1996 Turfgrass and Environmental Research Summary

THE USGA®

UNITED STATES GOLF ASSOCIATION 1894

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1996 Turfgrass and Environmental Research Summary

SUBMITTED BY:

The United States Golf Association
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Statement of Intent

It is the intent of the United States Golf Association (USGA) Executive Committee through the USGA Foundation, to collect and disseminate substantial amounts of money for support of research to: 1) produce improved turfgrasses which substantially reduce water use, pesticide use, and maintenance costs; 2) develop management practices for new and established turf which protect the environment while providing quality playing surfaces; and 3) encourage young scientists to become leaders in turfgrass research.

It is anticipated that funds for this purpose will be derived, in major part, from contributions to the USGA Foundation. Additional funds may be derived in the future from royalties attributed to marketable discoveries. The USGA intends to return any income received from royalties to the support of turfgrass research.

Historically, the sport of golf has maintained a leadership role in the development of improved turfgrasses through the activities of the USGA Green Section. While those developments have provided better playing areas for golf, they also have had a far-reaching impact on turfgrass improvement for other uses. Home lawns, parks, school grounds, highway rights-of-way and all other turfgrass areas have been improved by developments pioneered by the USGA.

The USGA expects to support research at numerous institutions. In some cases, several institutions will be involved with the development of grasses and maintenance practices where the research may interact and overlap.

In view of this Statement of Intent, it is expected that recipients of grants will embrace a spirit of cooperation and engage in a free exchange of information with other investigators

Executive Summary

Overall Goals:

- *Reduce turfgrass water requirements, pesticide use, and maintenance costs.*
- *Protect the environment while providing good quality playing surfaces.*
- *Encourage young scientists to become leaders in turfgrass research.*

The Turfgrass and Environmental Research Program sponsored by the United States Golf Association, in cooperation with the Golf Course Superintendents Association of America, has three primary goals:

First, develop turfgrasses for golf courses that substantially reduce water use, pesticide use and maintenance costs;

Second, develop management practices for new and established turfs that protect the environment while providing quality playing surfaces;

Third, encourage young scientists to become leaders in turfgrass research through the USGA's direct involvement in and financial support of higher education in the United States.

This annual research summary reviews the progress made by USGA-sponsored researchers in projects directed toward:

1. Plant breeding for the development of turfgrasses with better resistance to stress and pest problems;
2. Evaluation of cultural practices that have potential to improve the ability of golf course turf to tolerate stress;
3. Evaluation of alternative pest control methods for use in integrated turf management systems;
4. Demonstrating that pesticides and fertilizers can be applied to golf course turfs while protecting environmental quality;
5. Evaluation of the mobility and persistence in turfgrass systems of parent compounds and transformation products of commonly applied pesticides and fertilizers;
6. Identification of the best combinations of putting green construction, grow-in procedures and post-construction maintenance practices that prevent long-term problems, reduce environmental impacts, and produce high quality playing surfaces; and
7. Evaluation of methods to develop and manage golf courses that protect and enhance wildlife habitat.

Highlights for 1993 through 1996

Turfgrass Breeding

- CRENSHAW (Lofts Seed) and CATO (Pickseed West) creeping bentgrasses continue to do well in the southern United States. CATO has done very well in some northern variety tests.
- MARINER (Syn1-88), a re-selection from SEASIDE, was released to Pickseed West for low-maintenance areas using poor quality irrigation water (i.e., soluble salts).
- CENTURY (Syn92-1) and IMPERIAL (Syn92-5), selected for improved heat tolerance and rooting, were released to Burlingham & Sons. BACKSPIN (Syn92-2) was released to Turf Merchants International and Scotts.
- PENNLINKS (Tee-2-Green) and PROVIDENCE (Seed Research) creeping bentgrasses are still used very successfully throughout the United States.
- OKS 91-11 has demonstrated superior cold tolerance among seeded bermudagrasses and final preparations for release were completed. Seed companies in Oklahoma, Oregon and Arizona have expressed interest in the variety.
- A seeded bermudagrass study conducted at the University of Georgia indicated that three of the Oklahoma State University experimental varieties were consistently better than Arizona Common. A decision to release one of the three, OKS 91-3, will be delayed until 1997 to permit further evaluation and increase of basic propagating stock.
- TIFTON 94 (MI-40), a mutant of vegetatively propagated MIDIRON bermudagrass, was released by Dr. Wayne Hanna from the USDA-ARS at Tifton, Georgia, for use on golf course fairways.
- TW-72 was developed by Dr. Wayne Hanna and has performed well in a bermudagrass putting green management study at Auburn University.
- A formal release of an African bermudagrass (*Cynodon transvaalensis*) germplasm from Oklahoma State University is under consideration.
- MN 184 (*Poa annua* var. *reptans*) was released to Peterson Seed by the University of Minnesota. Small quantities of seed are being used for testing on golf courses.
- Several of the vegetatively propagated zoysiagrasses developed by the Texas A&M University, Dallas were released. DIAMOND (DALZ 8502), CAVALIER (DALZ8507), CROWNE (DALZ85012) and PALISADES (DALZ85014) were released in 1996.
- CODY and TATANKA seeded buffalograss were released by the University of Nebraska to the Native Turf Group (NaTurf).
- The vegetative buffalograss varieties '609', '315', and '378' all continue to perform well on golf course roughs. New varieties tolerant to fairway cutting heights are under development.
- Three new vegetative buffalograsses, NE 86-61, NE 86-120 and NE 91-118, are currently being processed for release. The three selections have excellent quality, density, low mowing tolerance and sod production characteristics.
- Close mowing trials have identified several putting green and fairway seashore paspalumgrasses that will be useful for golf courses in the South which use poor quality irrigation water high in soluble salts.

Cultural Practices

- Results from University of Nevada indicate that buffalograss can provide adequate turf for roughs with deficit irrigation of 50 to 60 percent of evapotranspiration (ET).
- Five methods of evaluating ET_o (reference evapotranspiration) vary by as much as 30% according to the results of the University of Arizona study.

- Biochemical analysis techniques continue to provide information on how some bermudagrass plants tolerate lower cold temperatures. Changes in the phospholipids of the cellular membrane may play an important role in winter acclimation.

Alternative Pest Management

- Creeping bentgrass plants resistant to glufosinate ammonium herbicide (Finale) were successfully produced using genetic engineering technology. The genetics of how this gene is sexually transferred to progeny is under evaluation.
- Biological technology is being used to produce disease resistant bentgrasses by introducing genes that produce the chitinase protein and protease inhibitor.
- Bentgrasses resistant to brown patch (*Rhizoctonia solani*) were successfully selected using the Host Plant Interaction System (HPIS) developed at Mississippi State University.
- Several bacteria are under evaluation for their disease suppressive characteristics on summer patch (*Magnaporthe poae*) and *Pythium*-incited diseases of creeping bentgrass.
- Results at the University of Kentucky suggest that the number of grubs required to cause noticeable injury was much higher than prevailing rule-of-thumb estimates used by the turf industry.
- Mowing at 1/8 or 3/16 of an inch removes nearly all of the black cutworm eggs laid on bentgrass greens. This suggests that cutworm infestations may originate from larger larvae that migrate onto greens from surrounds.
- Perennial ryegrass and tall fescue were found to be as suitable for cutworms as creeping bentgrass, but Kentucky bluegrass was highly unsuitable as a source of food.
- A new species of bacteria which parasitizes the sting nematode (*Belonolaimus longicaudatus*) is under evaluation at the University of Florida.
- Mole cricket behavior studies conducted at Cornell and NC State University indicate that their tunneling is affected by the presence of other crickets, soil type and subsurface placement of insecticides.
- A bioassay technique developed at University of Arkansas indicates that perennial ryegrass produces an allelopathic substance. However, field studies to examine if the allelopathic substance reduce crabgrass infestations were inconclusive.

Best Management Practices

- Pesticide and nutrient runoff research at Oklahoma State University has demonstrated that untreated buffer strips reduce the amount of chemical in runoff water. However, when the soil is saturated from extended periods of rain, the buffers strips have little or no effect.
- The volatilization research at University of Massachusetts has shown the importance of considering the vapor pressure of a pesticide. The critical vapor pressure below which no turfgrass pesticide will volatilize to the extent that it results in an unhealthy situation is between 3.3×10^{-6} to 5.6×10^{-5} mm Hg.
- University of Florida research thoroughly documented that irrigation amount and frequency influence the amount of fenamiphos and its metabolites that leach through high-sand putting green root zones. After a heavy rainfall, the amount of metabolite leaching through the green was the same for the high and low irrigation treatments (i.e., low irrigation treatment benefits were negated by a single heavy rainfall event).

Pesticide and Nutrient Fate

- Research at University of California has shown that the amount of chlorothalonil and metalaxyl to volatilize from putting green field plots is less than 1% over a 10-day period. The concentration of metalaxyl in leachate was negligible for the first 50 days after application, and then rose to a peak at 75 days (0.072% of total applied). Only 0.0021 percent of the applied chlorothalonil leached through the rootzone over a 150 day period.
- At University of Georgia, the results for nine pesticide products produced a high correlation ($r^2 = 0.91$) between the amount of pesticide found in runoff water and the pesticide's water solubility. Less than one percent of the applied

chlorothalonil, chlorpyrifos, benefin, and pendimethalin was transported from the plots in runoff water. However, as much as 9 to 16 percent of the 2,4-D, dicamba, mecoprop, and nitrate were transported in the surface runoff. Five times more pesticide was transported from fairway plots near field capacity compared to those near the wilting point.

- Purdue University results show that concentrations of metalaxyl, triadimefon, and vinclozolin in turfgrass clippings fell below detectable limits within 13, 10, and 17 days after application, respectively. At the termination of the experiment, chlorothalonil was detectable at low levels from clippings collected 27 days after application.
- The strong sorptive properties of turfgrass leaves and thatch trapped 99 percent of the applied cyproconazole at 2 hours after treatment according to the University of Illinois study.

Putting Green Construction and Management

- Sand friction angle and coefficient of uniformity measurements were used to determine putting green strength and stability at Michigan State University. An increase in sand particle-size distribution (i.e., higher uniformity coefficients) increased the strength and stability of the putting green root zone. However, a greater reduction in soil porosity after compaction occurred for well-graded sands as compared to uniform sands.
- At Pennsylvania State University, progress was made using the direct shear method, rotatable drum, dense soil angle of repose, and cone penetrometer to mechanically classify sand shape.
- A preliminary experiment at Ohio State University-OARDC confirmed that low permeability mixes exhibited higher water contents than the high permeability mixes. The low permeability mixes had substantially higher water contents with depth, particularly at downslope locations with a four percent slope.
- Rutgers University provided additional evidence for the correspondence of sand size distribution with hydraulic conductivity. Air-filled porosity at 40 cm tension was found to be within or slightly above the range recommended by the USGA for the ten sand mixes (without amendments) used in the study. Air-filled porosity at 40-cm water tension did not completely measure porosity responsible for saturated hydraulic conductivity.
- In many southern bentgrass greens, organic matter accumulates in the surface 0 to 2 inches, from 1.5 to 2.0 percent (by weight) at establishment, to 8 to 12 percent after two years. Oxygen levels in the surface 1-inch were below the acceptable minimum for 9 to 26 hours after irrigation. Cultivating with the HydroJect in a raised position (nozzle 4 inches off the surface) created approximately quarter-inch diameter holes that maintained acceptable infiltration rates for about three weeks. Wetting agent further enhanced infiltration.
- Preliminary data from Cornell University indicates that iprodione, mefenoxam, propiconazole benzamide and cyproconazole fungicides had little effect upon microbial communities. The survival of highly sensitive organisms suggests that fungitoxic concentrations do not penetrate one inch below the soil surface.
- A protocol was established for all cooperators (i.e., University of Florida, Clemson and Auburn) in a southeastern project to evaluate the bacterial populations and diversity in new and old putting greens.

Golf and Wildlife

- The Audubon Cooperative Sanctuary Program had 1,822 courses actively participating in the effort.
- The Wildlife Links Program has initiated three new studies: Wetland Restoration and Management, Bird Habit Management for Golf Courses, and the Golf Course Wildlife Habitat Database.

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Table 1. USGA Turfgrass and Environmental Research Budget - 1993 through 1997.

Project/Subproject	University/Investigator	1993	1994	1995	1996	1997	Total
Turfgrass Breeding:							
Bentgrass	Texas A&M Univ./Engelke	60,000	63,000	66,150	69,458	72,930	331,538
Cool Season	Rutgers University/Funk	8,000	8,000	8,000	8,000	8,000	40,000
Bermudagrass	USDA-UGA/Burton	8,000	8,000	8,000	8,000	8,000	40,000
Bermudagrass	Oklahoma St. Univ./Taliaferro	60,000	63,000	66,150	69,458	72,930	331,538
Buffalograss	Univ. of Nebraska/Riordan	60,000	63,000	66,150	69,458	72,930	331,538
Colonial Bentgrass	Univ. Rhode Island/Ruemmele	20,000	21,000	22,050			63,050
Seashore Paspalum	Univ. of Georgia/Duncan	20,000	21,000	22,050	40,000	40,000	143,050
Poa annua	Univ. of Minnesota/White	40,000	20,000	10,000	10,000	10,000	90,000
Zoysiagrass	Texas A&M Univ./Engelke	60,000	63,000	66,150	69,458	72,930	331,538
	Subtotal:	**336,000**	**330,000**	**334,700**	**343,830**	**357,722**	**1,702,252**
Alternative Pest Management:							
Mole Cricket	NC State Univ./Brandenburg		20,000	20,000	20,000	20,000	60,000
Black Turfgrass Ataenius	Univ. of California/Cowles		10,000				10,000
Black Turfgrass Ataenius	Cornell University/Villani		10,000				10,000
Sting Nematode Control	Univ. of Florida/Giblin-Davis		20,000	20,000	20,000	20,000	60,000
Allelopathy	Univ. of Arkansas/King		10,000	10,000	10,000		30,000
White Grubs	Univ. of Kentucky/Potter		20,000	20,000	20,000	20,000	60,000
Brown Patch Resistance	Mississippi State Univ./Krans	25,000	26,250	27,563			78,813
Disease Resistance	Michigan State Univ./Vargas		20,000	20,000	20,000	20,000	60,000
Disease Resistance	Virginia Poly Tech Univ./Ha	25,000	26,250	27,563			78,813
Herbicide/Disease Resistance	Rutgers University/Day	45,000	47,250	49,613	48,824	50,939	241,626
Disease Suppression	Cornell University/Nelson		20,000	20,000	20,000	20,000	60,000
Summer Patch Suppression	Rutgers University/Kobayashi	20,000	21,000	22,050			63,050
	Subtotal:	**115,000**	**250,750**	**236,788**	**158,824**	**150,939**	**812,301**
Cultural Practices:							
Water Use/Buffalograss	Univ. of Nevada/Bowman	15,000	15,750	16,538			47,288
Water Use/Bermudagrass	Univ. of Georgia/Carrow	12,273	12,359	13,488			38,120
Water Use/Zoysiagrass	Univ. of Georgia/Carrow	21,500					21,500
Water Use/Bentgrass	Univ. of Georgia/Carrow	6,000					6,000
Effluent Water	Univ. of Arizona/Brown	25,000	26,250	27,563			78,813
Low Temperature/Drought	Clemson University/Baird	20,000	21,000	22,050	20,000	20,000	103,050
Drought Stress/Bentgrass	Texas A&M Univ./White		22,453	23,576	24,754		70,783
Putting Green/Bermudagrass	Auburn University/Guertal			10,000	10,000	10,000	30,000
Mycorrhizae	Univ. Rhode Island/Jackson	40,000					40,000
	Subtotal	**139,773**	**97,812**	**113,214**	**54,754**	**30,000**	**435,553**
Best Management Practices:							
Runoff Management	Oklahoma State Univ./Baird		0	39,440	40,977	44,869	125,286
Volatilization	Univ. of Massachusetts/Clark		0	42,779	45,501	46,416	134,696
	Subtotal:		**0**	**82,219**	**86,478**	**91,285**	**259,982**
Pesticide and Nutrient Fate:							
Pesticide Leaching	Univ. of Illinois/Branham		65,000	46,911	45,527	46,518	203,956
Pesticide Leaching/Volatilization	University of California/Yates		0	44,322	44,728	44,097	133,147
Pesticide Leaching	Univ. of Florida/Snyder-Cisar		22,000	48,244	47,084	45,924	163,252
Pesticide Leaching/Runoff	University of Georgia/Smith		0	33,640	48,720	58,000	140,360
Degradation Rates	Purdue Univ./Turco-Throssell		0	45,291	41,152	42,214	128,657
Transport Modeling	University of Maryland/Carroll		0	38,042	36,569	35,380	109,991
Golf Course Siting	Iowa State University/Kuiper					25,000	25,000
Model Modification	Cohen/Smart		0	30,000	40,000	40,000	110,000
	Subtotal:		**87,000**	**286,450**	**303,780**	**337,133**	**1,014,363**
Golf Course Benefits:							
USGA Cooperative Sanctuary	Golf House		1,000	1,000	1,000	1,000	4,000
Cooperative Sanctuary Program	Audubon International		100,000	100,000	100,000	100,000	400,000
Wildlife Links Program	National Fish & Wildlife Foundation		0		100,000	100,000	200,000
	Subtotal:		**101,000**	**101,000**	**201,000**	**201,000**	**604,000**
Putting Green Construction:							
Engineering Characters	Michigan State Univ./Crum				20,000	20,000	40,000
Classifying Sand Shape	Penn State Univ./Mancino				10,000	10,000	40,000
Layers in Golf Greens	STRI/Baker				18,383	10,395	28,778
Hydrology of Greens	Ohio St. Univ.-OARDC/McCoy				10,000	10,000	40,000
Root Zone Mixes	Rutgers Univ./Murphy				10,000	10,000	40,000
New Construction Technology	NC State Univ./Bowman				20,000	20,000	40,000
Grow-in and Cultural Practices	Univ. of Nebraska/Gaussoin				10,000	10,000	40,000
Organic Matter Dynamics	Univ. of Georgia/Carrow				10,000	10,000	40,000
Non-target Fungicide Effects	Cornell University/Harmon				20,000	20,000	40,000
Bacterial Populations/Diversity	Univ. of Florida/Elliott				13,333	13,333	26,666
Bacterial Populations/Diversity	Auburn University/Guertal				13,333	13,333	26,666
Bacterial Populations/Diversity	Clemson University/Skipper				13,333	13,333	26,666
	Subtotal:				**168,382**	**160,394**	**428,776**
Other:							
International Turf Conference.	ITS/Watson	5,000				5,000	10,000
	Subtotal	**5,000**				**5,000**	**10,000**

Turfgrass Breeding

The quality and stress tolerance of a turf is the product of the environment, management practices, and genetic potential of the grass plant. In many cases, various stress effects are the major causes of poor quality turf.

The turfgrass breeding projects are directed at reducing water and pesticide use through the development of resistance to several stress and pest problems. The most desirable characteristics of potential new turfgrasses include:

- drought tolerance
- high and low temperature tolerance
- tolerance of non-potable water
- tolerance of acid, alkaline or saline soils
- reduced mowing requirements
- efficient use of fertilizers
- traffic tolerance
- genetic stability of characters
- disease, insect and nematode resistance
- competitiveness against weeds
- tolerance to smog and other pollutants
- shade tolerance

The USGA turfgrass breeding programs have focused on the improvement of zoysiagrass, native grasses, *Poa annua*, bermudagrass, bentgrass and seashore paspalum. The turfgrasses resulting from the sponsored research must meet the needs of golf courses. In the following table, the breeding projects, species, and status of varieties are summarized.

Table 2. Summary of USGA Turfgrass Breeding Projects.

Turfgrass	University	Status of Varieties
Creeping Bentgrass *Agrostis palustris*	Texas A&M University	CRENSHAW (Syn3-88), CATO (Syn4-88) and MARINER (Syn1-88), CENTURY (Syn92-1), IMPERIAL (Syn92-5), BACKSPIN (92-2) were released. All are entered in 1993 NTEP trials.[1]
	University of Rhode Island	PROVIDENCE was released.
	Pennsylvania State University	PENNLINKS was released
Colonial Bentgrass *Agrostis tenuis*	DSIR-New Zealand and University of Rhode Island	A preliminary line, BR-1518, was entered in the NTEP trials. A new line is being evaluated at the University of Rhode Island.
Bermudagrass *Cynodon dactylon*	New Mexico State University	NuMex SAHARA, SONESTA, PRIMAVERA and other seed propagated varieties were developed from this program.
	Oklahoma State University	Two seeded types, OKS 91-11, and OKS 91-1 were entered in the 1992 NTEP trials. OKS 91-11 was approved for release in 1996.
C. transvaalensis	Oklahoma State University	A release of germplasm for university and industry use is under consideration.
C. dactylon X C. transvaalensis	University of Georgia	TIFTON 10 and TIFTON 94 (MI-40) were released; a TIFWAY mutant (TW-72) is under evaluation for release.
Buffalograss *Buchloe dactyloides*	University of Nebraska	Vegetative varieties 609, 315, and 378 were released. Seeded varieties CODY and TATANKA were released. Three new vegetative selections, NE 86-61, NE 86-120 and NE 91-118, are currently being processed for release.
Alkaligrass *Puccinellia* spp.	Colorado State University	Ten improved families are under evaluation and have been released.
Blue grama *Bouteloua gracilis*	Colorado State University	ELITE, NICE, PLUS and NARROW are under evaluation in anticipation of release.
Fairway Crested Wheatgrass *Agropyron cristatum*	Colorado State University	Narrow leafed and rhizomatous populations were developed; nothing was released.
Curly Mesquitegrass *Hilaria belangeri*	University of Arizona	Seed increases of 'fine' and 'roadside' populations are available for germplasm release and further improvement.
Annual bluegrass *Poa annua* var *reptans*	University of Minnesota	Selections #42, #117, #184, #208, and #234 were released and are under evaluation for seed production.
Zoysiagrass *Zoysia japonica* and *Z. matrella*	Texas A&M University	Ten vegetative selections were entered in the 1991 NTEP trial. DIAMOND (DALZ8502), CAVALIER (DALZ-8507), CROWNE (DALZ8512) and PALISADES (DALZ8514) were released in 1996.
Seashore Paspalum *Paspalum vaginatum*	University of Georgia	Germplasm has been assembled and is under evaluation. Two green types (AP 10, AP 14) and one fairway type (PI 509018-1) are being evaluated on golf courses.

[1]National Turfgrass Evaluation Program, Beltsville Agricultural Research Center, Beltsville, MD 20705

Improvement of *Poa annua* var. *reptans* for Golf Turf

Dr. Donald White

University of Minnesota

Goals:

- *Expand the evaluation and development of the advanced selections for turf quality, seed production and testing recommendations.*
- *Continue and expand seed production evaluations in Oregon.*
- *Continue and expand the development of a breeder's seed supply.*
- *Expand seeded evaluation plantings at selected golf course and university locations.*

Three selections of *Poa annua* var *reptans* MN#42, MN#184 and MN#208, were released in an exclusive agreement to Peterson Seed Co. of Savage, Minnesota in 1994.

The November 1993 experimental seed production planting of these three selections continued under observation and seed was harvested for the last time before the planting was destroyed, as planned, this fall. Standard harvesting machinery and procedures were employed in this process.

One of the haunting questions of the growers relates to the ability to clean up a field once seeded to creeping bluegrass and to reclaim it for seed production of other grasses. For that and other reasons, this planting was purposefully destroyed during the late summer and fall of 1996. The 1992 trial plantings at Pickseed West were also eliminated this fall.

1994 seed from the above planting was utilized in seeding two semi-experimental fields, totaling 17 acres, to MN#184 during the fall of 1995. Unfortunately, the largest of those fields, approximately 11 acres, was flooded and had to be abandoned. The other field also was flooded and under water for several days; however the grower was able to maintain the planting and seed was harvested from approximately 3 acres in 1996.

A new 7-acre planting, to replace the flooded and abandoned seeding, was seeded to MN#184 (1994 seed) in April of 1996 with expectations for seed production in the spring of 1997.

Our research has clearly shown that MN#184 possesses an obligate vernalization

requirement. Plants in this seeding were not exposed to sufficient cold to fulfill that requirement (between 4 and 8 C for 10 to12 weeks). This allowed additional rouging of all plants that produced flowers during the 1996 growing season. This should ensure true-to-type seed from this field in 1997. Additionally, plantings were seeded in October of 1996 with the expectation that they will produce seed in June or July 1997. No new seed trials of MN#42 or MN#208 were initiated in 1996.

Much of the effort in 1996 focused on learning about seed production and seed production problems. Additional tests to evaluate seed harvested in Oregon for trueness to type were initiated and occupied substantial time and effort during 1996.

Cultural trials were initiated with a June 1995 seeding on a high sand content (90:10, sand:peat) green. A replicated trial was established with10 selections in the program, including MN#42, MN#184, and MN#208. The green was covered during the winter. Although some winter damage was observed to some selections, all recovered sufficiently.

The trial was attacked by dollar spot and *Rhizoctonia* which were identified from lab samples during the summer of 1996. However, symptoms also indicated the possibility of a severe *Anthracnose* or *Pythium* problem on several of the selections. MN#184 and some of the other numbered selections displayed remarkable resistance to the organism(s) involved.

In addition, MN#184 exhibited substantial resistance to *Fusarium* patch in both Washington and Oregon putting green trials over the 1995-96 winter. The 1995-96 winter was a particularly difficult year for *Fusarium* problems in the Pacific Northwest. MN#42 and MN#208 also exhibited some resistance in the Oregon trial.

Several new trials were established during 1996 or late in the Fall of 1995. Plantings at The Columbia Country Club in Columbia, Maryland; Bloomfield Hills, Michigan; University of Rhode Island; and the Greenbrier Country Club, White Sulphur Springs, West Virginia. Arrangements were made and seed delivered for future trials at the Broadmoor Country Club in Seattle, Washington; the Vancouver Country Club in Vancouver, Canada; and Pebble Beach.

A 5,000 square foot planting of bulked seed from many of the selections in the program was established to expand evaluations of mixtures and to serve as a source of materials in maintaining our gene bank for the future. In addition, this will offer us the opportunity to increase cultural practices research including: fertility, plant growth regulation, pest management, seed head control, stress management, selective herbicide tolerance, interseeding bentgrass and other important needs.

