (data not presented). Fungicide evalua-

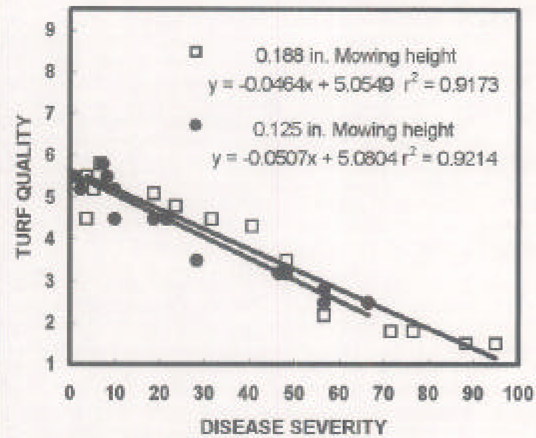
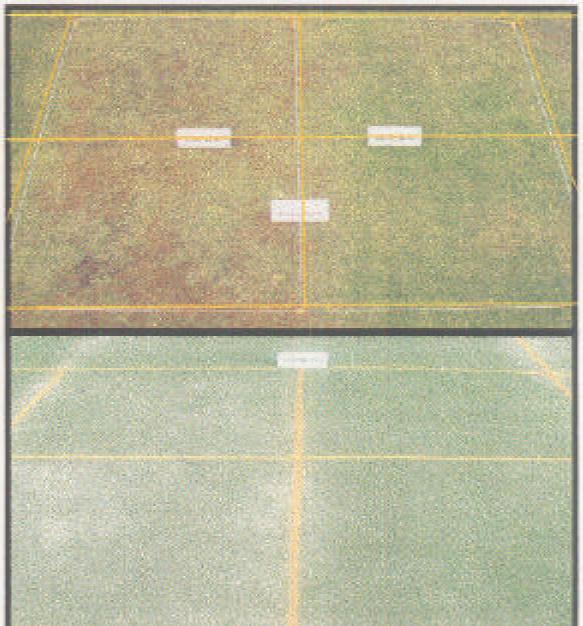


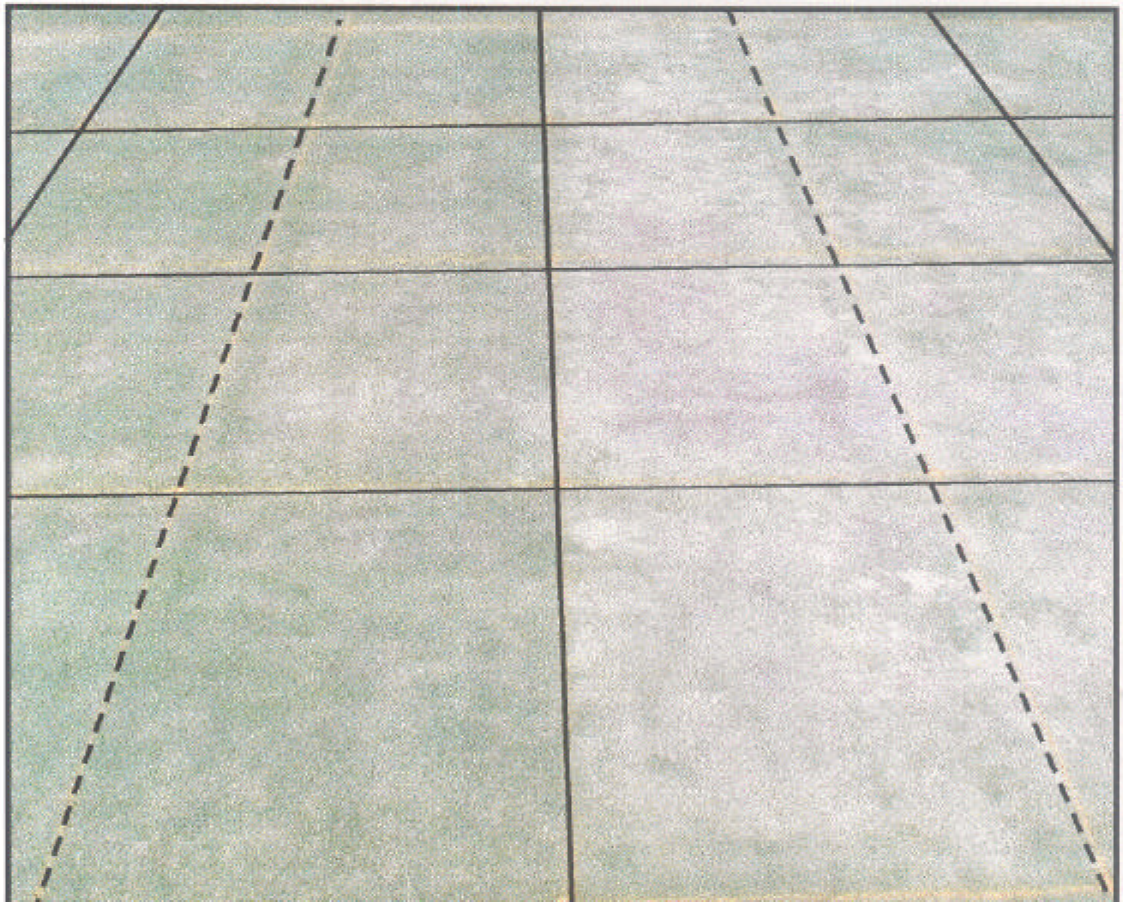
Figure 1. The relationship between turf quality and disease severity (percentage of plot area affected) for 15 bermuda cultivars on a golf green in College Station, TX during October 2000.