In response to a need to shorten turn-around time, we have initiated a limited program of starting promising materials. Materials are seeded into compartments in flats. After sufficient growth as been attained for the plants to be receptive to vernalization treatments, the plants are exposed to a cold treatment in a controlled temperature cooler. This procedure has proven to be quite successful in inducing flowering and subsequent seed development.

Two hundred accessions were advanced at least one generation during 1996. Field plantings included space planting of approximately 250 different accessions in units of ten plants for evaluation for plant growth habit, vigor, spreading ability, texture, color, and other characteristics important for adaptability to golf course use. This planting also was utilized for seed collection to increase desirable materials for further study and evaluation.

During the fall, more than 1,500 tillers from the most promising materials were collected for propagation and to ensure that these materials will be carried over to 1997. Some tillers were used to develop plants for seed increase over winter, while others were devoted to advancing to the next generation or simply for preservation of the plant material.

Forty different crosses were completed between superior selections in the program. Two of these crosses resulted in non-flowering progeny. Several progeny exhibited combinations of characteristics superior to either parent.

A project has been initiated to build a library for use in RFLP investigations with creeping bluegrass materials in this project.

We hope to construct a plastic greenhouse that will enable faster seed production by completing a full cycle of establishment in flats, vernalization, and flowering under complete isolation of clones and/or lines. This should speed up the process of evaluation, selection, seed increase and shorten the time to introduction.

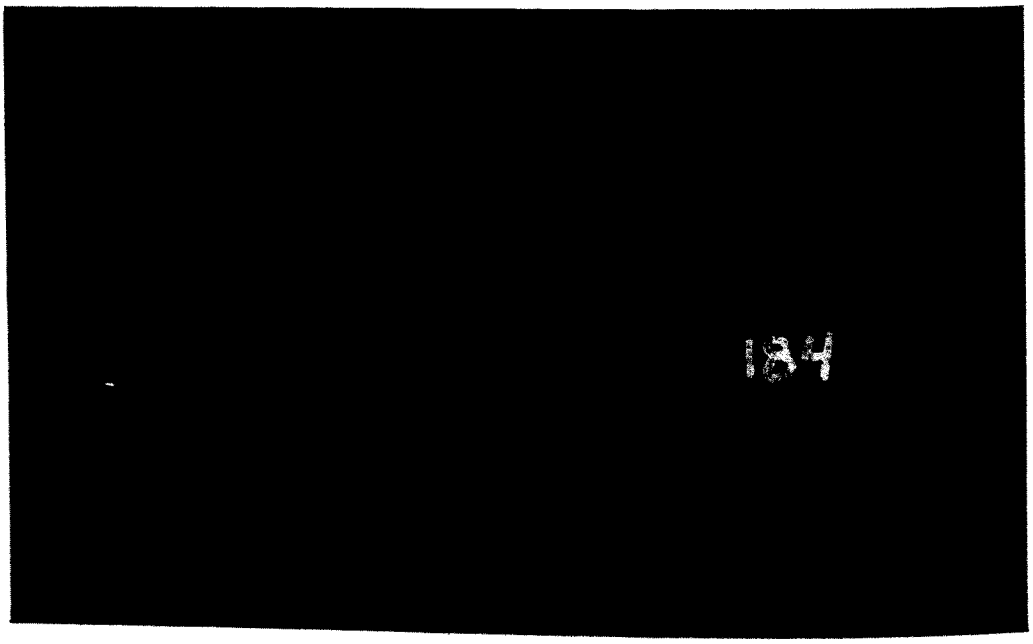

Figure 1. View of MN#184 bordered on two sides by disease susceptible selections. Dollar spot and brown patch were isolated from blighted areas. Small plots of some of the new selections (lower right of photograph) also exhibited some resistance.

Breeding and Evaluation of Kentucky Bluegrass, Tall Fescue, Perennial Ryegrass, and Bentgrass for Turf

Dr. C. Reed Funk

Rutgers University

Goals:

- *Collect and evaluate potentially useful turfgrass germplasm.*
- *Collect and evaluate endophytes associated with cool-season turfgrass species.*
- *Continue the breeding and development of new cool-season turfgrasses.*

Cooperators:

William A. Meyer
Jennifer Johnson-Cicalese
James Murphy
Michael Richardson
James White
Dirk Smith
Ronald Bara
Melissa Mohr
Rachael Roux
Christine Kubik
Pedro Perdomo
Stacy Bones
Joseph Clark
William K. Dickson
Barbara Smith

The USGA has enjoyed a very long and productive relationship with Dr. Reed Funk at Rutgers University. Today, the financial contribution of the USGA to his breeding program is small compared other royalty income received. Due to the efforts of Dr. Funk and the international stature of his breeding program, Dr. William Meyer has joined Rutgers University to carry on the outstanding contribution this institution and its faculty have made to the turfgrass industry.

Dr. William A. Meyer was assigned leadership of the newly invigorated turfgrass breeding program in April 1996. A total of over 50,000 plots of turfgrass cultivars, experimental selections, and germplasm sources are under observation and evaluation in field trials at Adelphia, North Brunswick, and Pittstown, New Jersey.

Over 8,500 new seeded turfgrass evaluation plots, over 20,000 clonal evaluation plots, and over eleven acres of spaced-plant nurseries were established in 1996.

Promising turfgrass germplasm and associated endophytes were collected from Poland, Austria, Switzerland, Germany, New Jersey, Connecticut, New York, and Oregon. Increased emphasis was placed on collecting creeping, colonial, dryland, and velvet bentgrasses.

Germplasm developed at the New Jersey Agricultural Experiment Station was used in a number of new turfgrass varieties including Palmer III, Premier II, Catalina, Wizard, and Divine perennial ryegrasses;

Genesis, Tarheel, Renegade, Jaguar 3, Grande, Barlexas, SR-8210, Gazelle, and Duster tall fescues; Treasure Chewings fescue; and Nordic hard fescue.

Studies were initiated to develop a more rapid method of screening for resistance to the stripe smut disease.

Kentucky bluegrasses with good field resistance to current races of stripe rust are being evaluated for other useful characteristics.

A seedling screening technique has proven successful in identifying promising hybrids in large populations obtained from crossing highly apomictic Kentucky bluegrasses.

Moderate wear treatments on newly established turfs have been effective in identifying fescues and perennial ryegrasses with improved resistance to net blotch and leaf spot diseases.

Chinch bugs caused severe damage to endophyte-free strong creeping and Chewings fescues, whereas half-sib progenies of the same fine fescues containing endophytes showed enhanced resistance in both field and laboratory tests. Petri-dish preference tests, using first-instar chinch bugs, were used to compare E+ fine fescue combinations with the E- - counterparts. A significantly higher percentage of nymphs were found on the E- tillers for four of the five comparisons. These studies demonstrated endophyte-enhanced chinch bug resistance for the first time in strong creeping red fescue.

Population improvement programs continue to show progress in the genetic improvement of perennial ryegrasses, tall fescues, Chewings fescues, hard fescues, strong creeping red fescues, and creeping bentgrass. Similar population improvement programs have been initiated on recent collections of colonial, dryland, and velvet bentgrasses.

Continued progress is being made in identifying and developing Kentucky bluegrasses with improved performance under severe summer stress and also at reduced maintenance.

Breeding and Development of Bentgrass

Dr. Milt Engelke

Texas A&M University

Goals:

- *Develop stress tolerant bentgrass cultivars with specific emphasis on heat tolerance, root growth characters, turf quality, and resistance to natural disease and insect pests.*
- *Continue genetic studies involving heritability and stability of biological traits associated with stress tolerance.*

Cooperators:

Ikuko Yamamoto
Jamie M. Mills
Marine Doin

The bentgrass breeding program is a cooperative research project funded jointly by the Texas Agricultural Experiment Station (TAES), the USGA and Bentgrass Research, Inc. (BRI). This project was initiated in April, 1985.

The bentgrass project released MARINER Creeping Bentgrass to the industry in 1996. The variety was licensed to Pickseed West, Inc. which also handles CATO Creeping Bentgrass, released in 1993. MARINER is a salt tolerant reselection from Seaside, and has improved turf quality. It is recognized as a specialized grass that will have considerable utility in areas where salinity is a problem.

Three additional grasses are being prepared for release in early 1997. E. F. Burlingham holds options on CENTURY (Syn92-1) and IMPERIAL (Syn92-5). TMI and Scotts hold an option on BACKSPIN (Syn92-2). The initial seed harvest from the Syn96 series was made in 1996 (planted in the fall of 1995) with great production expectations.

Three individual lines have been created which further combine added disease resistance, including total resistance to Dollar Spot along with improved genetic color, texture and density of stand. Preliminary indications suggest these will provide a substantial incremental improvement for biological adaptability to natural environmental conditions.

The bentgrass breeding program has initiated a program for genetic improvement utilizing the concepts of biotechnology. Nodal explants have been generated of each of the parental lines of CENTURY, all

having excellent stability of phenotypes. In cooperation with Dr. Phil Colbaugh (Turfgrass Pathology), the intent of the project will be to incorporate the gene(s) conditioning for Dollar Spot resistance directly into the parental clone(s) of CENTURY, followed by minimal reselection to develop a Dollar Spot resistant variety with the excellent agronomic and biological characteristics of CENTURY.

Research is also being conducted in cooperation with Dr. Richard White, Texas A&M College Station on methodology and success of interseeding of the new bentgrasses into existing bentgrass greens.

Preliminary results are very encouraging based on electrophoresis analysis of Penncross greens that have been interseeded with CENTURY utilizing various cultural procedures. Future efforts will also examine other methods of mechanical and chemical treatments and timing and rates of interseeding.

Table 3. 1995 mean turfgrass qauality ratings of bentgrass cultivars for each month grown on a green at twenty-five locations in the U.S. and Canada.

Name	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct	Nov.	Dec.	Mean
LOFT'S L-93	4.4	4.3	5.8	6.1	6.3	6.7	6.4	6.5	6.4	6.7	6.4	5.1	6.4
PENN A-1	4.1	4.6	5.3	6.0	6.2	6.3	6.3	6.2	6.2	6.6	6.3	5.1	6.1
PENN G-2	4.1	4.3	5.3	5.9	6.1	6.3	6.2	5.8	6.1	6.6	6.0	5.0	6.0
PENN A-4	4.5	5.0	5.5	6.0	6.3	6.3	6.1	6.1	6.0	6.4	6.2	5.3	6.0
CATO	4.1	4.3	5.5	5.6	6.1	6.2	6.1	6.1	6.2	6.3	5.8	5.2	6.0
PROVIDENCE	4.0	4.5	5.3	6.0	6.0	6.0	5.9	5.9	6.1	6.2	5.9	4.8	5.9
PENN G-6	3.6	4.2	5.5	5.6	6.0	6.0	6.2	6.0	6.0	6.2	5.8	4.2	5.9
SOUTHSHORE	4.4	4.5	5.6	5.7	5.9	6.1	5.8	5.7	5.8	5.9	5.9	4.7	5.8
IMPERIAL	4.0	4.2	5.7	5.7	5.9	5.9	5.6	5.6	5.5	5.9	5.4	4.7	5.6
CENTURY	4.2	4.5	5.5	5.7	5.7	5.7	5.7	5.6	5.5	5.8	5.5	4.7	5.6
PENNLINKS	4.1	4.0	5.5	5.5	5.6	5.8	5.6	5.6	5.6	5.7	5.3	4.5	5.6
CRENSHAW	3.4	4.2	5.5	5.4	5.6	5.8	5.7	5.6	5.5	5.9	5.6	4.2	5.5
BAR WS 42102	3.2	3.7	4.7	5.3	5.7	6.0	5.6	5.5	5.6	5.6	4.7	3.3	5.5
SR 1020	4.2	4.4	5.2	5.4	5.4	5.6	5.5	5.4	5.6	5.8	5.8	5.0	5.5
DG-P	3.9	3.9	5.1	5.1	5.3	5.4	5.4	5.6	5.7	6.0	5.4	4.6	5.5
BACKSPIN	3.6	4.0	5.4	5.5	5.8	5.7	5.5	5.5	5.3	5.6	5.0	4.4	5.5
ISI-AP-891500	3.5	4.0	5.3	5.0	5.4	5.8	5.3	5.4	5.8	5.8	5.3	4.5	5.5
MSUEB	3.8	4.0	4.9	5.4	5.3	5.5	5.5	5.5	5.7	5.6	5.1	4.5	5.4
LOPEZ	3.7	3.9	4.9	5.0	5.2	5.5	5.4	5.4	5.6	5.9	5.3	4.5	5.4
REGENT	4.1	3.9	5.4	5.0	5.1	5.4	5.3	5.5	5.5	5.7	5.2	4.4	5.3
PRO/CUP	3.5	3.7	5.4	4.8	5.1	5.3	5.4	5.3	5.2	5.4	5.1	4.2	5.2
TRUELINE	3.5	3.6	5.3	4.9	5.0	5.2	5.2	5.3	5.4	5.4	5.2	4.3	5.2
MARINER	4.3	4.1	5.2	4.9	5.1	5.2	5.0	5.2	5.3	5.5	4.9	4.4	5.1
PENNCROSS	3.7	3.9	5.0	5.1	5.1	5.2	5.0	5.1	5.2	5.3	4.7	4.0	5.1
18TH GREEN	3.1	3.6	4.6	4.8	5.1	5.4	5.4	5.4	5.0	5.1	4.3	3.6	5.0
BAR AS-492	4.6	4.1	4.2	4.0	4.1	4.0	4.0	4.0	4.8	4.7	5.0	4.5	4.3
TENDENZ	3.7	3.6	4.2	4.0	4.1	4.3	3.8	3.8	4.6	4.4	4.1	3.9	4.1
SEASIDE	3.7	3.4	4.0	3.7	3.7	3.8	3.7	3.9	4.5	4.3	4.4	4.0	4.0
$LSD_{0.05}$	1.4	1.2	1.0	0.7	0.5	0.5	0.4	0.5	0.6	0.6	0.9	1.2	0.4

[1]Turfgrass quality ratings on a 1 to 9 scale where 9 = ideal turf. To determine statistical differences among entries, subtract on entry's mean from another entry's mean. Statistical differences occur when this value is larger than the corresponding $LSD_{0.05}$ value.

Breeding and Evaluation of Cold-tolerant Bermudagrass Varieties Golf Courses

Dr. Charles Taliaferro

Oklahoma State University

Goals:

- *Assemble, evaluate, and maintain Cynodon germplasm with potential for contributing to the genetic improvement of the species for turf.*
- *Improve bermudagrass germplasm populations for seed production potential, cold tolerance, and other traits conditioning turf performance.*
- *Develop, evaluate and release superior seed-propagated, cold-tolerant, fine-textured, turf bermudagrass varieties for the U.S. transition zone and similar climates.*
- *Develop, evaluate and release improved vegetatively propagated bermudagrass varieties with specific adaptations and uses in the southern U.S., e.g. varieties for golf course putting greens in the deep South.*

Cooperators:

James Baird
Dennis Martin
Jeffery Anderson
Michael Anderson

The turf bermudagrass breeding program was initiated in 1986 at Oklahoma State University. The initial broad objective was to develop fine-textured, winter-hardy, seed-propagated varieties for the U.S. transition zone. The program was expanded in 1990 to include the development of superior vegetatively-propagated varieties.

The turf bermudagrass breeding program at Oklahoma State University is a team effort among scientists in stress physiology, molecular biology, plant breeding, genetics, and turfgrass management aimed at developing superior, fine-textured, cold-tolerant, seed- and vegetatively-propagated varieties.

Molecular research has led to the identification of differentially expressed mRNA's in Midiron control and cold-acclimated plants. Investigations of genetic relatedness of *Cynodon* taxa were also initiated this year. Polymerase chain reaction technology is being employed to assess DNA composition in plant materials.

Additional detail was prepared in a manuscript titled: "Molecular Identification Of Cold Acclimation Genes In, and Phylogenetic Relationships Among, Cynodon Species." A flow cytometry protocol was developed for bermudagrass, and nuclear DNA contents were determined for four cytotypes. Details were described in a manuscript titled: "Use of Flow Cytometry to Estimate Ploidy Level in Cynodon Species." Two experimental synthetic varieties have performed well in comparison to other seed-propagated varieties in various field tests. OKS 91-11 has consistently

ranked high in turf quality and cold hardiness in the 1992 National Turfgrass Evaluation Program test and in a field evaluation with JACKPOT and MIGRAGE seeded bermudagrasses at OSU. OKS 91-11 exhibited exceptional turf quality at both 0.5 and 1.5-inch mowing heights. Both seedling and mature stands of OKS 91-11 are tolerant to commonly-used postemergence herbicides. The formal release of OKS 91-11 will proceed during the winter of 1996-97. Seed companies in Oklahoma, Oregon, and Arizona have expressed interest in the variety.

OKS (BERPC) 91-3 has performed well in tests conducted in Georgia in terms of turf quality and stand persistence. A decision on release of OKS 91-3 will be delayed until 1997 to permit further evaluation and increase of basic propagating stock.

Three bermudagrasses collected from the Peoples Republic of China in 1993 demonstrated very good turf quality and reasonably high fertility in preliminary evaluations. Further evaluations will continue next year.

Tolerance to Spring Dead Spot (SDS) disease has been evaluated for several seed- and vegetatively-propagated bermudagrasses and a manuscript describing this research has been prepared. Additional bermudagrass selections were inoculated with a causal organism of SDS for evaluation in upcoming years.

Cynodon transvaalensis selections made over the past 5 years have provided new and valuable germplasm within this species to use both in intraspecific and inter-specific breeding. F_1 hybrid plants from interspecific crosses have been identified which have good turf quality characteristics. These plants are being expanded for further evaluation and potential release in the future. Some interspecific hybrid plants are cytogenetically unique and are proving valuable as parents in breeding.

Fifteen *C. transvaalensis* plants selected from screening nurseries over the past four years were planted in an isolated polycross in 1996. Polycross seed will be used to produce a new population for further selection. We are also considering a formal release of the resultant population as a germplasm since the *C. transvaalensis* germplasm base in collections in the USA and worldwide is very narrow.

A *C. transvaalensis* genetic population was field planted in 1996 to study genetic variation within the species. Management studies have revealed that *C. transvaalensis*: 1) responds to higher fertility levels, especially nitrogen; 2) is sensitive to higher rates of Dimension, Ronstar, and hormone-type herbicides when mowed at putting green cutting heights; 3) possesses an upright growth habit which results in less ball roll and susceptibility to scalping injury; 4) requires frequent topdressing and vertical mowing for maximum turf quality; 5) transitions out of dormancy faster than other bermudagrass species; 6) is severely weakened by winter overseeding; 7) undergoes an unexplainable period of decline during the summer; 8) possesses exceptional winter hardiness and tolerance to SDS; 9) looks best in terms of turf quality in the spring and fall; and 10) has potential for use on golf course putting greens, tees, and fairways.

Breeding, Evaluation and Culture of Buffalograss for Golf Course Turf

Dr. Terrance Riordan

University of Nebraska

Goals:

- *Develop vegetative and seeded turf-type buffalograsses which conserve energy and water.*
- *Develop buffalograss establishment protocols and management systems to provide acceptable golf course rough and fairway turf with significantly reduced cultural inputs.*
- *Determine the range of adaptation of turf-type buffalograss.*
- *Evaluate potential insect and disease pests of buffalograss.*
- *Evaluate physiological and biochemical principles of environmental stress and nutrient utilization in buffalograss.*

Cooperators:

Paul Johnson
Fred Baxendale
Roch Gaussoin
Leonard Wit
Charles Rodgers
Kevin Frank
Shuizhang Fei
T.M. Heng-Moss
Garald Horst
Robert Grisso
John Watkins
Gary Yuen
Robert Klucas

Through October, sales of buffalograss by Crenshaw & Doguet turfgrasses, Inc. has been above last year's level (approximately $1.5 million for '609'). A/G Sod of Phoenix, AZ, currently has 90 acres of '609' and PRAIRIE under production. This region has great market potential because of water issues in Arizona and the interest in using buffalograsses on golf courses.

Three selections: NE 86-61, NE 86-120 end NE 91-118, are currently being processed for release, protection, and commercialization. These genotypes have excellent quality, density, low mowing tolerance, and excellent sod production characteristics. Disclosures are being developed for these three genotypes, and they were entered into the 1996 National Turfgrass Evaluation Program Buffalograss Trial. Two of these selections have been vegetatively increased at Todd Valley Sod Farm at Mead, NE. The third will be planted next spring.

The older top selections in the program ('315', '378', 86-61, 86-120, 91-118) continue to perform well, but due to the mild conditions, fewer differences were seen this year. Additional vegetative selections, identified from nurseries and progeny rows, will be subjected to further evaluation.

Experimental seeded varieties show good performance compared to the vegetative varieties and better than standards. Single cross varieties were first evaluated in the field in 1996. Single crosses may provide improved uniformity

compared to the more typical synthetic crosses.

Inheritance studies continue to yield useful information. Selection for seed weight increased means by 13.7 and 25.6 mg per 100 caryopses in two populations. These gains from selection suggest increases in seedling vigor with additional cycles.

Buffalograss management research centered around planting date, mowing height, and nitrogen fertilization programs. The optimal seeding dates for buffalograss at Nebraska are April through June and at Utah, April through July. Late season plantings suffered winter kill or had inadequate buffalograss cover the next year.

Weed competition is the most important factor restricting buffalograss establishment. A major study was started in 1996 to determine best management practices for buffalograss. Mowing heights of 1, 2, and 3 in., and nitrogen levels of 0, 0.5, 1.0, 2.0, and 4.0 lb. N/1000ft2 were applied.

The lab component of this project includes tissue culture, DNA content measurement, and molecular marker research. Cell suspension cultures of buffalograss have been established from '609' and 84-45-3. Callus also can be initiated from unexpanded leaf material of 84-45-3 and '315'; however, no organogenesis has been observed so far. This research is essential for future transformation of buffalograss with genes, such as those conferring resistance to herbicides.

Flow cytometry has enabled differentiation of three ploidy levels among buffalograss accessions. It has identified a trend of tetraploids in southern Great Plains and hexaploids in the northern Plains.

Table 4. 1995 mean turfgrass quality turfgrass ratings of buffalograss cultivars for each month grown at twelve locations in the U.S.

Name	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Mean
NTG-3	5.0	5.3	5.7	6.0	5.7	6.2	5.9	5.5	5.5	4.8	3.6	2.5	5.5
378 (NE 85-378)	4.3	4.8	5.4	6.2	5.7	6.5	5.6	5.6	4.9	4.3	3.4	2.5	5.4
315 (NE 84-315)	4.5	4.7	5.4	6.2	6.1	6.2	5.7	5.5	4.9	4.0	3.0	2.3	5.4
609 (NE 84-609)	5.3	5.2	6.0	6.6	4.9	5.8	5.9	5.9	5.8	5.6	5.8	3.8	5.4
NTG-5	4.2	4.8	5.4	5.6	5.4	6.2	5.7	5.6	5.5	4.7	3.6	2.3	5.4
NE 84-436	5.0	5.0	5.6	5.8	5.5	6.2	5.6	5.6	5.3	4.3	3.6	2.2	5.4
TATANKA (NTG-1)	5.0	5.0	5.4	6.0	5.5	6.2	5.5	5.4	5.4	4.8	4.0	2.5	5.3
NTG-4	4.8	4.8	5.7	5.8	5.4	6.3	5.6	5.3	5.3	4.7	3.8	2.5	5.3
NTG-2	4.5	4.8	5.3	5.9	5.2	6.0	5.5	5.3	5.4	4.7	4.1	2.8	5.3
SHARPS IMPROVED	4.8	5.3	5.3	6.2	5.4	5.8	5.4	5.3	5.2	4.9	3.9	2.3	5.2
PRAIRIE	5.2	5.2	6.0	6.2	4.9	5.6	5.3	5.5	5.5	5.4	5.0	3.7	5.1
AZ 143	4.8	5.5	5.9	5.7	5.2	5.8	5.2	5.2	5.2	4.4	3.4	2.5	5.0
BISON	4.3	5.0	5.4	6.2	4.9	5.5	5.4	5.2	4.9	4.8	3.7	2.5	5.0
BUFFALAWN	5.8	5.3	5.6	5.8	4.7	6.1	5.3	5.1	5.2	4.7	5.1	3.3	5.0
TOP GUN (BAM 101)	4.5	5.0	5.3	5.8	4.9	5.7	5.1	5.0	5.0	4.8	4.1	2.7	4.9
TEXOKA	4.2	4.8	5.3	5.3	4.7	5.6	5.2	5.0	5.1	4.5	3.6	2.3	4.9
HIGHLIGHT 25	6.0	5.7	5.8	5.8	4.5	5.7	5.0	4.9	5.1	5.2	5.4	3.7	4.8
PLAINS (BAM 202)	4.5	5.0	5.3	5.6	4.8	5.6	5.2	4.7	4.5	4.7	3.9	2.7	4.7
NE 84-45-3	4.2	5.2	5.1	5.3	4.4	5.4	5.1	4.6	4.4	3.7	2.8	2.5	4.5
HIGHLIGHT 15	5.5	5.5	5.4	5.8	4.2	5.4	4.9	4.3	4.9	4.8	5.2	4.2	4.5
HIGHLIGHT 4	5.5	5.2	5.4	5.3	4.1	5.2	4.9	4.6	5.0	4.5	5.1	3.3	4.5
RUTGERS	5.8	5.2	5.3	5.3	3.8	5.0	4.6	4.7	5.1	5.0	4.8	3.0	4.4
$LSD_{0.05}$	1.4	1.3	0.7	0.7	0.8	0.8	0.8	0.8	0.9	1.0	1.1	1.6	0.7

[1]Turfgrass quality ratings on a 1 to 9 scale where 9 = ideal turf. To determine statistical differences among entries, subtract on entry's mean from another entry's mean. Statistical differences occur when this value is larger than the corresponding $LSD_{0.05}$ value.

Development of Stress Tolerant Seashore *Paspalum* for Golf Course Usage

Dr. Ron Duncan

University of Georgia

Goals:

- *Establish an extensive collection of genetic material.*
- *Improve the adaptability of the species with special emphasis on: acid soil stress tolerance with deep rooting and root plasticity in high bulk density (compacted) soil, winter hardiness to expand its adaptation zone, and wear resistance that will meet or surpass golf course requirements.*

Cooperators:

B.J. Johnson
Kris Braman
Wayne Hanna
Bob Carrow

A new green, a new tee, and two new fairways were built during 1996 to streamline initial evaluation of *Paspalum* ecotypes and provide larger sites for additional evaluation of putting green, tee and fairway types. Initial evaluation is on a green with mowing height 1/8 to 3/16 of an inch, which identifies fast-growing tee/fairway types and slow-growing putting green types. Variations in slow release and fast-release nitrogen fertilizers, irrigation, and verticutting were used to establish the new tee and new green from stolons.

Two putting green types (AP 10, AP 14) and one fairway type (PI 509018-1 from Argentina) are currently being evaluated on golf courses. Three courses in Atlanta—The Standard Club, Berkeley Hills CC, and Atlanta National CC—are evaluating the Paspalums; two in Texas—Kings Crossing G&CC in Corpus Christi and The Cliffs near Graford; and one in California—Tony Lema GC in San Leandro.

Studies are continuing using simple sequence repeats or microsatellites to genetically profile *Paspalum* ecotypes. Preemergent, postemergent and establishment herbicide strategies are being investigated in cooperation with B. J. Johnson. Field mole cricket evaluations are being conducted at Tifton, GA, in collaboration with Kris Braman and Wayne Hanna. Bob Carrow has refocused his research program to assess stress tolerance mechanisms in *Paspalum*. The three ecotypes being evaluated on golf courses have been planted in Lincoln, NE, Manhattan, KS, Stillwater, OK, and Dallas,

TX to determine their cold thermal threshold winter hardiness. They have survived - 8° F at Blairsville in North Georgia.

Somaclonal variation resulting from tissue culture regeneration has resulted in over 100 new selections from among 5,500 regenerated plants, with improvements in genetic color (darker green), spread (growth rate), density (short internode length, finer leaf texture) and winter hardiness (6° C lower cold thermal threshold).

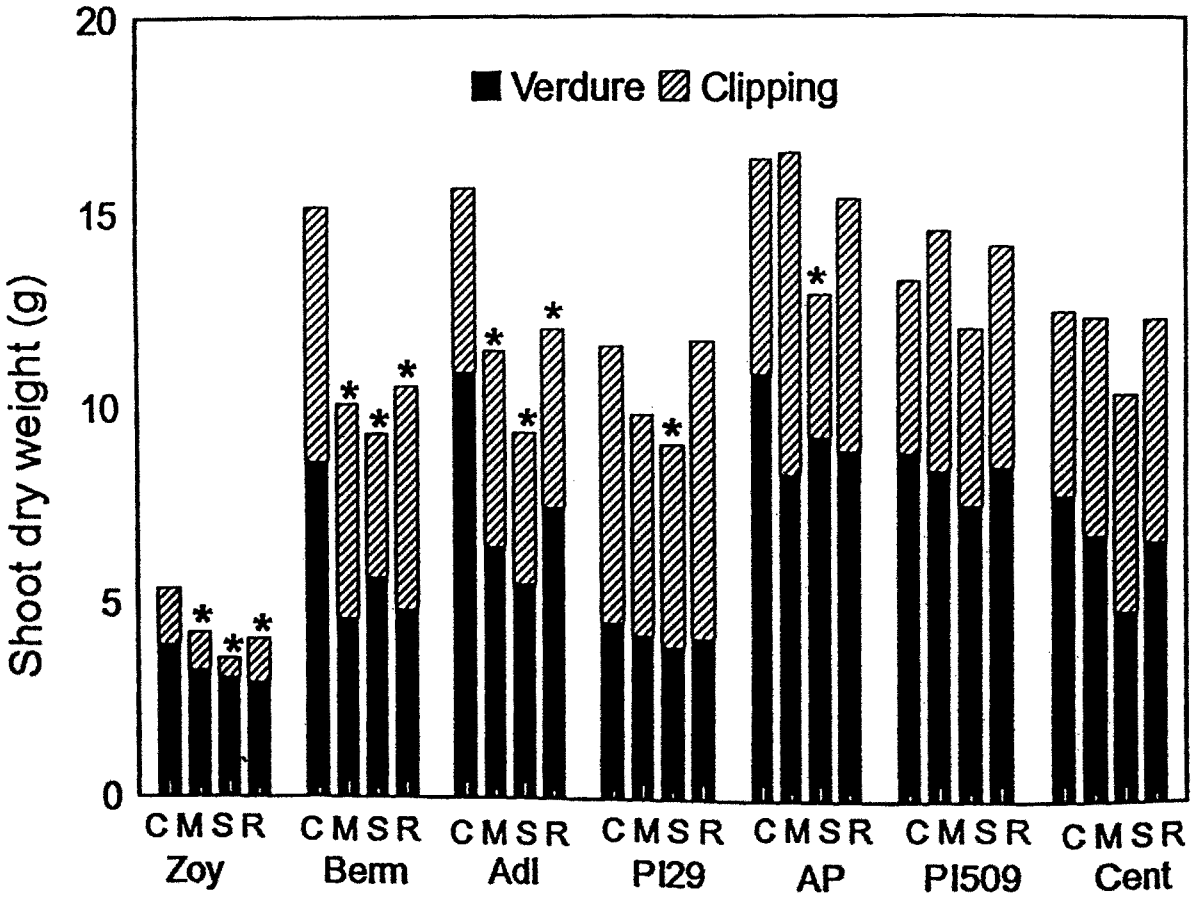

Figure 2. Shoot dry matter production, including clippings and verdure, of seven turfgrasses under various soil moisture conditions: control (C); moderate stress (M); severe stress (S); and rewatering (R). Bars marked with a '*' indicate significant differences from the respective controls base on a $LSD_{0.05}$ test. The seashore *Paspalums* in the study included Adl (ADALAYD), PI 29 (PI 299042), AP (AP14) and PI509 (PI509018). Other grass species included were Zoy (Emerald zoysiagrass), Berm (Common bermudagrass) and Cent (TIFBLAIR Centipedegrass).

Breeding and Development of Zoysiagrass

Dr. Milt Engelke

Texas A&M University

Goals:

- *Develop improved zoysiagrass cultivars with multiple character performance involving low water-use, persistence under drought and temperature stress, and tolerance to poor water quality.*
- *Develop seeded zoysiagrasses that are genetically stable, with improved turf quality, persistence, and competitive ability.*
- *Continue genetic studies involving the heritability and stability of biological traits.*

Cooperators:

Ikuko Yamamoto
Yaling Qian

After many years of selection, evaluation and extensive examinations, The Plant Improvement Review Committee at Texas A&M University officially released four high quality turf-type zoysiagrass cultivars 1996. DIAMOND, formerly identified as DALZ8502, is a very fine texture, dense, shade tolerant *Zoysia matrella*, suitable for golf course tee boxes, putting green surrounds, putting greens, and athletic fields in the southern United States.

CAVALIER (DALZ8507), is a fine-texture *Z. matrella*, suitable for golf course fairways, athletic fields, and home lawns. CAVALIER's overall turfgrass performance was evaluated as number one in the National Turfgrass Evaluation Program over a 3-year period.

CROWNE (DALZ8512) and PALISADES (DALZ8514) are medium to coarse texture varieties of *Z. japonica* and suitable for use on golf course roughs, sports fields, home lawns, or as utility turf. CROWNE is noted for excellent competition against weeds, and low water use needs. PALISADES also is noted for low water use, and has a more rapid sod harvest cycle than other zoysiagrasses.

All cultivars are vegetatively propagated by either stolons and/or rhizomes. The rate of establishment and harvest cycle differs considerably among them. DIAMOND reproduces primarily by a deep, dense rhizome system which requires approximately 15 months for the first harvest, with subsequent harvest in Dallas, Texas approximately every 6 months. CAVALIER is primarily stoloniferous and requires 10-12 months for establishment,

with a 12 month harvest cycle. CROWNE and PALISADES both reproduce extensively with stolons and rhizomes. CROWNE's harvest cycle will approach three crops in 24 months, whereas, PALISADES will provide two harvest in 12 months in environments similar to northern Texas. Approximately 1,100 m^2 of breeder fields and 7,000 to 8,600 m^2 of foundation fields are ready for harvest for CAVALIER, CROWNE and PALISADES. DIAMOND is available only as breeder stock, as a foundation field is not available.

Table 5. Summary agronomic merits and limitations of four new zoysiagrasses.

New Zoysiagrass	Agronomic merits	Agronomic limitations
DIAMOND (DALZ8502) is a fine textured highly rhizomatous, vegetatively propagated *Z. matrella* noted specifically for its excellent tolerance to low light and high salt conditions, and rapid recuperative ability. Diamond is suitable for use as a warm-season turfgrass for putting greens and tee boxes on golf courses, especially in the coastal regions of the southern United States where shade and salinity are a problem.	• Excellent salt tolerance • Excellent shade tolerance • Highly rhizomatous • Excellent sod strength • Low water requirements • Early spring green up • Good genetic color • Fall color retention • Fine leaf texture • High shoot density Disease Resistance: *Rhizoctonia* blight resistance Insect Resistance: Fall army worm and tawny mole cricket	• Lacks winter hardiness • Tropical and sub-tropical climates • Susceptible to the tropical sod web worm • Susceptible to zoysiagrass mite • Tendency to thatch and scalp • Will not tolerate overseeding • Slow initial establishment from sprigs
CAVALIER (DALZ8507) is a fine-textured, long-leaf, vegetatively propagated *Z. matrella* noted specifically for uniformity in appearance and distinct summer presentation. It is genetically stable, basically self-infertile and vegetatively propagated through weak rhizome and strong stolon growth.	• Cold hardy • Shade tolerant • Salt tolerant • High visual quality • Fine leaf texture • Spreads by stolons Good genetic color Insect resistance: tropical sod web worm, fall army worm, tawny mole cricket Disease resistance: *Pythium* blight and *Rhizoctonia* blight	• Requires sharp reel mower • Slow rate of establishment • Slow rate of recovery • Vegetative propagation required • Potential tendency of thatch • Susceptible to zoysiagrass mite
CROWNE (DALZ8512) is a coarse-textured, vegetatively propagated clone of *Z. japonica* which is suitable for use as warm-season turfgrass for golf course roughs, home lawns, industrial parks, and highway right-of-ways throughout the central mid-western states. Optimum mowing height will range from 5.0 to 7.5 cm; however, it can be mowed as close as 1.5 cm.	• Medium-coarse texture • High visual quality • Rapid establishment and regrowth • Good fall color retention • Shade tolerant • Salt tolerant • Cold hardy • Heat tolerant • Variable mowing height (1.0 to 7.5 cm)	• Susceptible to *Rhizoctonia* • Tendency to scalp
PALISADES (DALZ8514) is a medium-coarse textured vegetatively propagated clone of *Z. japonica* which is suitable as a warm-season turfgrass throughout the transition zone for golf course fairways and roughs, home lawns, sports fields, industrial parks, and highway medians. Optimum mowing height ranges from 1.0 to 5.0 cm. On tees and fairways, mowing heights of 8 mm is possible with acceptable results.	• Medium-coarse texture • High visual quality • Rapid establishment and regrowth • Good fall color retention • Shade tolerant • Salt tolerant • Cold hardy • Heat tolerant • Variable mowing height 1.0 to 5.0 cm)	• Susceptible to fall army worm

Cultural Practices

A series of research projects with the aim of substantial reduction in water use, pesticide use and maintenance costs have been and continue to be conducted on a regional basis. This is necessary because of regional differences in climate, soil, and stress conditions. The objectives of these studies have focused on the following:

- Range of adaptation and stress tolerance of new grasses resulting from the breeding projects
- Evaluation of direct and interacting effects of two or more cultural practices
- Management of native and low-maintenance grasses
- Development of cultural programs that substantially reduce weedy species in golf turf
- Development of cultural practices that allow efficient turf management under conditions of poor quality soils or severe air pollution, or that permit the use of effluent or other marginal-quality waters
- New research techniques that reduce pesticide and other chemical usage

The results of these studies have led to the development of maintenance programs that conserve substantial quantities of water, reduce fertilizer needs, and decrease mowing frequency; all without impairment of functional quality or aesthetic appeal.

Physiological Basis for Selection of Bentgrasses With Superior Drought Resistance

Dr. Richard White

Texas A&M University

Goals:

- *Determine the water balance in creeping bentgrasses with performance in adverse environments.*
- *Assess management systems for the incorporation of diverse bentgrass germplasm into existing bentgrass putting greens to improve their stress resistance and functional quality.*

Cooperators:

Dave Gilbert
Gene Taylor

Creeping bentgrass provides a premier surface for golf course putting greens. A preference for this species and increasing demands by the public for quality putting surfaces have fueled the expansion of bentgrass use throughout the deep South, well beyond the area of adaptation for this species. The expansion of bentgrasses throughout this environmentally stressful area has out-paced development of stress tolerant bentgrass cultivars.

Irrigation and syringing are used on bentgrasses throughout the South to prevent moisture and heat stress. Golf course superintendents pay close attention to soil conditions to ensure adequate soil moisture levels. However, shallow root systems and high evaporative demand frequently expose bentgrass putting greens to physiological drought when atmospheric demand exceeds the turgor maintenance capability of bentgrass. This in turn predisposes bentgrass to heat stress by limiting or even terminating the normal dissipation of thermal energy by evapotranspirational cooling.

Three experimental sites were selected for interseeding CRENSHAW creeping bentgrass into existing PENNCROSS putting greens, including the Texas A&M University Research and Extension Center at Dallas, Brookhaven Country Club, and Dallas Country Club. Mechanical disruption and chemical suppression treatments were employed in a multiple strip-split plot design. The most vigorous chemical suppressant was glyphosate, which was used to allow easy visual determination

of seedling emergence in dead bentgrass sod.

Cimectacarb (Primo) and no chemical suppression treatments also were used. Mechanical disruption treatments were none, vertical mowing, core aerification, and star-tine aerification. Interseeding was accomplished during April 1 through 15, 1995. Visual observations within the glyphosate treatments indicate that vertical mowing may be the most effective means of mechanical disruption. However, overall seedling emergence was less than expected at all sites. This experiment was planted again in October 1995 at the Dallas Country Club.

Electrophoretic analysis of isozyme banding patterns from samples collected from two inter-seeding locations is providing necessary information to determine population changes. Analysis of samples collected from the TAMU at Dallas location 6 and 14 months after inter-seeding indicate that Crenshaw contributed from about 1 0 to 95% of the plant population.

Analysis of samples collected from the Dallas Country Club location 4 weeks after interseeding indicated, based on plant density counts, successful emergence of CRENSHAW in an existing PENNCROSS bentgrass putting green and was superior to emergence observed in spring 1995 inter-seeding at the TAMU at Dallas location. Mechanical treatments had minimal effect on seedling emergence. However, isozyme analysis of samples collected from the Dallas Country Club location 6 months after inter-seeding indicate that, overall, CRENSHAW contributed less than 10% of the plant population. Water management during the extremely dry fall and winter of 1995 and 1996 probably contributed to very low percentages of CRENSHAW in the population at the Dallas Country Club location.

Selection of maternal clones and populations to assess mechanisms of stress resistance has progressed with the assistance and close cooperation of Dr. Milt Engelke. Initial stress tolerance of maternal clones was completed in fall 1995. Progeny were obtained and increased to assess progeny response and established in parent progeny tests in January 1996. Disease problems occurred in the initial parent/progeny plantings and through the summer of 1996. Parent progeny tests were re-established during fall 1996 and are progressing but behind schedule.

Studies to determine the effects of blending bentgrass cultivars on bentgrass putting green turf quality, disease resistance, and performance were established at the Turfgrass Field Laboratory in College Station, Texas during the fall 1995. A severe thunderstorm caused soil and seed movement and cross-contamination of treatments. These blending experiments are being reestablished on a newly constructed 25,000 square foot golf green in College Station. This concept is extensively used for other cool-season grasses, but has not been reported for creeping bentgrasses.

Evaluating Bermudagrass for Putting Greens

Dr. Elizabeth Guertal

Auburn University

Goals:

- *Evaluate new bermudagrass cultivars in comparison with TIFGREEN and TIFDWARF on both a USGA green and a native sandy loam soil.*
- *Evaluate management practices including mowing height, irrigation and topdressing frequency.*

Cooperators:

Coleman Ward
Harold Walker

Bermudagrass *(Cynodon dactylon)* is the best adapted species for putting greens in the warm humid regions of the United States due to its superior heat tolerance and recuperative ability under low mowing heights. To date, limited effort and resources have been expended to identify or develop bermudagrass cultivars with the quality of creeping bentgrass.

Soon after TIFGREEN was released, distinct *off-types* appeared in greens throughout the Southeast. Although TIFDWARF was the dominant cultivar released, others, such as PEE-DEE and TIFTURF were said to be distinctly different from TIFDWARF. Although TIFDWARF was the only one of the off-types to become established in the trade, there is considerable evidence that it is not the only variant existing originally, or at the present time. Turf managers have continually reported the occurrence of variants within TIFGREEN and TIFDWARF greens. In many cases attempts have been made to interest researchers in testing these strains of grasses, which are said to exhibit superior performance under conditions of excess moisture, heavy traffic, or poor soil structure common to the Southeast. To date, there has been little or no evaluation of these unique ecotypes to determine their value. Thus, the objective of this research was to evaluate bermudagrass cultivars or their TIFGREEN TIFDWARF *off-types* on both a USGA green and a native sandy loam soil.

A 5,000 ft^2 USGA-type golf putting green was constructed in August of 1993 at the Auburn University Turfgrass Research Unit. This putting green, along with a similarly sized native soil putting green, were used for evaluation of 12 bermudagrass cultivars. The 12 bermudagrass ecotypes or cultivars, were planted in replicated blocks on USGA and native soil putting greens.

Beginning in June 1996, mowing heights of 1/8 and 3/16 inch were superimposed over the grasses. The green was mowed 6 days per week. The plots receiving the 1/8-inch mowing height treatment were often double-mowed to prevent scalping and poor turf quality.

Data collection included: 1) evaluations of mole cricket damage (no significant difference due to grass type found), 2) quality ratings, 3) Stimpmeter readings, 4) overseed quality ratings, 5) seedhead production counts, end, 6) spring greenup ratings.

An additional study was initiated which evaluated ecotype/cultivar response to herbicide application. Preliminary evidence in this study indicates differences in ecotype/cultivar response to various herbicides.

Average Stimpmeter readings for the grasses were greater at the 1/8 inch mowing height than at the 3/16 inch mowing height. Average Stimpmeter distances at the 1/8 inch height were 6.6 on June 28 and 8.2 feet on Sept.19, and average distance at the 3/16 inch height were 6.4 on June 28 and 7.3 feet on Sept.19. Stimpmeter readings were always higher on the USGA green when compared to those obtained on the native soil green. Grasses with high quality turf that had the best Stimpmeter readings were TW72 and the ecotype Lakewood, a selection from the Lakewood C.C. in New Orleans.

The ecotype from the Mobile #10, from the #10 green of the Mobile C.C. (AL), always had the fastest spring greenup, but this grass also exhibited undesirable traits of seedhead production and poor turf quality later in the season. None of the other *C. dactylon x C. transvaalensis* hybrids demonstrated superior ability to green up in the spring. In later quality ratings the grasses TW72, Mobile #9, T596, Texas and TIFDWARF all exhibited high turf quality ratings. The ecotype from the #9 green of the Mobile Country Club and the cultivar TW72 both performed well at the 1/8-inch mowing height. These two grasses did not produce seedheads, as did several of the other grasses (Mobile #10, Lakewood, TIFGREEN, TIFDWARF).

Variants of TIFDWARF showed differences in phenotypic behavior, and some of these ecotypes (Mobile #9) show promise as putting green grasses. The cultivar TW72 performed well in most tests, and tolerates a 1/8 inch mowing height very well. This mowing height was very stressful to many of the grasses, especially TIFGREEN.

Low Temperature and Drought Regulated Gene Expression in Bermudagrass

Dr. Wm. Vance Baird

Clemson University

Goals:

- *Characterize membrane-specific changes in fatty acid and lipid composition during cold-acclimation.*
- *Characterize the expression of genes involved in fatty acid and lipid biosynthesis during cold acclimation, using heterologous gene probes.*
- *Clone fatty acid biosynthesis genes (e.g., desaturase) expressed in bermudagrass in response to low temperature*

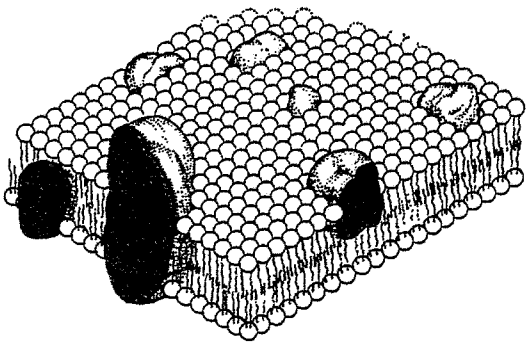

Figure 3. The lipid bilayer provides the necessary environment for proper functioning of membrane proteins.

The physical and biochemical changes, which occur in chilling sensitive plants exposed to reduced temperature, together with the subsequent expression of low temperature stress symptoms, are collectively referred to as cold or chilling injury. The physiological change includes alterations in cytoplasmic streaming, enzyme activity, respiration and photosynthesis as well as effects on membrane permeability, structure and composition. Which, if any, of these changes are responsible for the primary low temperature induced injury, remains uncertain.

The primary goal of this project is to gain a more complete understanding of the process of cold acclimation in bermudagrass by characterizing the changes in membrane composition and gene expression that accompany exposure to low temperature.

Disruption of cellular membrane integrity, as a result of low temperature-induced water removal, is a primary cause of cold injury. The lipid bilayer (Figure 3) provides the necessary environment for proper functioning of membrane proteins. Membrane lipid *fluidity* is thought to be one of the prerequisites for unimpaired survival at low temperature. Membrane fluidity is affected by the degree of unsaturation (i.e., number of double bonds) in the constituent fatty acid (FA) side-chains of membrane lipids. These double bonds induce *kinks* in the molecules (Figure 4), thus resisting molecular compaction, and maintaining fluidity. Therefore, increase in FA unsaturation

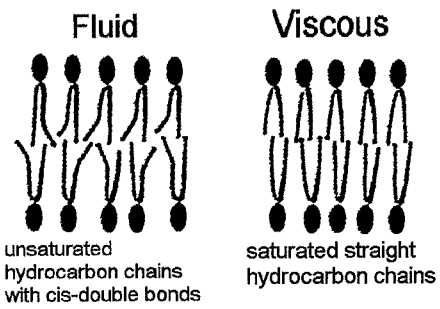

Figure 4. Double bonds in unsaturated hydrocarbon chains increase the fluidity of a phospholipid bilayer by making it more difficult to pack the chains together.

reduces the temperature at which membranes undergo damaging, dehydration-induced, phase transitions from a flexible to a more rigid, gel-like, state.

MIDIRON and U3 bermudagrass were exposed to conditions that induce cold acclimation, and crown tissue from rhizomes was harvested for total membrane lipid isolation. Fatty acid analysis of total lipids revealed a significant increase in tri-unsaturated species (i.e., linolenic acid; C18:3), over shorter and saturated species, and an overall increase in the double-bond index. These changes were more pronounced in MIDIRON (relatively cold tolerant) than in U3 (relatively cold sensitive) bermudagrass, during cold acclimation.

Preliminary biochemical analysis of the isolated membrane lipids identified neutral lipids, glycolipids and phospholipids. At least four species of neutral lipids were detected, two of which were in abundance. Three glycolipids species were detected, in equlmolar amounts. Phosphatidylcholine (PC), phosphatidylethanolamine (PE), phosphatidyl glycerol (PG) and phosphatidylserine (PS) were the four phospholipids detected. Their relative abundance is PC >> PE = PG = PS.

Differential display is used to identify genes expressed in bermudagrass during cold acclimation. Comparisons of *displays* from 0, 12, 24, 48 and 72 hours post-low temperature exposure to that from non-acclimating tissue over the same time period, allows for the identification of genes differentially expressed between treatments, time points and/or cultivars. The cDNA clones obtained represent both RAPD-type fragments, those with 0-mer/complimentary sequences on the ends, as well as gene fragments derived from amplifications utilizing both the anchor (e.g., $T_{11}AG$ or $T_{11}AC$) and a specific 10-mer. The latter have an easily recognizable poly(A) addition signal, just 5' of the anchor primer sequence. The clones range in size from 300 to 450 base pairs. All were chosen as *up-regulated* genes from differential display gels.

Searching DNA and protein databases with translations of these sequences failed to show significant homology to any previously cloned gene or protein/peptide sequence. This is to be expected for at least two reasons: 1) since the clones are biased toward the 3' untranslated end of a gene transcript, protein databases or those containing gene sequences from genomic or random-primed cDNA libraries may not have sequence data for this region of any of their clones; and 2) since, to date, few genes whose expression is regulated during cold acclimation have been cloned from any organism, such genes would be under-represented in current databases (i.e., we are cloning new, undiscovered genes).

Turfgrass Irrigation with Municipal Effluent: Nitrogen Fate, Turf K_c Values and Water Requirements

Dr. Paul Brown

University of Arizona

Goals:

- *Determine the potential movement of nitrogen contained in municipal secondarily treated wastewater used to irrigate turf.*
- *Determine how effluent irrigation influences the water and nitrogen requirements of turf.*
- *Evaluate five evapotranspiration equations currently used in the United States to predict actual turfgrass water use.*
- *Accumulate an atmospheric database and turfgrass water use database that can be used by the public and private sector to develop and test the accuracy of evapotranspiration equations.*

Cooperators:

Dr. Charles Mancino
Dr. Thomas Thompson
Dr. Peter Wierenga
Dr. David Kopec
Michael Young
Duane Otto

The fate of applied nitrogen (N) and turfgrass water use in high maintenance turfgrass systems irrigated with potable (well) water and effluent (wastewater) are being studied using two large weighing lysimeters located at the University of Arizona Karsten Turfgrass Research Center. Each water source is applied to a single lysimeter at rates sufficient to prevent water stress of TIFWAY bermudagrass (summer) and FROGHAIR intermediate ryegrass (winter).

The lysimeters, 13 ft deep and 8 ft in diameter, weigh approximately 100,000 pounds each and employ truck scales to measure changes in lysimeter mass due to evaporation. Sampling ports, located at a depth of 3.3' and then every additional 1.6' to a depth of 11.6', provide access to the lysimeter soil for extraction of soil water and measurement of soil water status.

Nitrogen, applied as labeled (N^{15}) ammonium sulfate, is applied to both lysimeters every two weeks. The rate of N applied to the lysimeter receiving wastewater is adjusted downward to ensure both lysimeters receive similar levels of N. A complete meteorological station is located at the lysimeter facility to provide environmental data required for estimating reference evapotranspiration (ET_o).