Photograph 4. Floradwarf in July 1999 (upper) and in September 2000 (lower) at the Texas A&M University Turfgrass Field Laboratory in College Station, TX. Left column receives 6 and right column receives 14 lb N 1000 ft^{-2} $year^{-1}$. All area in photographs received infrequent vertical mowing. Upper row receives frequent, light topdressing and lower row receives infrequent, heavy topdressing.

tions will continue during fall 2000 and during 2001.

Bermudagrass decline is usually associated with prolonged mowing at heights below the optimum for a specific cultivar. Subsequently, raising the mowing height is a cultural practice recommended for the alleviation of bermudagrass decline. During 2000, we had an opportunity to observe bermudagrass decline severity in 4 year old stands of 15 bermudagrass cultivars maintained under golf green conditions. Close mowing did not contribute to more severe or rapid development of bermudagrass decline. The greatest severity of bermudagrass decline was observed at a 0.188 inch, rather than at a 0.125 inch mowing height (Table 2 and Fig. 1). Most previous research on bermudagrass decline used Tifdwarf and Tifgreen to study the effects of mowing height on disease development. However, Tifdwarf and Tifgreen demonstrated resistance to *G. graminis* var. *graminis* as evidenced by minimal bermudagrass decline symptom development in 2000 when mowed at either 0.188 and 0.125 inch. Because many of



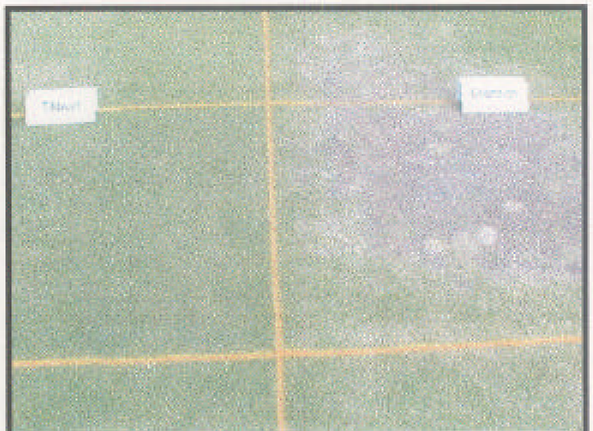
Photograph 5. Overview of one replication of Champion bermudagrass illustrating treatment effects and bermudagrass decline symptoms on 27 September 2000 at the Turfgrass Field Laboratory at Texas A&M University in College Station, Texas. Center vertical line represents a distance of 20 feet and divides infrequent, heavy (left) and frequent, light (right) vertical mowing treatments. Vertical dashed lines divide frequent, light treatments (outside columns) and heavy, infrequent (inside columns) topdressing treatments. Nitrogen treatments from frong to back rows are 6, 10, 14, and 18 lb N 1000 ft^{-2} annually.

the cultivars in this study have only recently been introduced, this study is the first to provide comparisons of the relative resistance of new cultivars with older cultivars such as Tifdwarf and Tifgreen.

Another opportunity to observe the effects of culture on the cure of bermudagrass decline was provided by altering the nitrogen source used in a bermudagrass management study and managing soil pH. Overall summer quality of Floradwarf in a management study was poor in 1999. Aggressive soil pH management approaches were taken beginning in 1999 and ammonium sulfate was used routinely to supply half the total annual N. Soil pH management was continued through 2000 and soil pH was maintained near 7.5. During 2000, a dramatic recovery of turf quality was observed and turf quality of Floradwarf was superior during summer of 2000 than in previous years (Photograph 4). Increasing N up to 14 lb 1000 ft^{-2} $year^{-1}$ increased turf quality. We attribute the recovery of Floradwarf from previous severe bermudagrass decline to alteration of soil pH.

Vertical mowing was also linked to bermudagrass decline development in 2000 in a related management study (Photograph 5). Frequent, light vertical mowing, a common practice currently used on bermudagrass golf greens caused increased bermudagrass decline symptoms when applied in late-summer particularly in Champion bermudagrass (Photograph 5).. Similar effects of vertical mowing on bermudagrass decline symptom expression were observed in Floradwarf and Miniverde and to a lesser extent in Tifeagle.

Many of the observations related to bermudagrass decline during 2000 were the result of ongoing USGA-Green Section sponsored research. Based on observations in 2000, cultural programs play a major role in development of bermudagrass decline. Well-defined, cultivar-specific cultural programs may prevent or allow recovery from damage caused by *G. graminis* var. *graminis*.