Turf responded positively to irrigation with wastewater, and generated more biomass than turf irrigated with potable water. The first 14 months of the study revealed nitrogen uptake of 223 lbs N/A and overall N use efficiency of 61 % for turf irrigated with wastewater. This compares

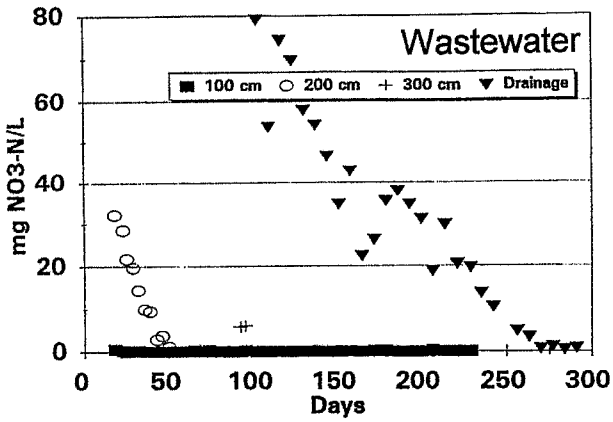

Figure 5. Nitrate nitrogen measured in soil solution samples and drainage water from the lysimeter irrigated with wastewater for the period April 10, 1995 through February 29, 1996.

positively with a N uptake rate of 173 lbs N/A and a N use efficiency of 42% for turf irrigated with potable water during the same period.

The uptake of fertilizer N in aboveground biomass was lower than for total N uptake. Fertilizer uptake efficiency totaled 26% and 22% for turf irrigated with wastewater and potable water, respectively. The low uptake efficiency of fertilizer N is not fully understood, though analysis of soil solution samples and drainage water indicate the losses are not due to leaching. Possible causes may be immobilization in the below-ground plant and microbial biomass or loss through denitrification.

Turf water use is determined from daily changes in lysimeter mass with appropriate compensation for irrigation and rainfall. The ratio of actual turf water use to ET_o, referred to as the crop coefficient (K_c), is required to convert ET_o to turf water use for irrigation purposes. Five popular methods of estimating ET_o are presently under evaluation -- the Penman Equations used by the four regional public weather networks (Arizona, California, New Mexico and Southern Nevada) and the Penman Montieth Equation.

Results from the second year of study show the five methods of estimating ET_o differ by as much as 30%, showing a clear need to match K_c with the method of ET_o estimation. Appropriate bermudagrass K_{cs} for the five methods of estimating ET_o varied from 0.64 to 0.85 for turf irrigated with potable water and 0.66 to 0.86 for turf irrigated with wastewater. Ryegrass K_c values ranged from 0.57 to 0.80 for turf irrigated with potable water and 0.57 to 0.84 for turf irrigated with wastewater. The higher water use (K_{cs}) observed with wastewater irrigation was associated with higher biomass production. Comparison of seasonal K_{cs} for 1995 and 1996 revealed slightly lower Kcs in 1996, regardless of ET_o procedure.

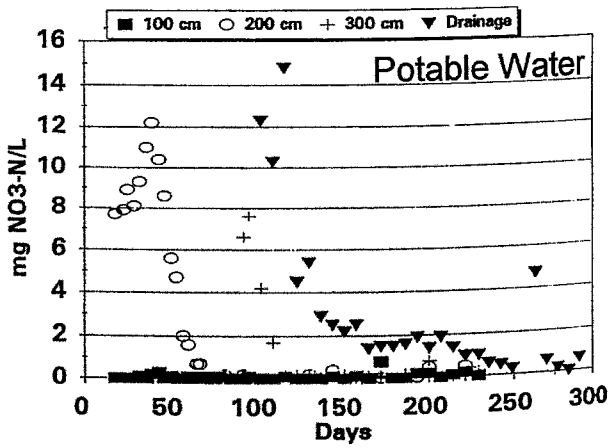

Figure 6. Nitrate nitrogen measured in soil solution samples and drainage water from the lysimeter irrigated with potable water for the period April 10, 1995 through February 29, 1996.

Assessment of Testing Methods for Establishing Golf Course Accessibility Guidelines

Dr. James A. Murphy

Rutgers University

Goal:

- *Assess the surface characteristics of putting greens*
- *Quantify the disruption of playing surfaces*

Cooperator:

Gary Gentilucci

The Americans with Disabilities Act of 1990 was passed to eliminate barriers which limit accessibility to the disabled. This has heightened the awareness of the play of disabled golfers, especially regarding the use of assistive devices for the playing of golf. Of particular concern is the impact that non-conventional forms of traffic have on playing surface quality, particularly putting greens.

Work during 1995 focused on developing quantitative tests to i) assess the surface characteristics of putting greens and ii) quantify the disruption of playing surfaces. Tests were conducted on golf course putting greens with a range of soil moisture content, soil texture, and turfgrass species to evaluate a number of techniques that characterize surface hardness and soil strength. Both *push-up* and high-sand rootzone greens were used in these tests.

Two relatively inexpensive devices were found that adequately characterized surface hardness and soil strength. A number of techniques were evaluated for the ability to measure the extremely subtle rutting caused by traffic with golf shoes and assistive devices. A depth gauge micrometer was adapted to measure the micro-relief of putting greens surfaces. Techniques to measure the effects of traffic on ball roll are still under development; however, we have made progress.

Current methodology utilizes a Stimpmeter to create a repeatable ball roll. Before traffic, the path of ball travel for an average (8 to 10-ft Stimpmeter roll) putt is determined, and the final resting point of the

ball is recorded by measuring the forward (x) and lateral (y) positions relative to the line of travel and end of the Stimpmeter. After traffic, ball roll is measured again to determine any deviation from the non-trafficked path of travel.

Work during 1996 focused on utilizing the quantitative tests described above to describe the relationships between putting green surface characteristics and the ability to bear traffic. Considerable data has been gathered from putting greens on eleven different golf courses located throughout New Jersey and is currently being summarized.

Traffic was applied to greens using wheelchairs, a single rider cart, and the heel of a golf shoe. Each type of traffic was evaluated for the amount of surface depression remaining after 30 seconds of static (stationary) pressure on the putting green. Stationary pressure was applied because this was considered the form of traffic that would result in the most obvious damage and the 30-second time would be representative of the approximate time of putting and waiting for fellow competitors to play out a putt.

Preliminary data indicates that relationships between soil strength and the depth of rutting are beginning to emerge. Edaphic features of each putting green, including the soil texture of the root zone, soil moisture content, thatch depth, organic matter content of the thatch, and particle size distribution of topdressing, are being determined and will be related to the ability to bear traffic.

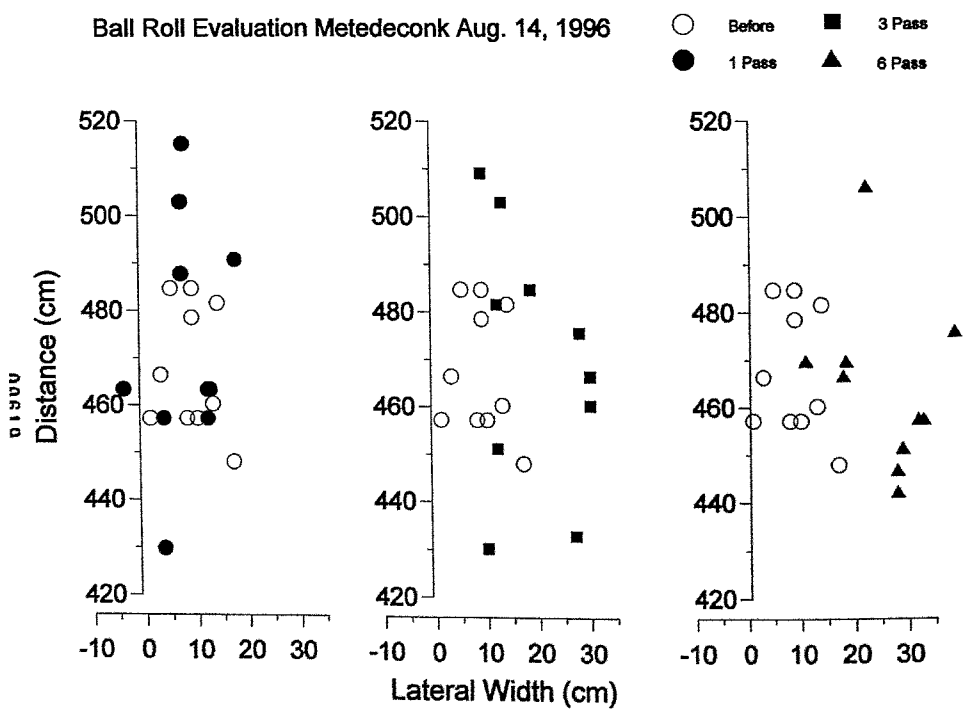

Figure 7. Ball roll deflection across the path of a hard tire wheelchair. The increasing pass number was across the same path and increased the depression depth and width.

Preliminary data indicates that relationships between soil strength and the depth of rutting, and soil strength and depth of rutting are beginning to emerge. Edaphic features of each putting green including the soil texture of the root zone, soil moisture content, thatch depth, organic matter content of the thatch, and particle size distribution of topdressing are being determined and will be related to the ability to bear traffic. Data collection and analysis will continue through 1996 to further develop the relationships discussed above

Alternative Pest Management

Alternative pest management methods are intended to reduce the amount of pesticide needed to maintain golf course turfgrasses. An alternative method of pest control needs to be highly effective and must be field testing under realistic golf course conditions in order to receive widespread acceptance by golf course superintendents. The USGA has provided funding for the development and evaluation of alternative methods of pest control. Even though a great deal of time and effort has been devoted to the area of biological control, there are few scientifically documented cases were these alternative controls perform as well as their pesticide counterparts.

In addition to new biological controls, more information is needed on the life cycle and behavior of common turfgrass pests. The correct treatment thresholds, cultural practices, use of resistant grasses, proper pesticide timing and placement all need to be considered carefully in all turfgrass management programs, especially in the case of soil-borne insect or disease problems.

The purpose of these research projects is to evaluate alternative methods of pest control for use in integrated turf management systems. Projects investigate alternative pest control methods that include:

- Biological control
- Non-chemical control, including cultural and mechanical practices
- Allelopathy
- Selection and breeding for pest resistance
- Ecological balance of plant species in turfgrass swards
- Application of integrated turf management practices utilizing IPM and low cultural inputs

Development of Improved Turfgrass with Herbicide Resistance and Disease Resistance Through Transformation

Dr. Peter Day

Rutgers University

Goals:

- *Establish a transformation system for creeping bentgrass.*
- *Improve the utility of creeping bentgrass by incorporating genes to confer herbicide resistance or enhanced resistance to fungal pathogens.*

Cooperators:

Faith Belinger
C. L. Hartman
N.E. Tumer
C. Laramore
William Meyer
Bruce Clark
Eric Lam

This project seeks to improve creeping bentgrass through transformation to provide golf course managers with more effective and selective weed control with herbicides and more environmentally sound and cost-effective control of plant diseases with reduced use of fungicides. During the past year we have accomplished several major goals.

As the first step in cultivar development of herbicide-resistant creeping bentgrass, bialaphos-resistant progeny from crosses of original transformants and non-transformed plants have been planted in the field. These plants will be maintained as mowed spaced plants. Next spring and summer, the Rutgers bentgrass breeder, Dr. William Meyer, can select those individuals with good overall turf qualities for incorporation into his breeding program. Progeny from crosses using new sources of non-transgenic plants are currently being screened for herbicide resistance and resistant plants will be placed in the field next spring.

We have made improvements in the efficiency of transformation by particle gun bombardment and have obtained plants transformed with the bacterio-opsin gene. In other species, this gene has conferred good broad-spectrum disease resistance. Next spring these plants will be field tested to evaluate the effect of the transgene. We have experiments in progress on other disease resistance and abiotic stress tolerance genes.

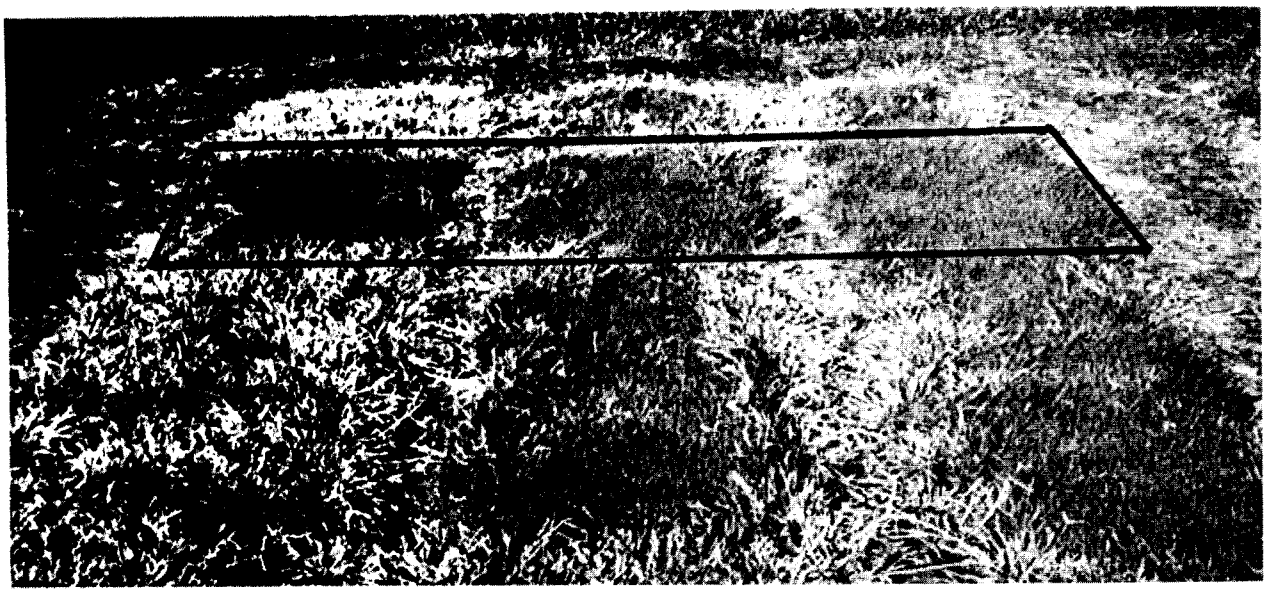

Figure 8. Bialaphos resistant bentgrass: Disease field study taken in September 1996. The treatments included bialaphos applied at label rate once in late May, bialaphos applied in late May, July and August at label rate, an untreated hand weeded check, and an untreated and non-weeded check.

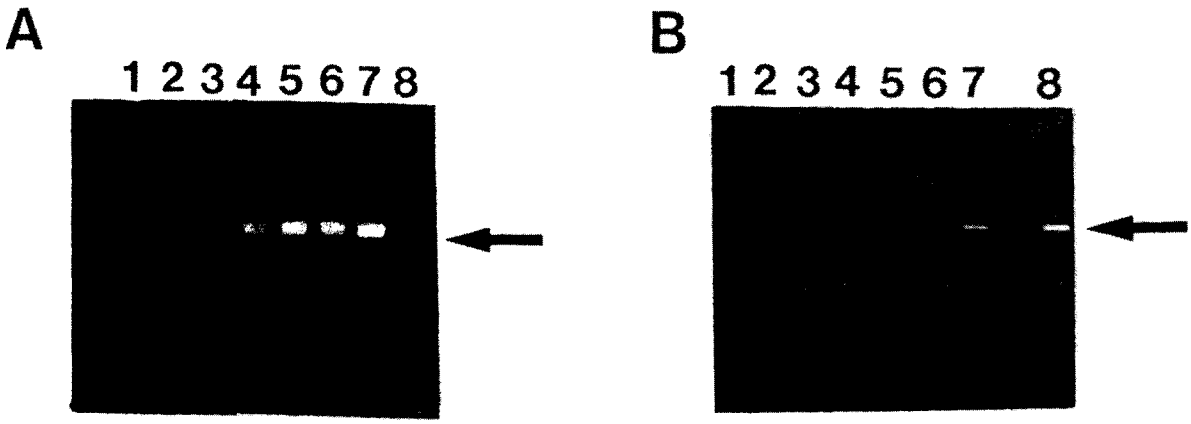

Figure 9. Polymerase chain reaction (PCR) confirmation of bentgrass transformation with the bacterio-opsin gene. DNA from non-transformed plants and four transformed individuals was used in PCR reactions with primers to either the *bar* (A) or to bacterio-opsin (B). The positions of the expected bands are indicated by arrows. Lane 1, no DNA control; lanes 2 and 3, DNA from non-transformed plants; lanes 4 through 7, DNA from transformed plants; and lane 8, plasmid control.

Development of Transgenic Creeping Bentgrass Resistant to the Major Pathogenic Fungi

Dr. Joseph Vargas, Jr.

Dr. Mariam Sticklen

Michigan State

Goals:

- *Express our cloned chitinase gene in E. coli, and purify and collect chitinase protein.*
- *Identify the level of chitinase required to control three major turfgrass pathogens.*
- *Transform bentgrass with plasmids containing the chitinase gene.*
- *Evaluate the transgenic plants for resistance to major turfgrass pathogenic fungi.*

A major problem associated with creeping bentgrass are pathogenic diseases. Most pathogens contain chitin in their cell walls, and therefore may be susceptible to the chitinase enzyme. The objective of this project was to develop fungal disease-resistant creeping bentgrass plants, initially by introducing a chitinase gene in this plant.

After the project began, we realized that one single gene may not necessarily work, and pathogens may develop resistance against a single gene product within a short period of time. Therefore, the effort has been supplemented with the following lines of research: 1) introduce a chitinase gene as proposed, 2) introduce a protease inhibitor gene in plants because these enzymes are essential for the survival of the pathogenic fungi, 3) introduce a drought resistance gene in plants to reduce the need for irrigation that would prevent growth and spread of disease, and 4) introduce a bialaphos resistance gene into creeping bentgrass that would simultaneously control weeds as well as certain pathogenic diseases.

During past year, we followed up on introducing a chitinase gene, a protease inhibitor gene , the bar (bialaphos resistance) gene, and a drought resistance (mannitol dehydrogenase) gene into creeping bentgrass.

As reported earlier, transgenic creeping bentgrass plants that express potato proteinase gene and the bialaphos-herbicide resistance were developed. These transgenic plants were sprayed with bialaphos, and their resistance to dollar spot, brown patch, and *Pythium* was evaluated. The results

confirmed that after we spray transgenic creeping bentgrass with bialaphos, we simultaneously control weeds, dollar spot and brown patch disease at the greenhouse level. This experiment will be repeated at the field level by Dr. Vargas next summer.

The chitinase gene and a drought resistance gene also have been introduced into creeping bentgrass. The selectable marker for this experiment also has been the bialaphos resistance gene. All plants regenerated are bialaphos resistant. Since the construct containing the drought resistance gene was linked to the bialaphos resistance gene, it is believed the transformed plants now contain the drought resistance gene. Hundreds of transgenic plants have been produced from the chitinase/drought resistance experiment. Work is in progress to confirm the stable integration and expression of the chitinase gene and the drought resistance gene in these plants.

Identification of Parasitic Bacteria as Biological Control Agents Against Summer Patch Disease

Dr. Donald Kobayashi

Rutgers University

Goals:

- *Isolate and identify bacteria which can colonize and parasitize the "mycelia" of Magnaporthe poae, the causal agent of summer patch disease.*
- *Screen isolated bacteria for disease control potential using controlled growth chamber and field studies.*

Cooperator:

Dr. Bruce Clarke

Summer patch disease is caused by the ectotrophic, root-feeding fungus, *Magnaporthe poae*. The disease is extremely damaging to turfgrass, affecting cool-season varieties under conditions of high soil temperature and high water potential. Disease development is enhanced by conditions that contribute to turfgrass root stress, such as low mowing heights or compacted soil. Our primary objective is to investigate the use of beneficial bacteria for control of summer patch and other diseases of turfgrass.

Stenotrophomonas (*Xanthomonas*) *maltophilia* 34S1 (Sm34S1) was previously identified as a biological control agent capable of controlling summer patch disease. Greenhouse/growth chamber studies indicated that Sm34S 1 reduced foliar symptoms on Kentucky bluegrass by as much as 70% compared to untreated disease controls. When Sm34S 1 was applied to plants on a repeated basis, summer patch was suppressed at high, sustained levels.

Colonization studies suggested that Sm34S1 populations should be established within the turfgrass rhizosphere at levels above 10^7 cfu/g sample during a two week period, and should remain above 10^5 cfu/g sample to achieve effective control. Sm34S1 was applied to pathogen-inoculated field plots located in a three year old Kentucky bluegrass stand that received minimal maintenance during the summer of 1995.

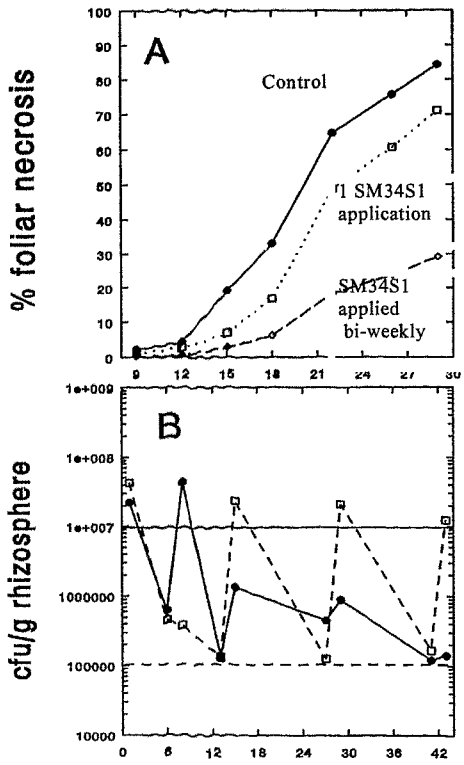

Figure 10. (A) Summer patch suppression on Kentucky bluegrass by repeated applications of SM34S1 (dashed line) in greenhouse/growth chamber studies. (B) Rhizosphere populations of SM34S1 in rootzone: solid line is one application, dashed line is bi-weekly applications.

Summer patch symptom development was not suppressed by Sm34S1during that year. Population studies indicated that Sm34S1 was maintained at levels between 10^4 and 10^7 cfu/g sample. Sm34S1 was applied to pathogen inoculated field plots in 1996 consisting of annual bluegrass/bentgrass green. Summer patch symptoms did not develop in field plots during 1996. Studies indicated that Sm34S1 populations fluctuated in the turfgrass rhizosphere over a range greater than that observed in 1995; however, on occasion, populations were established above the critically determined level of 10^7 cfu/g sample.

A single chitinase gene was cloned from Sm34S1 and the nucleotide sequence was determined. The gene encoded a single polypeptide of cat 1.6 kb, and was associated with a protein of 51.1 kdal in size. Site directed mutagenesis of the gene in 34S1 resulted in loss of chitinase activity, and a significant reduction in biocontrol of summer patch by this organism.

Chitinase activity and biocontrol of summer patch was restored when the cloned gene was reintroduced into the mutant. Studies indicated that chitinase was expressed under conditions of nutrient stress and in the presence of chitin. These studies provide strong evidence for the role of chitinase in biocontrol activity by 34S 1, and information towards understanding the conditions in which the gene is expressed.

Previously isolated biocontrol strains that appeared similar to *S. maltophilia* 34S1 were compared on a taxonomic basis. Fatty acid analysis (MIDI) and nutritional utilization (Biolog) suggested that two isolates, N4-7 and N4-15, previously recovered from the turfgrass rhizosphere and demonstrated to have summer patch suppressive abilities, were closely related *Stenotrophomonas*, *Xanthomonas* and *Xylella* species.

Serological tests using polyclonal antibodies made against N4-7 indicated relatedness to *Xylella* and N4-15, but not to *Stenotrophomonas*. Comparisons of 16s rDNA sequences confirmed the relatedness of both N4-7 and N4-15 to *Xylella* and *Stenotrophomonas*. However, N4-7 appeared most closely related to an unidentified, hydrothermal vent eubacterium.

Genetic Basis of Biological Control in a Bacterium Antagonistic to Turfgrass Pathogens

Dr. Eric Nelson

Cornell University

Goals:

- *Identify and clone genes involved in fatty acid metabolism in E. cloacae strain EcCT-501.*
- *Sequence fatty acid metabolic genes.*
- *Establish relationships between fatty acid metabolism and biological control of Pythium-incited diseases on creeping.*

Cooperator:

Karin van Dijk

The main goal of our project on *Enterobacter cloacae* genetics has been to identify the genetic determinants for biocontrol traits in *Enterobacter cloacae* so that their role in the suppression of *Pythium*-incited diseases of turfgrasses can be specifically elucidated. However, in the last year, we have had to modify our objectives slightly because of recent findings on the nature of pathogen suppression in this system.

In 1996, we obtained several additional mutants. The most notable of these are strains 3-1 and 4-1 that fail to grow on media containing linoleic acid as a sole carbon source, but grow well on a minimal media containing succinate. This selection protocol was chosen to avoid selecting mutants with disrupted Krebs cycle enzymes. As with mutants V58 and 21-1, mutants 3-1 and 4-1 are unable to reduce the stimulatory activity of linoleic acid, exudate from seed, and to protect bentgrass seedlings from infection by *P. ultimum*.

Subsequent complementation and sequence analysis has revealed that the mutation in strain 3-1 is in the *fad*AB operon, which encodes five structural genes central to the β-oxidation of fatty acids. While this mutant is severely debilitated in its ability to catabolize linoleic acid, it is not clear whether this mutation represents deficiencies in linoleic acid transport or in linoleic acid utilization. Therefore, we feel that a search for *fad*L and *fad*D mutants are central to our work.

We have spent considerable effort over the past year trying to sequence the entire

*fad*AB operon. We currently have the entire region sequenced upstream of the transposon insertion whereas the downstream portion is nearly 80% sequenced. We are currently in the process of trying to generate *fad*L and *fad*D mutants to allow us to ask questions about the role of fatty acid transport and utilization in biological control processes.

We currently feel we have strong laboratory evidence for the role of fatty acid metabolism in biological control processes with *Pythium* species on turfgrasses. Our work will focus over the next few years in trying to 1) determine whether these processes do indeed function in turfgrass soils; 2) further identify *fad*L and *fad*D mutants that will help us to distinguish between fatty acid uptake and utilization; 3) continue the sequencing of fatty acid genes; and 4) examine turfgrass species and varieties for fatty acid levels in seeds.

The knowledge that the inactivation of fatty acid germination stimulants could be an important mechanism by which bacterial biocontrol agents interfere with pathogens may have an influence on the screening methods for effective biocontrol organisms, since organisms best capable of inactivating stimulants could be selected. Development of turfgrasses that produce seed with low fatty acid content could help seedlings become less susceptible to certain soil-borne pathogens.

Table 6. Differential protection of creeping bentgrass from infection by different *Pythium* species by wild-type, mutant, and complemented strains of *Enterobacter cloacae*.

	Disease Rating 1-5 Scale		
E. cloacae strain	*P. ultimum*	*P. graminicola*	*P. aphanidermatum*
EcCT-501 (WT)	1.8*	1.3*	2.0*
3-1	4.0	5.0	3.3*
4-1	5.0	5.0	5.0
Non-treated	5.0	5.0	5.0
Uninoculated	1.0	1.0*	1.0*

Means followed by (*) are significantly different from non-treated plants according to T-tests.
Rating scale: 1 = healthy turf and 5 = 100% unemerged or necrotic.
Ratings were determined 7 days after inoculation.

Cultural Control, Risk Assessment, and Environmentally Responsible Management of White Grubs and Cutworms

Dr. Daniel Potter

University of Kentucky

Goals:

- *Determine factors that affect the distribution and abundance of white grubs and cutworms on golf courses.*
- *Reduce the use of insecticides by identifying methods to reduce white grub and cutworm insects through modified cultural practices.*
- *Provide better information on the effects of pesticides on natural enemies of turf-grass pests and other beneficial species that live in golf course turf.*

Cooperators:

A.J. Powell
K.F. Haynes
B.A. Crutchfield
R.C. Williamson

Research on the biology of black cutworms revealed ways that this pest can be more effectively managed. Nearly all of the eggs laid on creeping bentgrass putting greens are glued to the tips of grass blades, where they are removed by daily mowing and disposal of clippings. Most eggs can survive passage through the mower blades and will later hatch. We therefore advise golf superintendents to dispose of clippings well away from greens and tees.

Cutworm moths also lay eggs on higher-mowed turf in fairways and roughs, but here, most eggs are laid lower down on grass plants, where they would not be removed by mowing. Thus, reservoir populations may develop in high grass surrounding greens and tees.

Night-time observations revealed that cutworms are most active on putting greens between midnight and 1 hour before sunrise. Thus, pesticide treatments are best applied toward evening. Young cutworms feed mainly by "grazing" on the putting surface, whereas larger ones feed mainly from aerification holes or self-made burrows. Contrary to expectation, cutworms were not attracted to aerified bentgrass, although they tend to occupy aerification holes when such holes are available. Sand topdressing seems to partially deter cutworms.

Mowing an hour or so before dawn may provide substantial control by shredding. Our work shows that cutworms may crawl as far as 70 feet in a single night, and that they often invade greens from peripheral areas. We therefore suggest that when treating for cutworms, a 30 ft buffer zone

around the putting green should also be treated.

Perennial ryegrass and tall fescue were found to be as suitable for cutworms as creeping bentgrass, but Kentucky bluegrass was highly unsuitable as food. Endophyte-infected cultivars did not provide significant resistance. Putting greens surrounded by creeping bentgrass, tall fescue, or perennial ryegrass may be at greatest risk from invasion from peripheral areas. None of the 14 cultivars of creeping bentgrass we tested was significantly resistant. Nevertheless, use of Kentucky bluegrass around greens and tees, coupled with daily mowing of greens and clipping removal should provide substantial cultural control.

In a previous research project, an unidentified sex pheromone was found in both adult and larval stages of masked chafers. The fraction containing the chemical sex pheromone of masked chafers was pinpointed by gas chromatography and electro-antennogram/behavioral analysis. The active compound was characterized by mass spectroscopy. Identification and synthesis of this attractant will provide means for monitoring these pests on golf courses and home lawns.

Insecticides that are applied to golf courses can adversely affect beneficial invertebrates such as predators and earthworms. This can sometimes aggravate pest outbreaks or thatch buildup. In 1996, we began studying the side-effects of two important new insecticides, halofenozide (Mach 2) and imidacloprid (Merit) on the turfgrass environment. Golf course turf was treated in May, and impact on beneficial species was monitored bi-weekly until fall. Our results suggest that these new insecticides provide excellent control of white grubs with minimal impact on beneficial species.

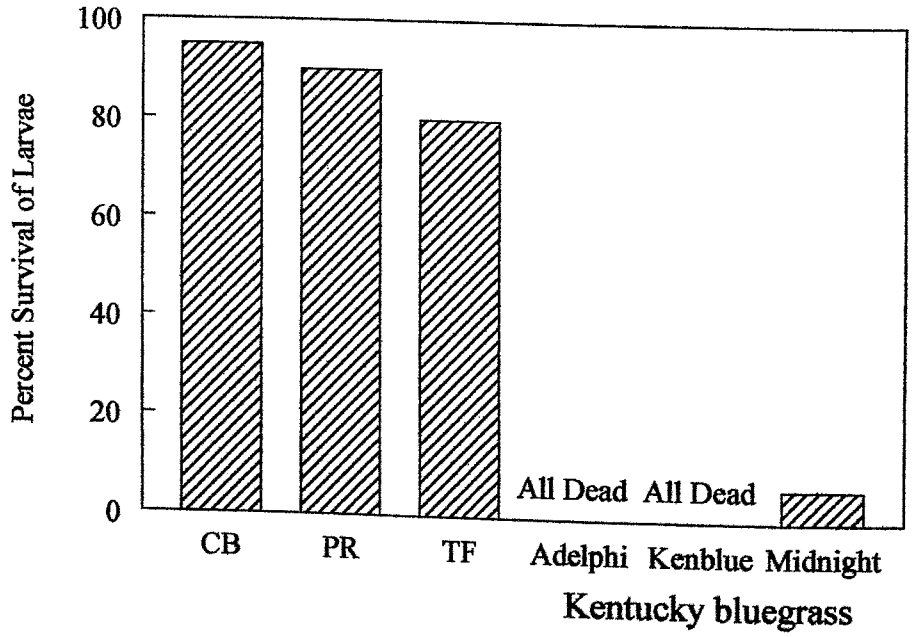

Figure 11. High survival of black cutworms reared on creeping bentgrass (CB), perennial ryegrass (PR) and tall fescue (TF), and lack of suitability of three diverse cultivars of Kentucky bluegrass.

Behavioral Studies of the Southern and Tawny Mole Cricket

Dr. Rick L. Brandenburg

North Carolina State University

Dr. Michael G. Villani

NY State Agricultural Experiment Station Geneva, NY

Goals:

- *Improve our understanding of tawny mole cricket and southern mole cricket behavior especially as affected by environmental conditions through radiographic studies.*
- *Isolate and determine the activity of sex, aggregation and alarm pheromones of the tawny and Southern mole crickets.*
- *Determine the behavior of tawny mole crickets in the presence of microbial and chemical insecticides.*
- *Initiate field studies to better understand tawny and southern mole cricket behavior as suggested by laboratory studies.*

Studies were begun using radiographic technology to visualize the movement and feeding patterns of both tawny and southern mole crickets in soil. Tawny mole crickets produce a characteristic 'Y' shaped tunnel that allows two escape routes to the surface and down into the soil, and a long tunnel into the soil profile that most likely aids in thermal and water regulation.

Environmental conditions can alter, but do not destroy, the stereotypical movement patterns of tawny mole cricket behavior. Predatory southern mole crickets appear to burrow at the thatch/soil interface, perhaps searching for food. Studies conducted in this project indicate that prey size is a major determinant in the acceptability of tawny mole crickets as southern mole cricket food.

When disturbed, both mole cricket species discharged an oily, highly odorous substance from their abdomen. Discharges were collected for biological and chemical assays in our laboratory. Radiographic analysis shows a clear avoidance of tawny mole cricket to areas near the discharge. Live tawny mole crickets do not seem to affect the tunnel patterns of their neighbors, suggesting that they do not discharge their compounds around other tawny mole crickets.

By comparison, live southern mole crickets move away as far from each other as possible when placed together in a chamber. This suggests, but does not conclusively confirm, the presence and activity of a chemically-mediated avoidance behavior in this species.

Adult southern and tawny mole crickets were dissected in order to remove anal and

protodeal glands. Gas chromatography and mass spectraphotometry of all samples indicated a range of hydrocarbon compounds. Electro-antennogram and electro-palpograms gave no differential response among the 13 extracts tested. We see no indication of the presence of a long-range male or female sex or aggregation pheromone in tawny or southern mole cricket adults.

Radiographic assays with a synthetic insecticide and the fungal pathogen *Beauveria* suggests that tawny mole crickets can sense and avoid high concentrations of the product in soil, thereby reducing overall insecticide activity. It should also be noted that this behavior did not occur in every insecticide-treated, chamber suggesting that the effect may be transient or be in response to only the parent or one or more breakdown products. Radiographic experiments designed so crickets could not escape insecticide suggested a decline in burrow construction and maintenance.

Field studies in North Carolina have provided significant new information on mole cricket development, dispersal, field behavior, interspecies relationships, and the influence of the soil environment on damage and control. The consistently earlier egg hatch and development of tawny mole cricket nymphs is a key to survival in areas also inhabited by southern mole crickets.

Since behavior is influenced by nymph size and since the initiation of control strategies is affected by egg hatch, the relationship that has been established with soil temperatures and degree day accumulation and the occurrence of these events is important new information. This will help target management strategies to those most susceptible stages as well as provide insight into the best timing to diminish the likelihood of mole cricket behavior minimizing the control strategies effectiveness and improved follow-up scouting and management efforts.

Additional research on the effect of soil moisture on egg hatch and surface damage helps us determine when visible surface damage is most likely and when environmental conditions favor significant egg survival in non-irrigated areas. This information has also helped us determine preferred areas of egg laying for both species and is providing significant insight into the identification of "high-risk" areas to help reduce scouting time and develop guidelines for targeting the use of new insecticides which are most effective when used in a preventive mode (Table 6).

Table 7. Effects of irrigation on the efficacy of Lambda-cyhalothrin applied for the control of mole cricket nymphs, Brierwood Golf Club, Brunswick County, NC, in August 1996.

Treatment	Rate (oz./A)	Irrigation Schedule	Average Damage Ratings[1]
Simitar GC	10	Pre/No Post	0.55
Simitar GC	10	No Pre/Post at 2 hr	2.05
Simitar GC	10	No irrigation	1.65
Simitar GC	10	Pre/Post immediately	1.55
Untreated	---	Pre/Post	2.40

[1]Damage ratings, where 0 = no damage, 9 = severe damage.

Allelopathy vs. *Acremonium* Endophytes vs. Competition Effect On Crabgrass Suppression by 12 Perennial Ryegrasses

Dr. John King

University of Arkansas

Goals:

- *Conduct Lemna bioassays for allelopathic effects from leaf-stem and root tissue extracts from field grown plants.*
- *Conduct crabgrass seedling bioassays by overseeding crabgrass into the field plots.*
- *Evaluate crabgrass suppression by overseeding the perennial ryegrass cultivars into a common bermudagrass lawn area and overseeding with crabgrass.*
- *Conduct crabgrass seedling bioassays by overseeding crabgrass into petri dishes containing the surface 1 cm of soil from a 5 cm diameter plug.*
- *Determine Acremonium endophyte content of field grown plant stems.*
- *Determine Acremonium endophyte contribution to allelopathy in the cultivar(s) showing strong allelopathic effects in the bioassays.*

Twelve (12) perennial ryegrasses that range from moderate to high stand density and zero to 95 percent endophyte infection were selected, and six replications of field plots were planted in late October, 1993. The cultivars and their expected percent endophyte infection are LORETTA (0), GATOR (0), DERBY (5-10), DERBY SUPREME (40-45), ENVY (40), OMEGA II (76), MANHATTAN II (50-90), SATURN (80), SR4200 (80-85), BRIGHTSTAR (90), ASSURE (95), and YORKTOWN III (97).

Determination of *Acremonium* content showed actual infection levels different from those expected in the original and later seedlots. New seedlots were obtained for fairway overseeding trials for 1994, 1995 and 1996. All plots were maintained with good fertilizer , weed control, irrigation and 2 cm mowing practices.

One half of each original field plot was overseeded to crabgrass in spring of 1994, 1995 and 1996. Bermudagrass fairway plots were overseeded with new seedlots of the 12 cultivars in the fall of 1994 and 1995. Half of each plot was overseeded with crabgrass each spring and evaluated for crabgrass suppression. No differences in crabgrass stand could be attributed to any of the 12 cultivars. A range of crabgrass stands occurred when it was overseeded into a strip in each plot of the 99 cultivars of the NTEP Perennial Ryegrass Test.

Our basic laboratory evaluation for allelopathy is the *Lemna minor* L. (duckweed) bioassay. The *Lemna* bioassay measures allelopathic effects of extracts of

plant tissues against the growth rate of duckweed fronds. Extracts from shoots are applied to duckweed cell plates at three concentrations. The amount of allelopathic inhibition (or stimulation) of duckweed varies with season of shoot tissue sample collection and extract concentration. All cultivars have affected duckweed growth, but inconsistently.

Development of a ryegrass extract-agar-crabgrass seed bioassay was attempted, but problems with fungal contamination and poor seed germination persisted. Bioassays using soil from under each cultivar, or mixing dried powdered leaf-stem tissue of each cultivar into soil in petri dishes showed inhibition of crabgrass seed germination and growth, but inconsistent results per cultivar over the tests.

We are conducting a well-rounded research approach to allelopathy in perennial ryegrasses, but inconsistencies in results over bioassays are very disappointing. Perhaps eventually, selection of ryegrass cultivars for crabgrass inhibition may become an important part of IPM programs.

Table 8. Crabgrass germination suppression by powdered tissue mixed into soil in petri dishes.

Cultivar	Tissue grams	Germination %	Sign	Cultivar	Tissue grams	Germination %	Sign
Loretta	0	51	-	Gator	0	58	-
	500	42	N		500	46	Y
	1000	43	N		1000	26	Y
	1500	41	Y		1500	24	Y
Derby	0	42	-	Derby Supreme	0	58	-
	500	40	N		500	44	Y
	1000	33	N		1000	49	N
	1500	34	N		1500	30	Y
Envy	0	34	-	Omega II	0	29	-
	500	18	Y		500	35	N
	1000	13	Y		1000	21	N
	1500	15	Y		1500	24	N
Manhattan II	0	28	-	Saturn	0	60	-
	500	15	Y		500	51	N
	1000	9	Y		1000	32	Y
	1500	9	Y		1500	31	Y
SR 4200	0	48	-	Brightstar	0	46	-
	500	44	N		500	42	N
	1000	35	N		1000	27	N
	1500	29	Y		1500	17	Y
Assure	0	33	-	Yorktown III	0	38	-
	500	32	N		500	19	Y
	1000	34	N		1000	16	Y
	1500	15	Y		1500	6	Y

Sign = significant difference at one standard deviation
Y = Significant phytotoxic effect compared to control
N = No significant phytotoxic effect compared to control

Pasteuria sp. for Biological Control of the Sting Nematode, *(Belonolaimus longicaudatus)*, in Turfgrass

Dr. Robin Giblin-Davis

University of Florida

Goals:

- *Examine bacteria ultrastructure with transmission electron microscopy and begin describing a new species of Pasteuria that was discovered parasitizing the sting nematode, Belonolaimus longicaudatus.*
- *Perform host range studies on this new Pasteuria sp.*
- *Begin studies to elucidate the population dynamics of this new Pasteuria sp. on sting nematode grown on St. Augustinegrass in laboratory pot cultures under controlled conditions.*

We are describing a new species of bacterium in the genus *Pasteuria,* discovered parasitizing the sting nematode, *Belonolaimus longicaudatus* in Florida. This obligate bacterial parasite of nematodes (*Pasteuria* n. sp. [S-1]) may have potential for inoculative biological control in golf course greens against the sting nematode; a destructive ectoparasite that can reduce the root dry weight of turfgrasses and other crops in sandy soils by as much as 30 to 50%.

In 1996, we completed ultrastructual studies with transmission electron microscopy (TEM) and low-temperature and regular scanning electron microscopy (SEM) that show that *Pasteuria* n. sp. (S-1) is a new species. We have elucidated the development and life cycle of this bacterium with excellent photomicrographs over the past 3 years.

In 1995, we began a monthly survey of 6 different sites of TIFDWARF and TIFGREEN hybrid bermudagrass (fairway conditions) at the Ft. Lauderdale Research and Education Center where *Pasteuria* n. sp. occurs naturally at different levels to monitor its suppressive effects on sting nematode populations at three different soil depths. Soil temperature was also monitored at these different depths.

After 18 months of sampling, we have documented what appear to be epizootics of the sting nematode caused by the *Pasteuria* n. sp. Locations that started with low levels of spore encumbrance have shown increases in the numbers of nematodes encumbered with spores and a decrease in the total sting

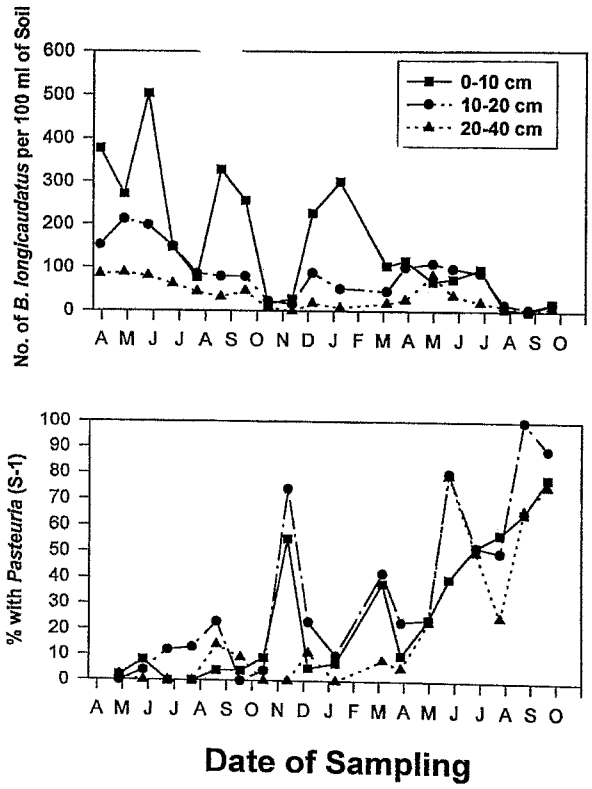

Figure 12. One of six field locations where sting nematodes and *Pasteuria* (s-1) n. sp. bacterial sampling and root dry weights were recorded. In the location depicted above, sting nematode populations were reduced as the *Pasteuria* (s-1) n. sp. populations increased.

nematode numbers. Areas that started with high encumbrance levels, suggesting that *Pasteuria* n. sp. was established, have continued to be suppressive in what appears to be a density dependent manner.

In 1996, a *Pasteuria* n. sp. spore encumbrance bioassay was developed using spores extracted from spore-filled cadavers and inoculated into 1 gm of soil in tubes at different doses (0, 10, 100, 500, 1000, 5000, 10,000, and 100,000 spores). Ten sting nematodes were then inoculated into the soil and incubated at 25 C for 21 days, and extracted and stained and counted for spore-encumbrance levels. These data are being used for a model to estimate spore-densities from unknown soils.

In 1994-1995, our 390-day lab study demonstrated that inoculative release of *Pasteuria* n. sp. encumbered sting nematodes was unacceptable for establishment and population suppression of healthy sting nematodes. Therefore, a field study was undertaken in 1996 to determine whether inoculation of *Pasteuria* n. sp.-infested soil from one of the survey areas which appeared to be suppressive had any promise. Soil was collected and pooled from a heavily *Pasteuria* n. sp.-infested area near to location E from the field epizootic study.

The spore encumbrance bioassay was used to estimate the numbers of spores in the randomly mixed and dried soil. There were two treatments of the soil: 1) control soil that was autoclaved for 2 hours, killing all nematodes and *Pasteuria* n. sp.; and 2) soil heated to 47 C for 48 hours to kill the sting nematodes but not the *Pasteuria* n. sp. A plot of TIFDWARF bermudagrass was divided up into a grid of 1 m^2 plots with 15 cm borders. Pre-counts of sting nematodes present per 100 cm^3 subsample were taken using the sugar flotation method.

Plots were ranked according to sting nematode density and treatments were randomly assigned within ranks. A 15 cm diameter cup cutter was used to remove a core from the center of each 1 m^2 plot. Soil (900 cm^3) was removed and replaced with an equal volume of the assigned treated soil. The core was then replaced and leveled. Six months after inoculation, sting nematode densities were statistically equal for both treatments. However, there was a significant difference in the proportion of sting nematodes encumbered (90% vs. 7%) and filled (5% vs. 1 %) for the heat-treated vs.

autoclaved soil treatments, respectively) with *Pasteuria* n. sp. endospores.

These data suggest that *Pasteuria* n. sp. was present but undetected before the experiment was started and that the inoculation of soil was successful at establishing the *Pasteuria* n. sp. in the turfgrass ecosystem. We are continuing to monitor the spread (increase of the radius of the *Pasteuria* n. sp. infestation) and whether sting nematode densities are suppressed by the bacterial disease over time in a golf course green.

Best Management Practices

Golf courses provide beautiful green areas within our urban and suburban landscapes. However, there is public concern about the possible effects of golf courses on the environment. In response to this concern, the USGA completed a three-year research program in 1994 that examined the degradation and fate of turfgrass chemicals, as well as the development of alternative pest control methods and documentation of the turfgrass and golf courses benefits to humans, wildlife and the environment.

As a continuation of a responsible and scientifically-based investigation of the environmental impact of golf courses, the USGA is sponsoring further research to understand the effects of turfgrass pest management and fertilization on water quality and the environment. To achieve this goal, three-year research projects were initiated in 1995 to focus on *Best Management Practices* and *Pesticide and Nutrient Fate.*

The purpose of the Best Management Practices research is to develop pesticide and fertilizer programs for golf courses that protect environmental quality. The current research projects focus on:

1. Evaluating the effects of specific pesticides and nutrients that have a perceived environmental problem; and

2. Identifying cultural practice systems that minimize pesticide and nutrient volatilization, surface runoff, and groundwater contamination.

Evaluation of Best Management Practices to Protect Surface Water from Pesticides and Fertilizer Applied to Bermudagrass Fairways

Dr. James H. Baird

Oklahoma State University

Goals:

- *Develop effective and practical management practices that protect surface water from runoff of pesticides and fertilizer applied to golf course fairways and other turf areas*

Cooperators:

Raymond Huhnke
Nicholas Basta
Gordon Johnson
Daniel Storm
Mark Payton
Michael Smolen
Dennis Martin
James Cole

This project represents a team effort of scientists in turfgrass science, soil fertility and chemistry, engineering, water quality, and statistics aimed at developing effective and practical management practices to protect surface water from the runoff of pesticides and fertilizer applied to golf course bermudagrass fairways.

In 1995, research was conducted to evaluate the influence of buffer-strip length, height, and verification on pesticide and nutrient runoff from bermudagrass turf. A manuscript describing the research was accepted by the Journal of Environmental Quality in November 1996.

In 1996, two experiments were conducted to further examine the effects of buffer-strip mowing height and buffer-strip length on pesticide and nutrient runoff from bermudagrass turf on a Kirkland silt loam (fine, mixed, thermic Udertic Paleustolls) on a 6% slope. In the mowing height experiment, treatments evaluated were buffer-strips (6-ft width x 16-ft length) mowed at 0.5, 1.5, and 3.0 inches.

In addition, a buffer-strip mowed at 1.5 inches was used as an untreated control to determine antecedent nutrient levels. In the length experiment, treatments evaluated were buffer-strips (6-ft width) measuring 0, 4, 8, and 16 ft in length and mowed at 1.5 inches. In both experiments, the area receiving pesticides and fertilizer (6-ft width x 16-ft length) was located upslope from the buffer and was mowed at 0.5 inches. Urea (applied in the mowing height experiment), sulfur-coated urea (SCU) (applied in the

buffer-strip length experiment), triple superphosphate, chlorpyrifos [granular (applied in the mowing height experiment) or wettable powder (applied in the length experiment)], and the dimethylamine salts of 2,4-D, mecoprop and dicamba were applied at recommended rates to each experiment. A portable rainfall simulator was used to apply a precipitation rate of 2.5 inches per hour for 75 minutes within 24 hours after chemical application.

Chlorpyrifos recoveries in the 1996 runoff samples were much lower than those found in 1995; consequently, chlorpyrifos data were not presented and the runoff samples will be reanalyzed using an enzyme-linked immunosorbant assay (ELISA) specific for detection of the insecticide.

In the mowing height experiment, the 3-inch buffer was most effective in delaying time to start of runoff and decreasing total runoff volume. Pesticide and nutrient losses to surface runoff were as great as 11% and 10%, respectively, from the 1.5-inch mowing height treatment. Overall, there appeared to be no advantage in mowing the buffer-strip at either 0.5 or 1.5 inches in terms of reducing pesticide and nutrient runoff. Although not statistically significant, the 3-inch buffer-strip mowing height was most effective in reducing pesticide nutrient runoff in July compared to the other treatments. However, in August, pesticide and nutrient recoveries in runoff water from the 3.0-inch buffer-strip treatment were equal to the other treatments. The positive effect of the 3-inch buffer was most likely overcome by higher soil moisture conditions and subsequent surface runoff of water in August compared to July.

Pesticide and nutrient loss to surface runoff was less than 7% in the buffer-strip length experiment. The differences in surface runoff losses between the two experiments were most likely due to differences in soil moisture caused by experiment location. The buffer-strip length study was positioned on the drier upslope from the mowing height study. Overall, data from this experiment reaffirmed that buffer-strips are effective in reducing pesticide and nutrient runoff. In addition, these data may be very useful for extrapolating effective buffer-strip lengths for testing on larger scale watersheds.

A reduction in nitrogen found in surface runoff occurred for SCU applied in the buffer-strip length study compared to urea applied in the buffer-strip mowing height study; however, these results may have been caused by differences in soil moisture between the experimental locations mentioned above.

Similar to 1995, results of the 1996 experiments confirm that use of buffer-strips, application of pesticides and fertilizers with lower water solubilities, and avoidance of pesticide and nutrient application when the soil is saturated all help to reduce chemical loss in surface runoff from turf.