Photograph 6. Differential resistance to *G. graminis* var. *graminis* demonstrated by Tifdwarf (left) and Champion (right) bermudagrasses at College Station, Texas in September 2000.

***Investigations of Bermudagrass Germplasm Disease Reaction to G. graminis* var. *graminis*.** Fifteen bermudagrass cultivars and experimental selections at the Texas A&M University Turfgrass Field Laboratory in College Station, Texas exhibit no symptoms of bermudagrass decline in 1999. During 2000, bermudagrass decline symptoms were evident in a number of bermudagrasses. The range of resistance demonstrated by bermudagrasses in this test to *G. graminis* var. *graminis* was substantial with newer cultivars, in general, having a lower level of resistance than older cultivars such as Tifgreen and Tifdwarf (Table 2 and Photograph 6). Although mowing height had an influencing on symptom development, cultivar had a pronounced effect of disease severity. Previous work in Florida suggested that there was no significant difference in response of 28 bermudagrass accessions to root rot caused by *G. graminis* var. *graminis* (Elliott, 1995). Observations of the roots and stolons from these cultivars indicated that ectotrophic hypae and root rotting were present in each plot supporting previous reports (Elliott, 1995). However, there appears to be a substantial difference in expression of bermudagrass decline symptoms among bermudagrass cultivars when the pathogen is present.

Table 2. Turf quality and bermudagrass decline severity for 15 bermudagrasses and one zoysiagrass maintained at two mowing heights during 2000 at College Station, Texas.

Cultivar	Turf quality†	Disease severity
	------------ 0.188 in. mowing height ------------	
Diamond	7.1	1
Lakewood	5.0	4
MS Supreme	4.9	7
Tifdwarf	4.7	5
TXDB67	4.5	19
Tifgreen	4.3	5
Miniverde	4.1	24
Baby	4.0	4
TIF94-21	3.7	57
Tifeagle	3.6	32
Mobile	3.6	32
Floradwarf	3.1	48
TIF94-16	3.0	72
TIF94-18	2.9	95
TIF94-29	2.7	77
Champion	1.9	88
MSD‡	2.0	27
	------------ 0.125 in. mowing height ------------	
Diamond	7.2	9
TXDB67	5.1	8
Miniverde	5.0	8
Mobile	4.8	7
Lakewood	4.7	1
TIF94-21	4.5	47
MS Supreme	4.3	19
Tifdwarf	4.2	2
Tifgreen	4.1	10
Tifeagle	4.1	22
TIF94-16	3.9	48
Baby	3.9	28
Floradwarf	3.7	10
TIF94-18	3.7	57
Champion	3.0	57
TIF94-29	2.6	67
MSD	2.4	28

†Turf quality based on a scale of 1 equal to bare ground and 9 equal to most uniform, dense, and smooth, and finest leaf texture. Means are the average of observations for August, September, and October.
‡MSD, minimum significant difference at the 0.05 level of probability for comparison of cultivar means within columns and mowing heights based on Tukey's Multiple Range Test.

SUMMARY

Summer fungicide applications did not control bermudagrass decline. The phototoxic effects of several fungicides, due in part to application when summer temperatures were high, may actually have been counter productive to recovery from bermudagrass decline. Mowing is extremely important in the maintenance of high quality putting surfaces. Decreasing mowing height did not increase bermudagrass decline symptoms. During 2000, symptoms were more severe at 0.188 than at 0.125 inch. Vertical mowing had a major impact on the expression of bermudagrass decline symptoms and frequent, light vertical mowing during late-summer was devastating to Champion, Floradwarf, and Miniverde bermudagrasses. Routine defoliation and mechanical stress caused by frequent, light vertical mowing increased bermudagrass decline symptoms. Nitrogen nutrition affected bermudagrass decline severity in a complex manner. Increasing N increased bermudagrass decline severity in Champion and Miniverde but decreased severity in Floradwarf bermudagrass. Nitrogen source may also be important in management of bermudagrass decline. An acidifying N source reduced and nearly eliminated symptoms of bermudagrass decline when applied to Floradwarf growing on a golf green with above neutral soil pH. Although we have not documented resistance of bermudagrass to *G. graminis* var. *graminis*, we did observe differences in expression of bermudagrass decline symptoms among 15 bermudagrass cultivars. Bermudagrass decline symptoms were less severe in Tifwarf than in several of the newer dwarf bermudagrass cultivars.

FUTURE WORK

During 2001, we will continue to focus on resistance to *G. graminis* var. *graminis* among bermudagrass cultivars and methods to assess infection progress. Above ground Bermudagrass decline symptom expression in this study was not always associated with presence or absence of *G. graminis* var. *graminis.* Cultural treatments will be initiated on newly established Floradwarf and Tifdwarf to investigate the effects of mowing height and nitrogen source and amount on the development of bermudagrass decline. Fungicide application timing will also be assessed. Cultural practices, including nitrogen regimes, mowing heights, and fungicides will also be assessed to determine the effects of each on Tifeagle bermudagrass recovery from bermudagrass decline.

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