Evaluation of Management Factors Affecting Volatile Loss and Dislodgeable Foliar Residues

Dr. John M. Clark

University of Massachusetts

Goals:

- *The role of vapor pressure and temperature will be evaluated in terms of developing a screening system for turfgrass pesticides*
- *Pesticides with possible safety concerns will be further evaluated in the context of best management practices, including the role of spray volume and adjuvants.*
- *The role of thatch accumulation on the dissipation of volatile and dislodgeable residues will be assessed.*

Cooperators:
R. Cooper, NC State University
D. Haith, Cornell University

Volatilization can be a major route of pesticide loss following application to turfgrass. Consequently, a significant portion of applied pesticide may be available for human exposure via volatile and dislodgeable residues. In previous USGA-funded research carried out by this laboratory, volatile and dislodgeable residues were determined following application of triadimefon, MCPP, trichlorfon and isazofos to an established plot of PENNCROSS creeping bentgrass. For each application, a 10-meter radius plot was sprayed and the Theoretical Profile Shape (TPS) method was used to estimate volatile flux. Dislodgeable residues were concurrently determined by wiping treated turfgrass with a water-dampened piece of cheesecloth.

Less than 8% of the total applied triadimefon was measured as volatile residues with nearly all volatilization loss occurring within 5 to 7 days of application. Diurnal patterns of triadimefon volatilization were evident. Mid-day (11-1500 h) triadimefon volatile flux on Days 2 (4.6 g ha^{-2} h^{-1}) and 3 (2.4 g ha^{-2} h^{-1}) was 2 and 1.4 times, respectively, greater than the average of morning and late afternoon volatile flux on these respective days.

Less than 1% of the total applied MCPP was measured as volatile residue. Volatile MCPP residues decreased over time to non-detectable levels by Day 5. Both triadimefon and MCPP dislodgeable residues were greatest on Day 1 following application and dissipated over time. By

Day 5, triadimefon dislodgeable residues decreased to 0.04% of the initial residue level immediately following application and MCPP dislodgeable residues were non-detectable.

For trichlorfon and isazofos applications, less than 12% of applied insecticides were lost as measured volatile resides during the experimental sampling periods. Volatile loss declined in a diphasic pattern with most loss occurring within 5 to 7 days of application. Irrigation greatly reduced initial volatile and dislodgeable residues. Subsequent volatile and dislodgeable residues, however, increased substantially on Days 2 and 3 compared with residues levels in the absence of irrigation.

Trichlorfon dislodgeable residues never exceeded 1% of applied compound in the absence of irrigation, whereas with irrigation, trichlorfon and isazofos dislodgeable residues were never greater than 0.5% of applied compound. Irrigation increased the transformation of trichlorfon to DDVP, a more toxic insecticide.

Inhalation and dermal exposures were estimated using measured air concentrations and dislodgeable residues, respectively, and hazard quotients (HQs) were calculated for both volatile and dislodgeable residues of each pesticide. Exposures (i.e., doses) divided by reference doses (RfDs) resulted in hazard quotients (HQs). A HQ less than 1 indicated that the residue level is below a concentration that might reasonably be expected to cause adverse effects in humans.

Triadimefon and MCPP volatile and dislodgeable residues resulted in HQs below 1.0 throughout the entire 15-day experimental period, indicating that exposures were below any level expected to cause adverse health effects.

Calculated inhalation HQs for volatile residues were equal to or less than 1 for all sampling periods except Days 1 (HQ = 5.0), 2 (HQ =4.5) and 3 (HQ=1.5) following isazofos application. Calculated dermal HQs from dislodgeable residues were equal to or less than 1 for each sampling period except for DDVP on Day 2 (HQ = 4.6) when trichlorfon application was followed by irrigation, and on Days 2 (HQ = 14.3) and 3 (HQ = 5.7) following isazofos application.

This year, we have completed all the method development for the determination of 13 turfgrass pesticides in three separate multi-residue analyses. All experiments and field samples have been collected. A total of 13 separate experiments have been conducted and a total of 585 samples have been collected. Residue analysis of this sample set is 80% completed.

We have determined that the critical vapor pressure below which no turfgrass pesticide will volatilize to the extent that it results in an inhalation HQ greater than 1.0 to be between 3.3×10^{-6} to 5.6×10^{-5} mm Hg. We have determined the critical US EPA Office of Pesticide Programs RfD above which no turfgrass pesticide will result in a dermal HQ greater than 1.0 to be between 0.005 to 0.013.

We have collected appropriate weather data with this residue data set and have met with Dr. D. Haith, Department Agriculture Engineering, Cornell University, who has agreed to cooperate with us by modeling this data into a temperature-dependent algorithm that will determine the critical surface temperature below which no volatile turfgrass pesticide will result in an

inhalation HQ greater than 1.0. This model will be available Spring/Summer 1997.

Two applications of the spreader/stricker adjuvant, Exhalt 800, have been made to determine if such ammedments can attenuate the exposure levels determined previously for the organophosphate insecticides. These data are currently being analyzed (residue data set 50% completed).

In summary, we have shown that organophosphate insecticides that possess high toxicity and volatility may result in exposure situations that cannot be deemed completely safe as judged by the US EPA Hazard Quotient determination. This assessment, however, must be viewed in terms of the assumptions that were used in making these estimations.

In all instances, maximum pesticide concentrations were used for the entire 4 hour exposure period, maximum rates for pesticide applications were used, and dermal transfer coefficients and dermal permeability factors were taken from non-turfgrass situations that are likely to exceed those that would take place on a golf course. Because of this, we view such estimates as worst case scenarios.

In order to more accurately predict the health implications of pesticide exposure to golfers, a relevant dosimetry evaluation of golfers, playing golf on a golf course, needs to be carried out. With more accurate exposure estimates, it is our belief that the exposure levels reported in this report will be found to be in excess of the true exposure to pesticides on a golf course.

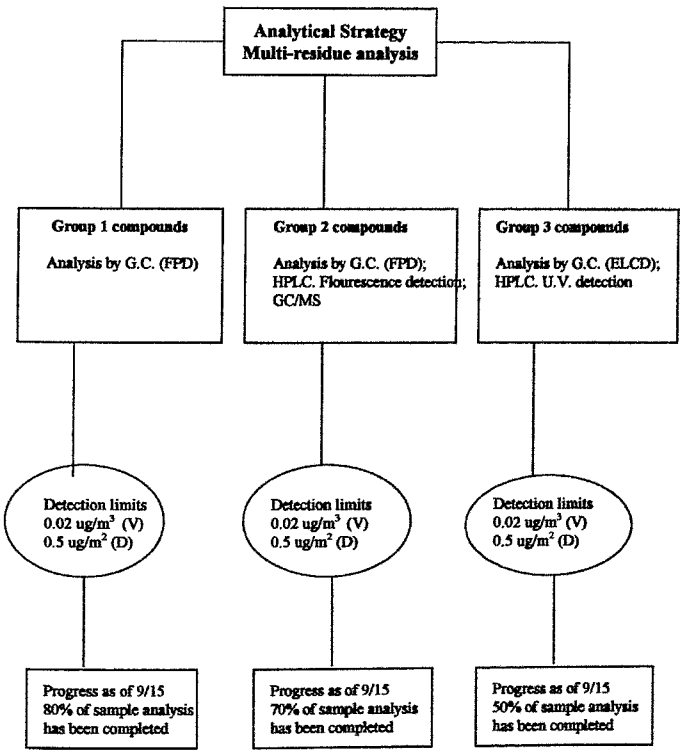

Figure 13. Analytical Strategy for multi-residue analysis. Group 1 includes ethoprop, diazinon, isazofos, chlorpyrifos and isofenphos. In Group 2 there are trichlorfon/DDVP, bendiocarb, carbaryl and cyfluthrin. Group 3 contains chlorothalonil, propiconizol, iprodione and thiophanate-methyl.

Table 9. Inhalation hazard quotients (IHQs) for turfgrass pesticides in the high, intermediate and low vapor pressure group.

Group	Pesticide	Day 1	Day 2	Day 3
		----------	IHQ[1]	----------
Group 1: high vapor pressure (i.e., vapor pressures > 1.0×10^{-5} mm Hg)	DDVP	0.06	0.04	0.02
	ethoprop	50.0	26	1.2
	diazinon	3.3	2.4	1.2
	isazofos	8.6	6.7	3.4
	chlorpyrifos	0.09	0.1	0.04
Group 2: intermediate vapor pressure (i.e., 10^{-5} mm Hg > vapor pressures > 10^{-7} mm Hg)	trichlorfon	0.02	0.004	0.004
	bendiocarb	0.02	0.002	0.002
	isofenphos	n/d[2]	0.02	n/d
	chlorothalonil	0.001	0.001	0.0003
	propiconazole	n/d	n/d	n/d
	carbaryl	0.0005	0.0001	0.00004
Group 3: low vapor pressure (i.e., vapor pressure < 10^{-7} mm Hg)	thiophanate-methyl	n/d	n/d	n/d
	iprodione	n/d	n/d	n/d
	cyfluthrin	n/d	n/d	n/d

[1]The IHQs reported are the maximum daily IHQ's measured, all of which occurred during the 11:00 a.m. to 3:00 p.m. sampling period.

[2]n/d = non-detect

Table 10. Dermal hazard quotients (DHQs) over a three-day post-application period for turfgrass pesticides listed by increasing RfD.

		Day 1			Day 2	Day 3
Pesticide	RfD	15 min.	5 hours	8 hours	12:00 p.m.	12:00 p.m.
ethoprop	0.000015	160	16.4	13.5	2.3	3.4
isazofos	0.00002	105	11.7	9.7	1.6	2.1
diazinon	0.00009	30	2.8	2.2	0.4	0.5
isofenphos	0.0005	3.2	0.5	0.5	n/d[2]	0.1
DDVP	0.0005	0.6	0.03	0.03	0.08	n/d
trichlorfon	0.002	6.4	0.07	0.09	0.03	0.05
chlorpyrifos	0.003	1.7	0.2	0.16	0.06	0.04
bendiocarb	0.005	3.1	0.06	0.1	0.005	0.008
propiconazole	0.0125	0.002	0.03	0.002	0.006	0.002
carbaryl	0.14	0.3	0.008	0.01	---	0.0002
cyfluthrin	0.25	---	---	---	0.004	---
iprodione	0.61	0.004	0.003	0.003	---	0.003
thiophanate-methyl	0.08	---	---	---	---	---

[1]--- = no data available at the time of this report.

n/d = not detected.

Mobility and Persistence of Turfgrass Pesticides in a USGA Green

Dr. George H. Snyder

Dr. John L. Cisar

University of Florida, IFAS

Goals:

- *Conduct mobility (leaching and dislodgeability) and persistence studies on pesticides not examined in previous work.*
- *Monitor percolate collected on a golf course site for applied pesticides*
- *Quantify volatilization of certain pesticides applied to golf turf.*
- *Develop and document the results of using best management practices (BMPs) for fenamiphos and other pesticides that appear to have appreciable mobility, including evaluation of pesticide-adsorbing amendments.*

The use of reduced irrigation for one week following fenamiphos application was studied as a means of reducing fenamiphos and its metabolites leaching from a USGA green in south Florida. Leaching was reduced during the period of limited irrigation, but total leaching was equivalent for low and high irrigation treatments over a longer period that included plentiful irrigation and rainfall. It appeared that the fenamiphos and its metabolites that were not leached when irrigation was restricted eventually leached when excessive irrigation and rainfall occurred.

The percolate collection system in the USGA green at the Ft. Lauderdale Research and Education Center was expanded to include twelve lysimeters. This will permit greater numbers of replications in studies involving two or more treatments, which is very important for pesticide studies.

During excavation it was noted that 7 cm of topdressing had accumulated on the green since the lysimeters were first installed. This layer appeared to hold more water than the underlying media. It contained somewhat higher percentages of the finer sand sizes. It also had considerably more organic matter than either the original rooting mix or than the topdressing material. No movement of rootzone mix into the coarse sand layer, or of coarse sand into the underlying gravel, was observed during excavation for the newly added lysimeters.

Volatilization of the organophosphate pesticides isazofos, chlorpyrifos, and fenamiphos was measured in two studies

using the Theoretical Profile Shape technique. Volatilization was greatest for chlorpyrifos, and least for fenamiphos. It was less for an application that was followed by rainfall than for one followed by dry weather. Isazofos volatilization amounted to 1 and 9 % of that applied for the two rainfall situations, respectively.

Fenamiphos and fenamiphos metabolite adsorption by a stabilized organic polymer (SOP) was investigated in the laboratory. It was determined that when mixed with sand at the rate of 15 percent by volume, SOP could retain an amount of metabolite equivalent to the recommended rate of fenamiphos. Sufficient SOP has been prepared for field studies on the USGA green.

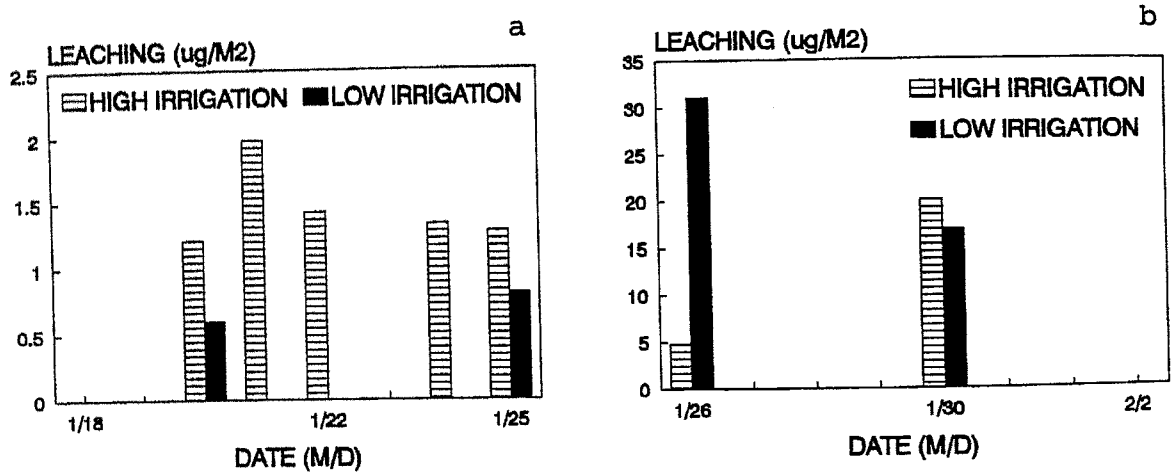

Figure 14. Effect of irrigation on fenamiphos leaching following a fenamiphos application on January 16, 1996 for a) the first week after application, and b) following exposure of all plots to routine irrigation and to rainfall.

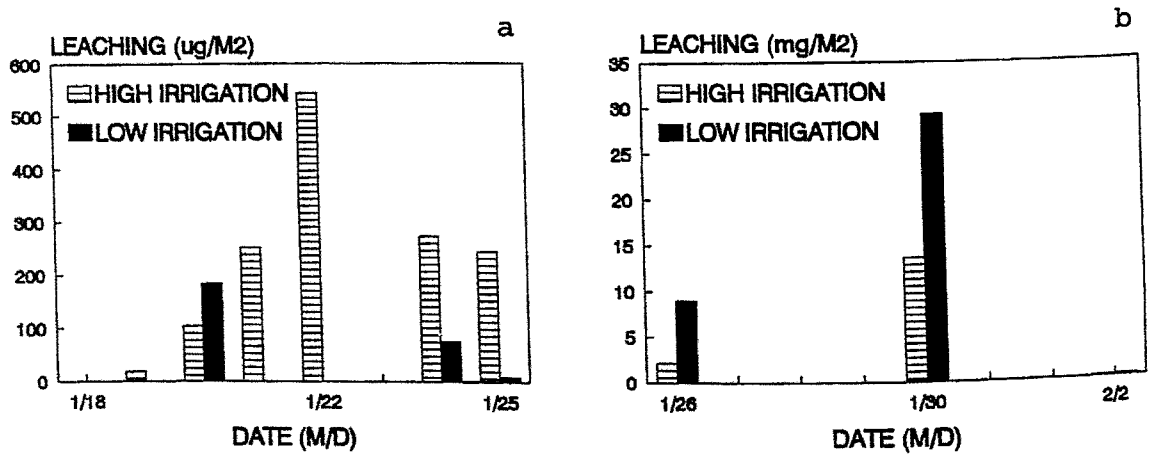

Figure 15. Effect of irrigation on metabolite leaching following fenamiphos application on January 16, 1996 for a) the first week after application, and b) following exposure of all plots to routine irrigation and to rainfall.

Pesticide and Nutrient Fate

Understanding and quantifying the fate of applied turfgrass pesticides and fertilizers are required for accurate prediction of the environmental impacts of golf courses. From 1991 through 1994, USGA-sponsored research demonstrated that 1) the measured nitrogen and pesticide leaching generally is minimal, 2) the turf/soil ecosystem enhances pesticide degradation, and 3) the current agricultural models need calibration/validation in order to accurately predict the fate of pesticides and fertilizers applied to turfgrasses grown under golf course conditions.

The purpose of the projects described in the following pages is to further evaluate the mobility and persistence of parent compounds and transformation products of commonly applied pesticides and fertilizers. Research results from these projects will provide information on:

- Degradation and volatilization rates for commonly used pesticides in several important turfgrass environments
- Identification of conditions that enhance microbial degradation
- Adsorption coefficients for organic and inorganic materials as a function of residence time in the turfgrass environment
- A mass balance assessment of the fate of applied pesticides that takes into account the initial distribution among volatilization, turfgrass, soil, runoff, and leachate

Nitrogen fertilizer studies include research to assess the importance of factors which influence volatilization, denitrification, mobilization, immobilization, adsorption, plant uptake, and fixation, as well as assess loss by surface runoff and leaching. Similar experimental conditions and research techniques are being used to determine the fate of phosphorous in the turfgrass environment.

Modeling Pesticide Transport in Turfgrass Thatch and Foliage

Dr. Mark Carroll

Dr. Robert Hill

University of Maryland

Goals:

- *To quantify the washoff of pesticides from bentgrass foliage as a function of time after application and pesticide formulation.*
- *To determine the effect of solution residence time on the sorption of pesticides to turfgrass thatch.*
- *To determine if the linear equilibrium form of convection/dispersion equation is able to provide accurate estimates of pesticide transport in turf.*

Cooperator:

Dr. Albert Herner
USDA Beltsville
Environmental Chemistry Laboratory

Pesticides applied to mature turf move into the soil only after being washed off foliage and moving through turfgrass thatch. Any attempt to predict the movement of pesticides applied to turf requires that the retention characteristics of the pesticide to foliage and thatch be known.

Research evaluating the washoff of pesticides from SOUTHSHORE creeping bentgrass foliage was conducted in the summer of 1995 and 1996. The turf was mowed to 5/8 inches prior to the application of each pesticide and approximately 1.25 inches of simulated rainfall was applied 1, 8, 24 and 72 hours after pesticide application.

Pesticide washoff from the foliage was determined by mowing strips of turf at a 3/8-inch height immediately before and after simulated rainfall. The strips were located adjacent to one another inside 6 by 7 foot plots.

Three formulations of chlorothalonil, (Daconil 2787 4F, Daconil Ultrex WDG, and Daconil 2787 5G) were applied at a target rate of 9 lbs chlorothalonil per acre on four dates in 1995, and on two dates in 1996. Each formulation was applied to a separate block of turf on each of the six dates, and to a single plot within each block sampled at one of the four designated residence time intervals. Similarly, four replicate blocks of SOUTHSHORE creeping bentgrass were treated with target rates of 0.5 lbs dicamba per acre or 7.7 lbs of carbaryl per acre on a single date in 1995, using Banvel or Chipco Sevin 4SL.

Chlorothalonil was more resistant to washoff than carbaryl or dicamba. Over the

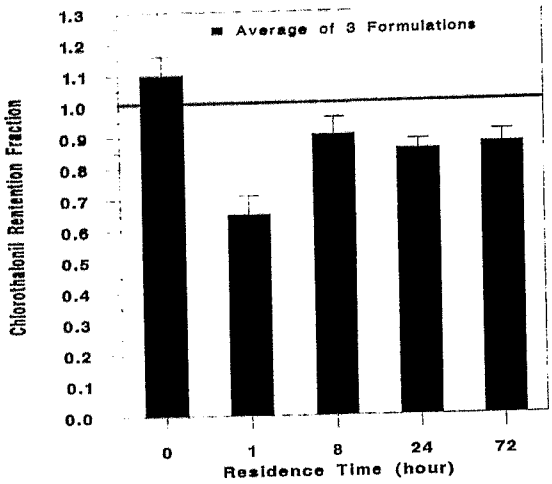

Figure 16. Washoff of chlorothalonil from bentgrass foliage. Means and standard errors are based on six replicates. A total of 1.24 (+ 0.01) inches of simulated rainfall was applied at the prescribed residence times.

72-hour evaluation period, foliar levels of chlorothalonil were 20 to 46 percent higher in turf treated with Daconil 27875G than in turf treated with F or WDG formulated Daconil 2787. There was, however, no difference among the three formulations in the fraction of chlorothalonil that was removed by rainfall. When averaged over the 3 formulations, about 35 percent of the chlorothalonil was removed from the foliage when rainfall occurred 1 hour after application. At longer residence times, no more than 15 percent of the chlorothalonil was removed from the foliage with rainfall.

Rainfall that occurred within 8 hours of the application of Banvel removed 70 percent of the dicamba present on the foliage. Dicamba became more resistant to washoff at longer residence times. Only 44 percent of the dicamba present on bentgrass foliage was removed when rainfall first occurred 72 hours after application of Banvel.

Replicate measurements of the fraction of carbaryl retained on bentgrass foliage were variable. The amount of carbaryl washoff, however, did not vary much with residence time. Washoff of carbaryl from bentgrass foliage ranged from 64 to 79 percent over the 72 hour residence time evaluation period.

Research in 1997 will focus on conducting sorption and transport studies aimed at obtaining the transport parameters needed to model 2,4-D, carbaryl and chlorothalonil movement using equilibrium and non-equilibrium forms of the convection dispersion equation. Our initial transport study conducted in 1996 revealed that the presence of a surface thatch layer reduced the transport of 2,4-D through shallow (i.e., 6 inches deep) soil cores by at least 50 percent. Cores having a 3.5 year old 0.7-inch surface layer of SOUTHSHORE creeping bentgrass thatch were more effective in reducing 2,4-D transport than cores having a 6 year old 1.3- inch surface layer of MEYER zoysiagrass thatch.

Measurement and Model Prediction of Pesticide Partitioning in Field-Scale Turfgrass

Dr. Marylynn Yates

Dr. Robert Green

University of California

Goals:

- *Determine the partitioning of commonly-used turfgrass pesticides among the components of a turfgrass system including the atmosphere, soil, soil-water, leachate, thatch, verdure, and clippings.*
- *Assess the ability of mathematical models, such as CHAIN_2D and PRZM2, to accurately predict pesticide movement in a field-plot-scale turfgrass system.*
- *Modify mathematical models and/or change the data collection protocol as necessary to improve the accuracy of model predictions.*
- *Test the model using independently-derived data to further assess its predictive capabilities.*
- *Conduct a sensitivity analysis of the mathematical model to determine which input parameters have the greatest effect on the model predictions and therefore should be known to the highest degree of accuracy.*

Concern over environmental contamination by pesticides has become widespread during the last several years. The United States Environmental Protection Agency has established mandatory standards for several pesticides, including 2,4-D, glyphosate and atrazine, in drinking water. In addition, several states have established regulations to limit further environmental contamination by pesticides.

Previous USGA-funded research at the University of California, Riverside (UCR) indicated that less than 0.1 percent of the applied carbaryl was lost by volatilization and leaching through the putting green plots. More of the applied 2,4-D could be accounted for: approximately 1 percent volatilized into the atmosphere, and approximately 5 percent leached through the soil. However, in both cases, more than 90 percent of the applied compound was not accounted for. In this project, we are performing more detailed analysis of the fate of pesticides in field plots to enable a determination of the mass balance.

A second area of concern is the need to predict ground-water concentrations of pesticides. It is usually not feasible to monitor ground water for the pesticides of concern, so measurements of pesticide concentrations in the near-surface soil and soil water are made. Mathematical models are then used to predict the concentration of pesticides that one might expect at deeper points in the subsurface.

The cumulative volatilization of metalaxyl was 0.08 percent of the applied mass. This was higher than predicted by the

model (0%); however, it is a negligible amount. For 120 days after application, the concentration of metalaxyl in the upper 2 cm of soil decreased substantially. The concentration of metalaxyl in the leachate was negligible for the first 50 days of the experiment, and then rose to a peak at 75 days.

This is in good agreement with the model predictions, which estimated that none of the applied mass would leach during the first 30 days. The mass of metalaxyl that leached during the experiment was 0.072 percent of the applied amount. Approximately 0.139 percent of the applied mass was removed from the turfgrass clippings.

The mass of chlorothalonil that volatilized during the experiment was 0.017 percent. The model predicted that 0.6 percent of the applied mass would volatilize within 7 days of application. Detectable concentrations were seen throughout the entire soil profile by day 2 of the experiment, and measurable concentrations were detected at all depths at day 15.

The model predicted that none of the chlorothalonil would be detected in the leachate. In this experiment, detectable concentrations of the compound were found for at least 150 days. However, the concentrations were very low (less than 0.25 ppb). Only 0.0012 percent of the applied mass of chlorothalonil leached through the rootzone. The total amount of chlorothalonil removed in the clippings was 0.137 percent of the total applied.

The cumulative volatilization of chlorpyrifos was 15.7 percent of the applied mass. Essentially no chlorpyrifos was detectable in the soil below a depth of 20 cm. No discernible chlorpyrifos peak was observed in the leachate; the concentrations measured were very low, and near the analytical detection limit for the compound. A very small fraction (0.00037%) of the compound leached through the soil. Approximately 0.237 percent of the applied mass was removed from turfgrass clippings.

The mass of trichlorfon that volatilized during the experiment was 0.094 percent. Detectable concentrations were seen throughout the entire soil profile by day 2 of the experiment, and measurable concentrations were detected at all depths at day 90. Concentrations of the compound in the leachate were found for 72 days. The concentration peaked at about day 20, and moved through the system in a pulse for another few weeks. Only 0.003 percent of the applied mass of trichlorfon leached through the rootzone . The total amount of trichlorfon removed in the clippings was 0.05 percent of the total applied.

Potential Movement of Certain Pesticides Following Application to Golf Courses

Dr. Albert E. Smith

Dr. David C. Bridges

University of Georgia

Goals:

- *To obtain and develop mathematical equations for predicting the potential movement of pesticides through golf course greens constructed according to USGA guidelines.*
- *To determine the potential runoff movement of pesticides from golf course fairways on Piedmont soils and to develop management strategies for reducing the movement.*

The objectives of our research program are to evaluate the potential movement of pesticides and fertilizer components following application to golf courses and to develop Best Management Practices to reduce the potential for pesticide transport to potable water systems.

Results indicate that only very small quantities of the pesticides applied to simulated golf course greens are transported through the root zone and into surface water. The more water soluble pesticides (i.e., 2,4-D; dicamba; and mecoprop) were found to have short residence time under the sod due to rapid microbial degradation of the molecules. The pesticides with lower water solubilities (i.e., benefin, pendimethalin, dithiopyr, chlorothalonil, and chlorpyrifos) had higher soil sorption capacities, increasing their residence time in the root zone and allowing for biotic and abiotic degradation even if the half-lives were fairly long.

In some areas of the United States, as much as 70 percent of the rainfall/irrigation water can be lost from fairways as surface runoff. Results of our research indicate that fairly high quantities of the more water-soluble pesticides (i.e., 2,4-D; mecoprop and dicamba) are transported from the treated fairway. The less water-soluble pesticides are more resistant to transport in surface water.

Up to five times more pesticide was transported from fairways near field capacity compared to those near the wilting point. Sequencing irrigation prior to and following pesticide application reduces the

quantity of analyte to be transported in surface water runoff.

More pesticide was transported from dormant sod than green sod. Pressure injection of pesticides reduced the pesticide transport in surface water by 6 fold and did not influence the quantity transported through the root zone.

A buffer zone between the point of application and the exit point did not reduce the fraction of applied pesticide transported in surface-water solution. It only dilutes the concentration due to less area treated. The less water-soluble pesticides have a longer residence time on the foliage, resulting in as much as 20 percent of these pesticides to be removed with the leaf clippings.

Future research will be directed toward the development of practices for reducing the potential movement of chemicals applied to golf courses. Methods of application, types of analyses and formulations, sequencing of irrigation and chemical application, methods for increasing the infiltration/percolation rate of the soil, and use of pesticide absorbents on the soil surface will be investigated. These strategies for pesticide application and site management will be tested in the simulated greens for transport through the root zone. Models will be refined/developed to predict the potential for pesticide movement from golf courses.

We anticipate developing a project for determining the urban contribution to the watershed load of contaminants. The Atlanta watershed to be used will include one 18-hole golf course. The watershed-scale research is the next level following the development of the models from small plot research data. The conclusion of the project will be the development of a complete guide of Best Management Practices for applying chemicals to golf courses based on valid data.

Table 11. Influence of soil moisture content at first simulated rain event following treatment (24 HAT) on the applied pesticide transported in runoff water at 24 and 48 HAT. Fraction trasported is the percent (%) of applied pesticide and water transported.

Pesticide	Application rate	Soil Moisture 24 HAT	Fraction Transported 24 HAT	48 HAT	Total : AVE
	--- kg ae ha^{-1} ---	----- % -----	---------- % pesticide : %water		----------
2.4-D	2.24	10.9[1]	2.6 : 16	0.9 : 42	3.5 : 29
Dicamba	0.56	10.9	3.1 : 16	1.6 : 42	4.7 : 29
Mecoprop	1.68	10.9	1.3 : 16	0.6 : 42	1.9 : 29
2,4-D	2.24	18.5[2]	7.3 : 44	2.3 : 70	9.6 : 57
Dicamba	0.56	18.5	9.7 : 44	4.9 : 70	14.6 : 57
Mecoprop	1.68	18.5	9.5 : 44	4.9 : 70	14.4 : 57

[1] Simulated dry soil treatment where the soil moisture content was near wilting point (soil moisture content at 15 bar = 8.4%).

[2] In previous experiments, routine pesticide applications were made at a soil moisture content between 18 and 19%.

Quantifying the Effect of Turf on Pesticide Fate

Bruce E. Branham

University of Illinois

Goal:

- *Quantify the ability of the turf organic matter to bind, degrade and slow the movement of a pesticide through the soil.*

This research project was initiated in the spring of 1996. The first experiment was designed to measure the impact of the surface organic matter present in a mature turf on the vertical movement and rate of dissipation of a pesticide used in turf. The fungicide cyproconazole was chosen for this experiment since it is a relatively new pesticide used in turf, with little published information regarding its fate in turf.

In order to determine the effect of turf and associated organic matter, four organic matter treatments were created. A normal bentgrass fairway mowed at 1.25 cm was used as one organic matter treatment. Strips within this area were thinned of surface organic by vertical mowing until 67 and 33 percent of the organic matter in a full turf remained. The last organic matter treatment was the removal of the sod, leaving the underlying bare soil.

Movement and dissipation were measured using a mini-lysimeter approach. The mini-lysimeters were 20 cm diameter by 30 cm lengths of PVC that were inserted into the turf, flush with the soil/turf surface. The lysimeters were treated with cyproconazole on July 15, 1996 at a rate of 400 gm a.i. ha^{-1} (0.36 lbs a.i. A^{-1}). Lysimeters were removed from the soil at 2 hours after application, and at 4, 8, 16, 32, 64, and 128 days after application. Each organic matter by sampling date treatment was replicated three times.

After the lysimeters were removed from the soil, the plastic was cut open and the core sectioned into verdure (any green leaf tissue), thatch, and 0 to 1, 1 to 3, 3 to 5, 5 to 15, and 15 to 30 cm soil intervals. Each

sample will be extracted for cyproconazole and residues determined by gas chromatography.

To date, the 2 hour after application sampling has been completely analyzed. Each sampling date requires 81 separate extraction, purification, and analysis steps. So far, the data support the strong sorptive properties of turfgrass leaves and thatch. In the full-turf treatment, 90 percent of the applied cyproconazole was recovered in the verdure sample at 2 hours after treatment, even with a relatively high spray volume of 1.5 gallons per thousand square feet. An additional 9 percent was recovered in the thatch and only 1.1 percent of the applied material was in the 0 to 1 cm soil depth.

In the 33 percent organic matter removal treatment, 18 percent of the applied cyproconazole was in the verdure, 59 percent was in the thatch layer, and 22 percent was in the 0 to 1 cm soil depth. For the 67 percent organic matter removal treatment, 96 percent was in the thatch layer and 4 percent was in the 0 to 1 cm layer. In the bare ground treatment, all of the material was in the 0 to 1 cm soil layer. This data is preliminary as some of the samples will require confirmation.

The data will be more interesting as the other sampling dates are analyzed and degradation rates and vertical movement can be correlated to surface organic matter content. This study will be expanded and repeated in 1997.

Table 12. Cyproconazole distribution 2 hours after treatment in a creeping bentgrass fairway with four levels of organic matter (i.e., verdure and thatch) above the soil surface.

	Cyproconazole Recovered[1]			
Cross-Section	Bare Soil	67% OM Removed	33% OM Removed	Full Stand
	mg kg^{-1} sample			
Verdure	---	---	387.0	659.0
Thatch	---	23.4	17.8	3.0
0-1 cm soil	10.4	0.357	2.04	0.177
1-3 cm soil	nd[2]	0.017	nd	nd
3-5 cm soil	nd	nd	nd	nd
5-15 cm soil	nd	nd	nd	nd
15-30 cm soil	nd	nd	nd	nd

[1] Limit of detection is 0.010 mg cyproconazole per kg soil and 0.60 cyproconazole per kg plant tissue.

[2] nd = non-

Construction and Maintenance of Greens

After years of investigation, the USGA Green Section introduced its *Specifications for a Method of Putting Green Construction* in 1960. The method utilized sand as the principal component of the rootzone mix to provide adequate drainage and resistance to compaction, and incorporated a perched water table in the profile to provide a reservoir of moisture for use by the turf. When built and maintained properly, USGA greens have provided good results over a period of many years for golf courses in most regions of the United States and the world.

During the past 10 to 15 years, changes have occurred in the way greens are maintained and in the number of products and technologies that have been developed. Play has increased, golfers have demanded closer mowing and perfection in maintenance, new grasses have been developed that have different maintenance requirements, and many more golf courses are using recycled water or poor quality water sources for irrigation. A wide array of organic and inorganic soil amendments have been introduced, and ideas for new green construction methods have been proposed. In addition to agronomic changes, the cost of golf course construction has increased dramatically, threatening to limit the growth of the game.

To take advantage of new ideas and technologies, and to address the environmental and economic challenges of the coming decades, the USGA will sponsor research studies on construction and maintenance of golf course greens. The goal of this research is to:

Identify the best combinations of construction, grow-in procedures and post-construction maintenance practices that prevent long-term problems, reduce environmental impacts, and produce high quality playing surfaces.

The reduction of maintenance costs and resource inputs, and the simplification of construction procedures were included among the research project objectives addressing this goal.

Engineering Characteristics and Maintenance of Golf Putting Greens

Dr. James Crum

Dr. John N. Rogers, III

Michigan State University

Goals:

- *Study the engineering characteristics of sands used in putting green construction to ensure a stable and agronomically sound rootzone mixture.*
- *Compare post grow-in (3-7 years) changes which occur under traffic on a USGA specification putting green to two other construction methods for differences in putting green quality and speed as well as long term differences in the organic matter, rooting, edaphic and nutritional characteristics.*

Cooperators:

Thomas F. Wolff
Eldor A. Paul
Joseph M. Vargas
Fred S. Warner

Phase I

To initiate the project, the strength of the selected sands were evaluated under dry and moist conditions. Even though putting greens are not built with dry sands, we need to understand how these sands behave under different moisture levels. From the literature review, we know that bulk density, porosity, moisture content, and particle-size distribution influence sand behavior.

There were no surprises for the tests evaluating soil bulk density before and after compaction under both dry and moist conditions. The data confirm that bulk density increases with compaction.

The results of sieve analysis for cohesionless soils are presented as grain-size distribution curves. The diameter in the grain-size distribution curve corresponding to 10 percent finer is defined as the effective size D_{10}; 60 percent finer is D_{60}. The uniformity coefficient, Cu, is then expressed as $Cu = D_{60}/D_{10}$. A higher value of Cu indicates the soil sample is well-graded.

Friction angles of six sands were determined when dry. The friction angle is determined by plotting the relationship of normal stress (confining force) verses shear stress (pulling force). The angle of the resultant regression line yields the friction angle. As this angle increases, more energy is required to shear the soil and indicates a the sand will have a higher bearing capacity.

The greatest friction angle was derived from the compacted, well-graded sand. The lowest angle was derived from an uncompacted, uniform sand sample. From the review of the literature, this is the

expected result. In order to increase the strength and stability of high sand putting green root zone mixtures, the particle-size distribution should be increased, resulting in a higher uniformity coefficient (Cu).

There are some agronomic disadvantages of increasing the Cu of sands. For example, we find a greater reduction in soil porosity after compaction with the well-graded sands as compared to the uniform sands. Although we have not yet measured the hydraulic conductivity of these sands, the implication is that the well-graded sands would yield a lower conductivity than the uniform sands.

We feel we are making substantial progress in understanding the variables that control the engineering properties of high sand content root zones. We know the wider the particle-size distribution of the sand, the greater will be its friction angle and the greater will be its strength and bearing capacity. Agronomically, as the distribution of the sand is widened, soil porosity decreases. With a decreased porosity, saturated hydraulic conductivity will also decrease.

During 1997, we will concentrate our efforts on completing the testing matrix of the six selected sands, determining agronomically important effects, and expanding our testing to the field with the CBR (California Bearing Ratio) testing device to better understand the conditions in the field.

Phase II

The research answering this set of objectives is conducted on a 14,400 ft^2 (120 x 120 ft) experimental putting green constructed in summer 1992 and seeded in spring 1993. The three rootzone mixes are: an 80:20 (sand:peat) mixture built to USGA recommendations, a 80:10:10 (sand:soil:peat) mixture built with subsurface tile drainage; and an unamended sandy clay loam textured (58% sand, 20.5% silt, and 21.5% clay) "push-up" style green. These putting greens are 1,600 ft^2 (40 x 40 ft), replicated three times, and have individual irrigation control.

The area was mowed six times a week at a 0.157-inch cutting height. To simulate golf course management practices, the entire experimental area was sand topdressed lightly and frequently throughout the growing season. Each of the nine subplots were irrigated as necessary to prevent moisture stress. Core cultivation was performed in fall 1996 with a vertically operating, hollow-tine unit.

Traffic to simulate wear on a putting green was applied 6 times per week with a triplex greensmower modified with spiked rollers in lieu of reel units. The rollers are 60 cm long and 20 cm in diameter. Metal spikes (6 mm) are spaced at 2.5 cm intervals on the unit. Data was collected with a Stimpmeter three hours after rolling in 1996.

The most significant finding regarding green speed was obtained from the "roll then mow" data. When talking with golf course managers and students who return from internships, it was learned that greens are often rolled first and then mowed. This most likely occurs because rollers and mowers are on the course at the same time. With this scenario, there was a substantial decrease in green speed compared to the gain recorded for the "mow then rolling" treatment.

Color and quality ratings of the putting greens were recorded over the growing

season. Though not always statistically significant, rolling appears to have decreased color and quality. It is noteworthy that the 80:10:10 mix suffered a large decrease in color and quality after 14 weeks of rolling.

Dollar spot data was collected in 1995 and 1996. In 1995, differences in dollar spot activity were observed between rolled and unrolled plots as the year progressed. In 1996, dollar spot activity was statistically significant on most dates, with the rolled plots showing two- to three-fold decreases in dollar spot severity.

In July 1996, soil physical properties were determined from putting green samples. Measurements include bulk density, total porosity and porosities at 0.04, 0.1, and 0.33 bar. No significant differences occurred between rolled and non-rolled plots for bulk density and total porosity. However, at 0.04 bar the rolled USGA and 80:10:10 greens had significantly less macropores than their non-rolled counterparts. The 80:10:10 mix also had less porosity at 0.1and 0.33 bars.

The preliminary results indicate that light weight rolling decreased macro-porosity without decreasing total porosity This could explain why less localized dry spot was observed on the rolled plots. Also of interest, was that more nitrogen was found in the clippings from the rolled plots. This may be linked to the decrease in macropores and the presence of less dollar spot and increased pink snow mold activity on the rolled plots. Certainly, more data is necessary before any conclusions can be drawn.

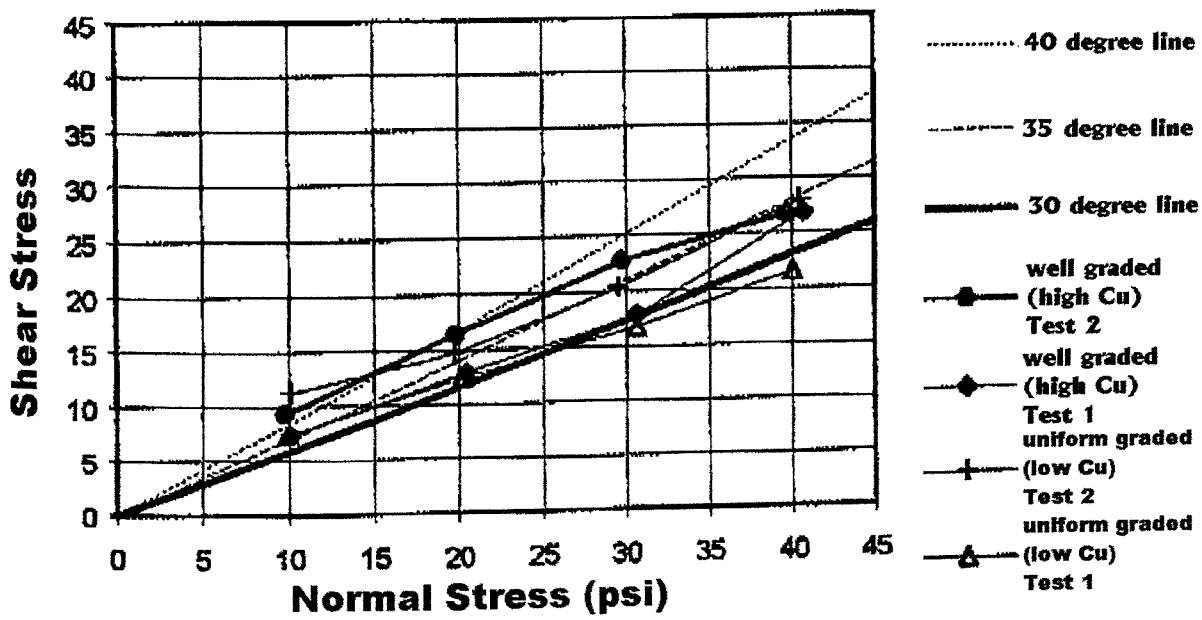

Figure 17. Plot of shear stress verses normal stress for the intermediate sized, well graded (high Cu) and uniform sands (low Cu) before and after compaction.

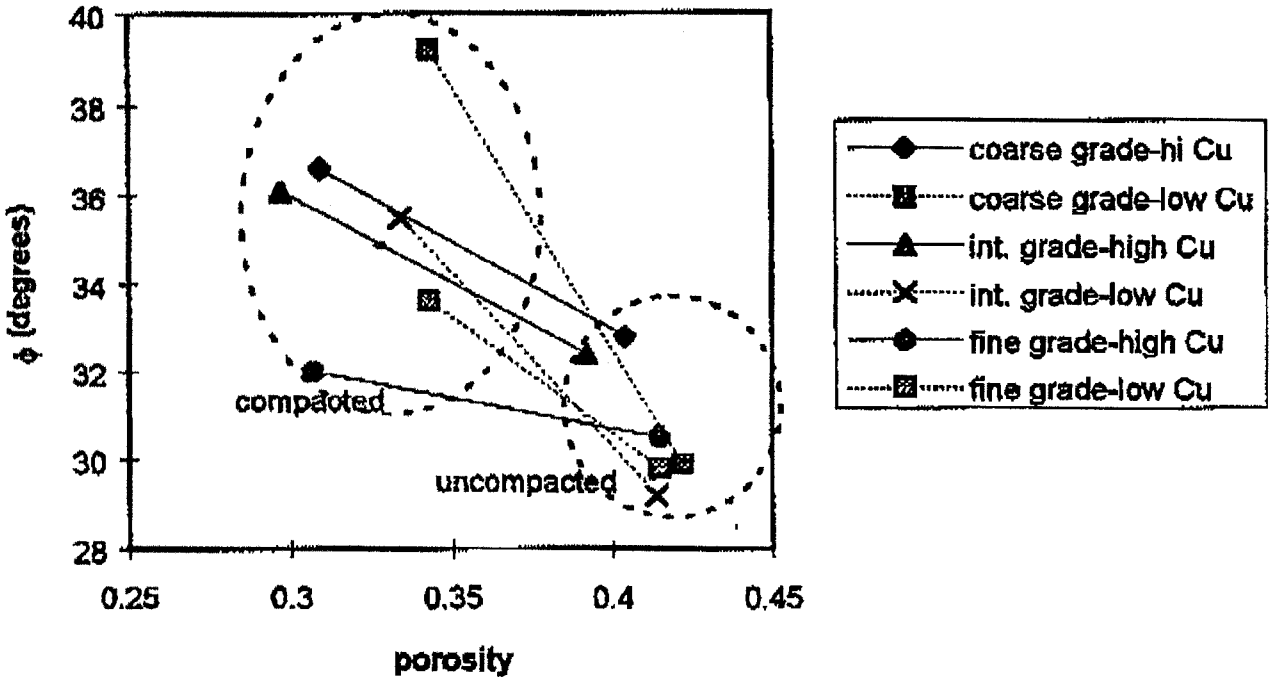

Figure 18. Plot of porosity versus friction angle (Φ) before and after compaction of the six selected sands.

Table 13. Soil physical properties for three putting green construction methods measured four years after construction.

Treatment	Bulk Density	Porosity 0.04 bar	Porosity 0.1 bar	Porosity 0.33 bar	Total Porosity
USGA Rolled	1.57	20.7	24.7	26.0	40.7
USGA Check	1.54	23.0	27.0	28.0	41.0
80:10:10 Rolled	1.62	11.0	14.7	17.3	38.0
80:10:10 Check	1.57	14.3	19.0	21.7	38.3
Native Rolled	1.72	6.7	8.7	10.7	36.3
Native Check	1.71	5.3	7.0	8.3	36.3
Prob. @ 0.05	ns	0.029	0.027	0.013	ns
$LSD_{0.05}$		2.3	2.8	2.7	

Methods for Classifying Sand Shape and the Effects of Sand Shape on USGA Specification Rootzone Physical Properties

Dr. Charles Mancino

The Pennsylvania State University

Goals:

- *Determine if a simple, inexpensive and quantitative procedure can be used to give a reliable estimate of sand shape without having to examine individual grains.*
- *Determine the effect of sand shape on the physical properties of rootzone sands and whether particle size distributions of USGA rootzone sands should be modified to account for differences in sand shape.*

Cooperators:

P.J. Landschoot
A. McNitt

Sand shape has been shown to have an influence on soil bulk density, compactibility, total porosity, aeration and capillary porosity, playing surface stability, and root penetration. However, specifications and recommendations concerning the shape of sand for use in USGA rootzone mix construction is lacking. The purpose of this project is to determine a fast, inexpensive and quantitative way to determine the shape of sands used in putting green rootzone mixes. In addition, we will determine the effect of shape on rootzone mix physical properties.

Our methodology for determining sand shape involves visual and mechanical assessments. The visual methods being tested include the *Riley Sphericity Index* and a *Krumbein Roundness Chart*. These methods are subjective. Another way for determining sand shape may be through the use of the shape analysis software program ArcInfo. This software was developed for global information systems and land analysis. ArcInfo determines the number and lengths of arcs required to outline the sand grain silhouettes, as well as perimeter lengths, volume and axis lengths.

Mechanical methods being tested include: *1) Direct Shear Method* - This determines the amount of sidewards force (shear force) required to cause the sand to slide over itself while a static downward force is being applied. An angular material should require more shear force than a round material. So far we are finding that mixtures of sand sizes and compaction help to delineate between round and angular

sands; *2) Rotatable Drum Method* - This method determines the critical angle that an uncompacted sand can reach before it begins to avalanche. Our angular sand has a greater critical angle than the round sand, but further testing is still needed to maximize these differences; *3) Dense Soil Angle of Repose* - In this technique the sand is compacted with a vibrator and then tilted until it fails at some critical angle. As in the rotatable drum method, the critical angle should be related to the surface characteristics of the sand. We are currently building the apparatus required to perform this test; and *4) Cone Penetrometer* - The force required to push a cone-shaped tip into a confined sand sample is measured. An angular sand should offer more resistance. We have not begun testing this method yet.

We are also determining the physical properties of the sand materials as outlined by USGA guidelines while visual and mechanical tests are being performed. Recently we have completed USGA testing on the round and angular sands when mixed with different proportions of fine or coarse peat, as well as with small amounts of a silt loam soil.

Table 15. Comparison of physical properties of 0.25 mm fractions of a round, spherical sand and an angular, non-spherical sand. Compacted data are shown in parentheses.

Parameter	Round Sand	Angular Sand
Bulk Density	1.62	1.52 (1.8)
Total Porosity (v/v)	39.2	45.8 (16.4)
Aeration Porosity (v/v)	33.1	32.2 (4.3)
Capillary Porosity (v/v)	6.1	13.6 12.1)
K_{sat} (in/hr)	74.5	32.9 (12.0)
Sphericity Index	0.87	0.77
Krumbein Roundness	0.83	0.57

Table 14. Internal friction angle values for a round and angular sand under different uniformities and bulk densities.

Shape	Size	Bulk Density	Friction Angle
Round	0.25 mm	1.4	34.0
Angular	0.25 mm	1.4	35.5
Round	Mix[1]	1.4	39.0
Angular	Mix	1.4	35.5
Round	0.25 mm	1.5	38.7
Angular	0.25 mm	1.5	36.9
Round	0.25 mm	1.6	45.0
Angular	0.25 mm	1.6	36.0
Round	Mix	1.5	39.8
Angular	Mix	1.5	33.7

[1] Mix = 0.5 mm:0.25 mm:0.15 mm sand in ration 8:10:2

Understanding the Hydrology of Modern Putting Green Construction Methods

Dr. Edward McCoy

The Ohio State University - OARDC

Goals:

- *Examine the effects of rootzone composition and putting green construction method on water drainage and redistribution within the profile.*
- *Examine the effects of rootzone composition, soil depth and degree of water perching on turf water use and irrigation management.*
- *Examine long-term changes in physical, biochemical and microbiological properties of the rootzone; and relate these changes to the long-term hydrologic behavior of modern putting green designs.*

Cooperators:

Warren Dick
Mike Boehm

The two most prevalent putting green construction specifications are the United States Golf Association (USGA) and the California (CA) green construction techniques. This research is directed toward a more complete understanding of how profile design, rootzone composition, green slope, drain spacing, and irrigation protocol impact the hydrology of these modern putting green construction methods.

This research program was initiated in the spring of 1996. The principal scheduled activity was the setup and preliminary testing of an experiment to examine water infiltration and movement within USGA and CA putting green soil profiles. Additionally, each soil profile design contains either a high or low water permeability root zone, resulting in four, soil profile/rootzone composition treatments for the overall experiment. Three replicate profiles were constructed for each treatment combination.

The unique feature of this experiment is the provision for variable slope adjustment in these experimental greens. As such, 12 experimental units were constructed with each containing a 4 by 24 ft section of each putting green treatment supported 1 ft above ground level. The soil profiles were contained within wooden boxes supported by a legged, metal framework and placed on a cement pad. Slope adjustment is accomplished by raising one end of each unit until the desired slope is attained.

Additionally, simulated drain lines are built into each unit to allow for variable drain spacing of 10, 15, or 20 feet. Fifteen

soil moisture probes were installed at 3 depths and 5 distances along each unit for detailed monitoring of water movement within each profile.

Finally, devices to deliver controlled rainfall and record drain line flow were designed and constructed. PENNCROSS creeping bentgrass was established on each experimental green and, after grow-in, will be maintained as an actual putting green.

A preliminary experiment revealed that the four soil profile/rootzone composition treatments exhibit different hydrologic behaviors. As expected, the low permeability mixes exhibited higher water contents than the high permeability mixes. There also were substantially higher water contents with depth and particularly at downslope locations with the greens set to a 4% slope. Further, the measurement and control systems for this experiment were shown to perform within their design specifications. A preliminary statistical test conducted from the data of this experiment suggests that valid treatment comparisons will be achieved from the experimental protocol.

Finally, baseline analyses of the soil physical, chemical and microbiological properties of the soil profile root zones are in progress. These observations will be combined with subsequent measurements to monitor changes that occur in these properties with time.

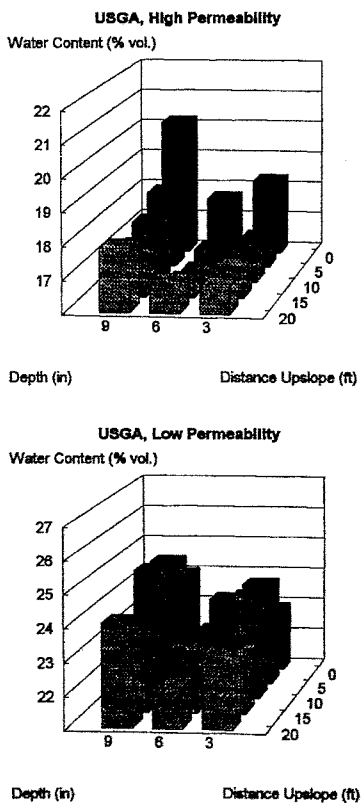

Figure 19. Mean soil water contents as a function of soil depth and distance up slope for the USGA method.

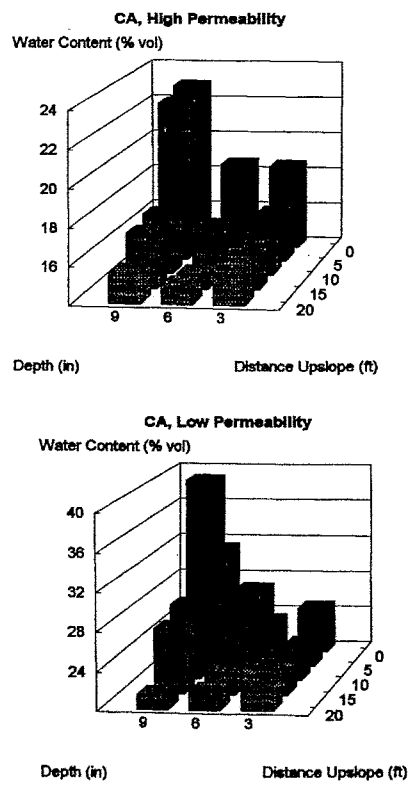

Figure 20. Mean soil water contents as a function of soil depth and distance up slope for the California method.

Assessing Differential Root Zone Mixes for Putting Greens Over Time Under Two Environmental Conditions

Dr. James Murphy

Rutgers/Cook College

Goals:

- *Improve recommendations for sand particle size distribution and the depth of the root zone by consideration of the microenvironment.*
- *Evaluate composts as organic additives and inorganic products for root zone mixes compared to peat sources*
- *Assess the potential of various root zone mixes to reduce management and resource inputs*
- *Monitor the physical, chemical, and biological changes that occur in root zones as greens mature for understanding factors that contribute to the success or failure of greens.*

Cooperators:

S. Murphy
J. Honig
K. Motto
B. Clarke
R. Tate

Ten sand mixes have been constructed to give a wide range of size distributions falling within the USGA's recommendations for root zone mixes. Packed cores of the sand mixes have been made, and characterization of the sand mixes in terms of physical properties is underway. Saturated hydraulic conductivity has been measured for the ten sand mixes (without amendments); all are above the lower acceptable limit, and six of the ten mixes are above the upper acceptable limit for the accelerated range of saturated hydraulic conductivity.

As expected, correspondence of sand size distribution with saturated hydraulic conductivity was evident. Air-filled porosity at 40 cm tension was found to be within or slightly above the range recommended by the USGA. It was evident that air-filled porosity at 40-cm water tension did not completely measure porosity responsible for saturated hydraulic conductivity.

Other physical properties are currently being measured. Irish moss peat, sphagnum moss peat, reed sedge peat, and sewage sludge products have been obtained as organic matter sources and are in the process of being characterized. Leaf compost and mushroom compost also will be obtained for characterization and inclusion in test mixes. Physical measurements of sand mixes with organic amendments will follow in the near future.

Laboratory assessment of the sand mixes alone and in combination with amendments will be completed spring of 1997. Based on these laboratory data, root zone mixes

having a range of characteristics will be identified for study in the two micro-environments of the field research facility at North Brunswick, New Jersey. It is anticipated that putting green construction will be completed in late summer of 1997. Therefore, turf grow-in will be performed over the fall, winter, and spring of 1997-1998.

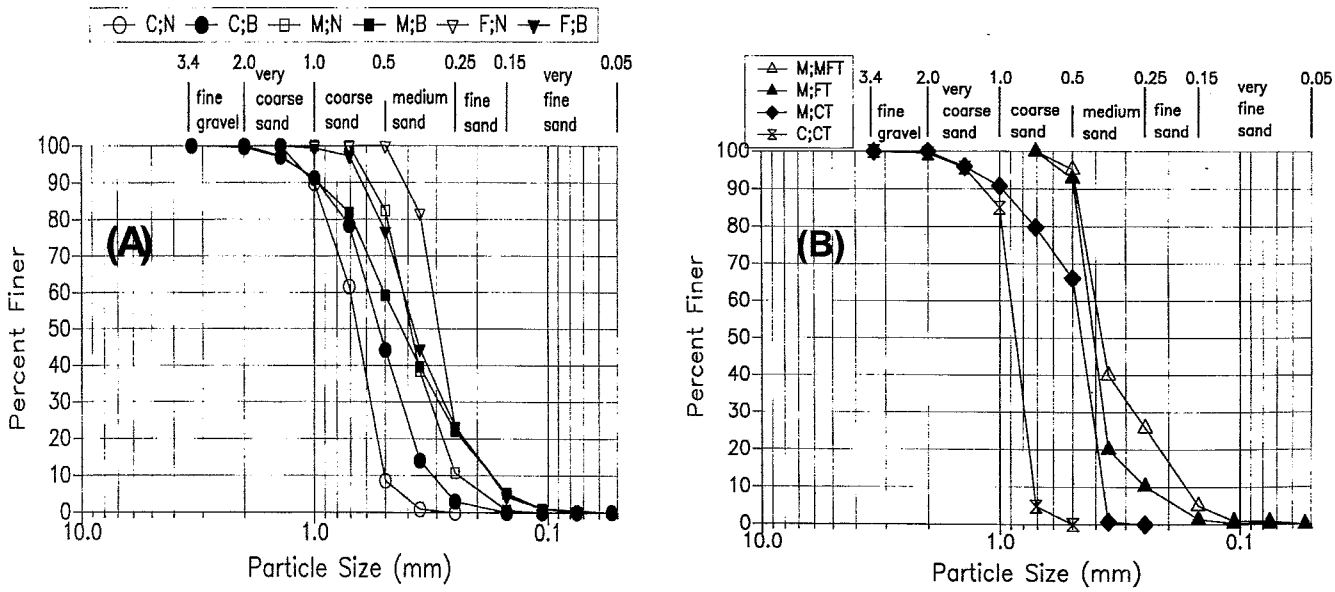

Figure 21. Sand size distribution curves for (A) coarse, medium and fine sand mixes with narrow or broad distributions, and (B) mixes modified within the fine or coarse sand classes.

Table 16. Saturated hydraulic conductivity and air-filled porosity at 40 cm water tension of sands varying in particle size distribution.

Sand Mix	Code	Saturated Hydraulic Conductivity	Air-filled Porosity at 40 cm
Coarse Narrow	C;N	138	30.0
Coarse Broad	C;B	93	29.8
Coarse Coarse Tail	C:CT	153	30.3
Medium Narrow	M;N	80	31.8
Medium Broad	M;B	41	24.0
Medium Coarse Tail	M;CT	97	31.5
Medium Fine Tail	M;FT	73	30.9
Medium Maximum Fine Tail	M;MFT	40	27.7
Fine Narrow	F;N	43	29.1
Fine Broad	F;B	42	25.8
$LSD_{0.05}$		22	1.0
C.V.		19	2.4

Grow-in and Cultural Practice Inputs on USGA Putting Greens and Their Microbial Communities

Dr. Roch Gaussoin

University of Nebraska

Goals:

- *Evaluate grow-in procedure effects on putting green establishment and performance, and develop criteria and recommendations for new putting green readiness for play.*
- *Determine grow-in procedure impacts on root zone physical and chemical properties.*
- *Evaluate post grow-in cultural practice effects on putting green long-term performance.*
- *Determine temporal and spatial (by depth) patterns of rhizosphere community development in golf greens during accelerated and controlled grow-in of select root zone mixes and during long-term green maintenance.*

Cooperators:

Rhae Drijber
William Powers
Mine Aslan
Milda Vaitkus
Leonard Wit

The overall goal of this project is to develop a better understanding of the impact of grow-in procedures on putting green establishment and performance. Impacts on the physical, chemical, and microbiological factors associated with the USGA root zones and rhizosphere are emphasized in the project.

The project is being conducted at the University of Nebraska's John Seaton Anderson Turfgrass Research Facility located near Ithaca, NE. The five year project is composed of three phases: Construction and Grow-in, Microbial Community Assessments, and Grow-in Procedure Impacts on the Long-term Performance of the Putting Green. The first two phases will span three-year periods, while phase three will involve experiments repeated over the five years of the project.

Materials for the gravel layer and rootzone mix were sampled from two local (Nebraska) sand and gravel suppliers with experience in golf green construction. The goal was to develop two separate USGA-specification root zone mixtures - one composed of sand and peat, and one a combination of sand, soil, and peat. Materials were tested for compliance with USGA green construction recommendations for physical characteristics and organic matter content. Based upon analytical results, a supplier was chosen. The putting green site was constructed and rootzone mixture plots established. Thus, year one construction objectives were met and plots are ready for creeping bentgrass establishment in spring of 1997.

In the spring of 1997, creeping bentgrass will be seeded into the year one plots. Year two plots also will be constructed and seeded. Grow-in procedure treatments effects on establishment will be evaluated in both year one and year two plots. An extensive microbiological survey of the year one and year two plots will be performed to determine temporal and spatial rhizosphere community patterns during grow-in. All of these studies will focus on the comparison of the accelerated versus controlled grow-in treatments.

To provide oversight for this project, an advisory committee of six golf course superintendents from the Nebraska Golf Course Superintendents Association was formed. Their input on a variety of management issues will be solicited and used in the development of grow-in procedures.

Table 17. Physical and chemical properties of rootzone mixes under evaluation at the University of Nebraska.

	Supplier A							Supplier B
Analysis	90:10	90:5:5	85:10:5	85:5:10	80:20	80:10:10	80:5:15	Rootzone Mix
% Soil Separates								
Sand	98.8	97.9	95.8	96.3	98.9	95.6	97.4	98.4
Silt	0.8	1.5	3.2	2.8	0.8	3.4	2.2	1.0
Clay	0.4	0.6	1.0	0.9	0.3	1.0	0.4	0.6
Particle Diameter (mm) % Retained								
Gravel	1.6	1.8	1.8	1.2	1.3	1.4	1.5	5.0
Very Coarse	8.0	8.1	8.8	7.6	8.0	7.2	7.8	29.2
Coarse	22.7	23.9	22.4	22.4	29.1	25.2	26.6	28.8
Medium	47.4	46.0	42.5	45.6	44.1	41.9	43.9	25.3
Fine	16.4	15.0	15.2	15.6	13.9	14.5	14.0	8.1
Very Fine	2.7	3.1	5.1	3.9	2.5	5.4	3.6	2.0
Sphericity	medium	medium	medium	medium	medium	medium	medium	medium
Angularity	subrounded	subrounded	subrounded	subrounded	subrounded	subrounded	subrounded	subrounded
pH	7.6	8.0	8.3	7.5	5.3	7.2	7.0	5.7
D_{85}	0.80	0.80	0.85	0.75	0.80	0.78	0.82	1.5
Cu	2.2	2.3	2.9	2.6	2.4	3.0	2.6	3.7
Particle Density, g/cc	2.62	2.63	2.63	2.62	2.62	2.63	2.62	2.63
Bulk Density, g/cc	1.65	1.71	1.72	1.69	1.63	1.72	1.67	1.76
Saturated Conductivity, in/hr	17.7	11.3	3.8	5.0	13.3	4.8	8.9	7.6
Porosity, %								
Total	36.9	34.8	34.4	35.5	37.8	34.6	36.2	33.2
Aeration	20.4	18.9	17.0	15.6	17.6	13.3	16.3	15.9
Capilary	16.5	16.0	17.4	19.9	20.2	21.3	19.9	17.3
Organic Matter, %	0.7	0.42	0.48	0.86	1.04	0.62	0.75	0.83

Organic Matter Dynamics in the Surface Zone of a USGA Green: Practices to Alleviate Problems

Dr. Robert Carrow

University of Georgia

Goals:

- *Determine the effectiveness of selected fall/spring-applied cultivation on enhancement of bentgrass root development, water infiltration, and soil oxygen status during spring and fall root development periods.*
- *Determine the effectiveness of selected summer-applied cultivation, topdressing and wetting agent practices on bentgrass root maintenance and viability, water infiltration, and soil oxygen status during the summer months when root decline occurs.*
- *The best treatments from the objectives above will be combined to develop an integrated year-round program for maximum root development and maintenance during stress periods.*

It is the hypothesis of the author that two turfgrass growth problems arise as organic matter accumulates in the surface 0 to 2 inch zone of a USGA green. Previous research efforts revealed that organic matter increased from 1.5 to 2.0 percent (by weight) at establishment to 8 to 12 percent after 2 years. Organic matter accumulation even occurs under excellent management and regardless of construction specifications. The two problems this research will address are: 1) to evaluate summer bentgrass decline in response to root deterioration and plugging of the macropores that are important for soil O_2 and infiltration of water, and 2) to determine the reasons for the inhibition of spring and fall root development in the zone of high organic matter content.

Summer Bentgrass Decline in Response to Root Deterioration and Plugging of the Macropores that are Important for Soil O_2 and Infiltration of Water. A project was initiated in late spring 1996 to investigate the influence of treatments (summer cultivation, sand topdressing, sand substitutes and wetting agents) on maintaining infiltration, soil O_2 status, and root viability. To date, O_2 levels in the surface 1 inch can be below the acceptable minimum for 9 to 26 hours after irrigation. This indicates that O_2 stress may be a common occurrence as bentgrass roots deteriorate and the organic matter changes from live roots to dead material in the summer months. Cultivating with the Hydro-Ject in a raised position (nozzles 4 inches off the surface) created

approximately 0.25 inch diameter holes that maintained acceptable infiltration rates for about 3 weeks. Wetting agent further enhanced infiltration.

Inhibition of Root Development (in Spring/Fall) from the Zone of High Organic Matter Content. A second project was initiated in winter 1996 to investigate the influence of selected, non-disruptive cultivation procedures on root development. Wetting agent and sand substitute treatments also were included. The goal is to determine whether better root growth/depth can be achieved by increasing macropores in the surface 0 to 2 inch zone without conducting the traditional spring/fall core aeration operation. Rooting data are unavailable at this time but improvements in O_2 status and water infiltration have been noted from selected treatments.

Table 18. Saturated hydraulic conductivity at selected days after the cultivation treatment (DAT) in summer 1996.

Treatment and Contrast[1]	7/19/96 3 DAT	8/6/96 21 DAT	8/15/96 7 DAT	9/3/96 26 DAT	9/9/96 4 DAT	9/23/96 18 DAT
Control *vs*	199	219	67	137	223	53
Core Aerification	299	93	116	116	223	64
HydroJect						
Lowered	190	222	192	764	538	390
Raised	448	190	470	775	652	457
Raised + Sand[2]	838	217	830	1136	622	599
Raised + Greenschoice[2]	488	160	776	545	883	307
Raised + Wetting Agent	791	145	1024	505	961	737
Raised + Biostimulant	636	100	861	413	868	379
Raised + Sand + Wetting Agent[2]	658	123	830	821	705	385
Raised + Sand + Wetting Agent + Biostimulant[2]	930	108	343	446	608	500
LandPride + Greenschoice[2]	176	80	233	100	323	234
$LSD_{0.05}$	322	197	579	506	427	256
F-Test	**	0.78	**	**	**	**
CV, %	43	91	77	67	49	49

**, *, † Significant at $P \leq 0.01$, 0.05 and 0.10, respectively.

[1] Contrast versus Control based on LSD value.

[2] Sand topdressing and Greenschoice applied 8 and 30 July. Wetting agent appied 9 and 29 July. Biostimulant applied 9 July and 9 August. Cultivation treatments were on 16 July, 8 August and 4 September.

Nontarget Effects of Turfgrass Fungicides on Microbial Communities in USGA Putting Green Profiles

Dr. Gary Harmon

Cornell University

Goals:

- *Establish and microbially characterize standard and biological-augmented root zones on USGA and soil-based putting greens.*
- *Determine comparative responses of native and constructed microbial communities to fungicide applications on USGA and soil-based putting greens.*
- *Assess sensitivities of important groups of turf-associated microbes to common turfgrass fungicides.*
- *Evaluate impacts of fungicide applications on levels of biological control in native and microbially-augmented USGA and soil-based putting greens.*

Cooperators:

Eric B. Nelson
Kristen L. Ondik

This research is examining the non-target effects of fungicides commonly used for disease control on golf course putting greens. Our goal is to understand the scope and magnitude of microbial responses to fungicide applications so that potentially detrimental side effects may be avoided.

We established plots on sand/peat-based bentgrass greens constructed using USGA specifications, and similar greens to which brewery compost was added during construction and to which the biocontrol fungus *Trichoderma harzianum* was added at the beginning of the experiment. These green structures were used because they were expected to contain different microbial populations. It was expected that fungicides would have dissimilar non-target effects on these different microbial communities.

The fungicides chosen for these experiments were Daconil Ultrex (chlorothalonil), Chipco 26019 Flo (iprodione), Subdue Maxx (mefenoxam), Banner Maxx (propiconazole), Bayleton 25W (triadimefon), Prostar 50WP (benzamide), and Sentinel (cyproconazole).

Surprisingly, the first preliminary data suggests that the various fungicides, even when multiple applications were made at their maximum legal rates, had little effect upon microbial communities. Numbers of organisms known to be highly sensitive to the fungicides being applied were little affected by the treatments used in this experiment. These data suggest that these fungicides are not present at the fungitoxic concentrations below about 1 inch in the soil surface. Several reasons for this lack of

efficacy may be possible, including adsorbing to soil particles and rapid microbial degradation.

This lack of efficacy suggests that the fungicides tested may be less disruptive to normal soil microflora than originally expected. Second, the data suggest that the fungicides should largely be effective only on leaf diseases and have little effect upon subterranean fungal populations and root health.

Augmentation of plots with the compost + *T. harzianum* addition had two noticeable effects. First, levels of *T. harzianum* increased about 1,000 fold with the addition of this biocontrol product and remained at a consistent level over the sampling times. Second, levels of *Actinomycetes* were lower in augmented plots than in non-augmented plots at the second sampling time.

These results are preliminary and will be followed by additional tests on other microflora with measures of both soil microfloral activity and further measures of microbial diversity.

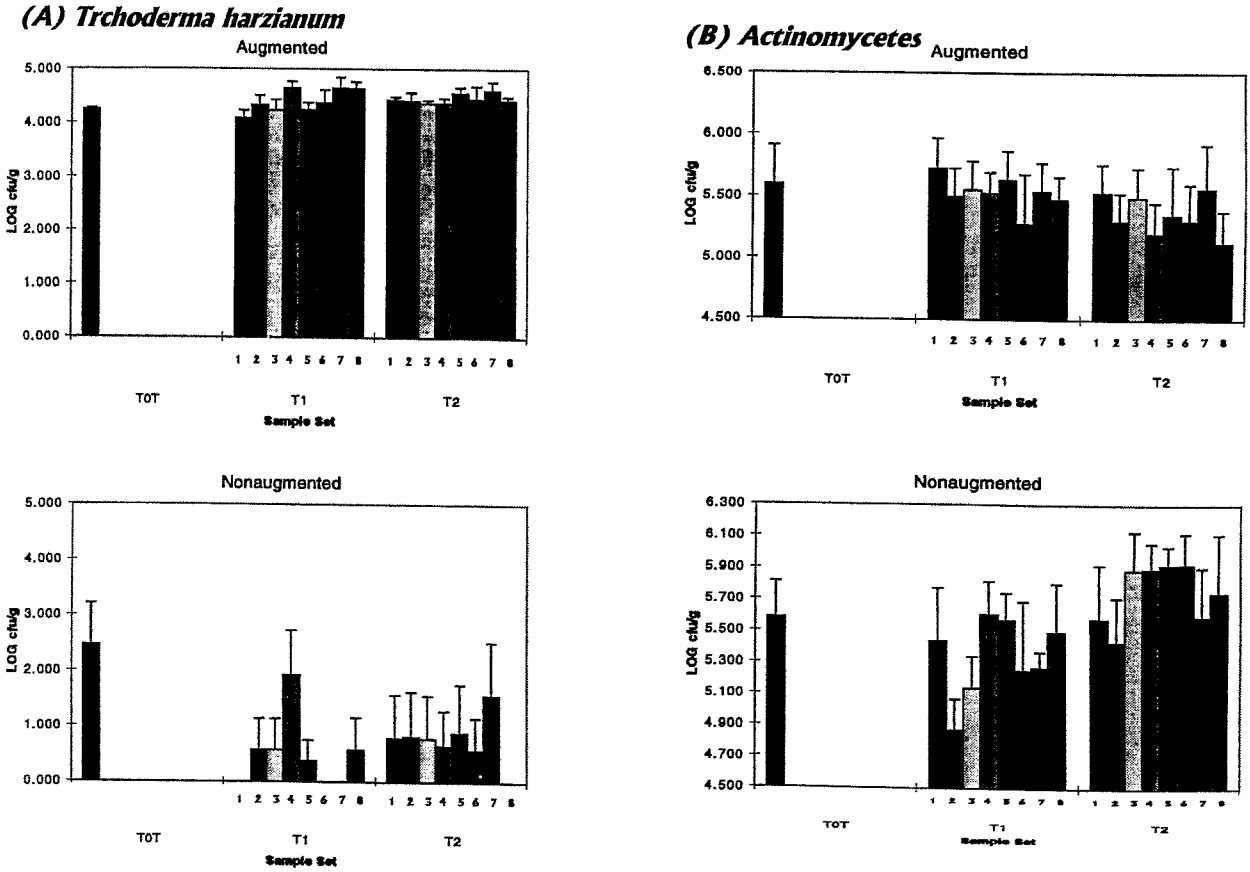

Figure 22. Fungicide effects on (A) *Trichoderma harzianum* and (B) *Actinomycetes* in a sand/peat putting green root zone augmented with brewery-waste compost and *T. harzianum* compared to non-augmented sand/peat root zones. Key: 1) control, 2) chlorothalonil, 3) iprodione, 4) mefenoxam, 5) propiconazole, 6) triadimefon, 7) benzamide, and 8) cyproconazole. The sampling times included: T_{0T} = May 22, T_1 = June 25 and T_2 = July 31, 1996.

Bacterial Populations and Diversity withing New USGA Putting Greens

Dr. M. Elliott, University of Florida

Dr. E. Guertal, Auburn University

Dr. H. Skipper Clemson University

Goals:

- *Determine bacterial populations associated with putting green root-zone mix materials.*
- *Determine bacterial populations of the rootzone mixes before and after fumigation.*
- *Compare rhizosphere bacterial populations on two different turfgrasses - bentgrass and bermudagrass..*
- *Compare rhizosphere bacterial populations of bentgrass in two different locations - Alabama and South Carolina.*
- *Compare rhizosphere bacterial populations of bermudagrass in two differrent locations - southern Florida and northern Florida.*
- *Compare thatch development, rooting and bacterial population of bentgrass in relation to rootzone mix and nitrogen fertilization.*
- *Compare soil and rhizosphere bacterial populations of rootzone mixes containing various clay sources.*
- *Document rhizosphere bacterial population dynamics on bentgrass and bermudagrass over a four-year time period.*

This is a comprehensive, regional project involving three land grant universities in the southeastern United States. The overall objective is to develop baseline data concerning bacterial composition (population and diversity) of new USGA putting greens, both during and after construction.

University of Florida. In order to accomplish the objectives of this project, it was first necessary to ascertain the best sampling and laboratory methods for identifying a bacteria within putting green root zones. At the University of Florida, various diluents and media for each specific group of organisms were evaluated for enumeration of bacteria.

The best overall diluent to use, across all media, was 0.1% glycerol pyrophosphate with 1% glycerol. The following media will be used for enumeration:

a) S-1 medium for fluorescent pseudomonads,

b) selective medium for *Stenotrophomonas maltophilia* (formerly *Xanthomonas maltophilia),*

c) reduced arginine soluble starch medium for actinomycetes,

d) solidified 1/10 strength tryptic soy broth for total bacterial counts,

e) Azide blood base agar for gram-positive bacterial counts,

f) Crystal violet agar for gram-negative bacterial counts, and

g) dilutions heated for 10 minutes at 80 C followed by plating on solidified 1/10 strength tryptic soy broth for heat tolerant bacteria such as *Bacillus* spp.

A protocol was established for all the project cooperators to follow.

Clemson University. Mark Stoddard, CGCS, superintendent of the Charlotte Country Club, has agreed to be a cooperator for this project. The greens were rebuilt to USGA guidelines in the spring and summer of 1996 and seeded with bentgrass in early September 1996. Soil and root samples will be collected from the four bentgrass greens. Assessments of turfgrass quality will be made throughout the experiment.

Auburn University. Miniature greens (1 m by 0.5 m by 1 m), each separately drained to allow collection of leachate, have been constructed. Specific treatments at the Auburn site are two nitrogen rates (1 or 2 lb N/1000 ft^2) and two putting green mixes (100% sand and a 80:20 sand:peat mix). CRENSHAW creeping bentgrass was established on the experimental putting green area.

Soil and root samples will be collected from golf course and university research sites during the months of November, February, May and August. Samples will be subjected to the standardized dilution plating techniques and media developed at University of Florida. Selected rhizobacterial isolates will be identified using GC FAME analysis. Soil and leachate samples will be analyzed for NO_3-N and NH_4-N concentrations using 2M KCI extractions (soil) and standard calorimetric techniques (soil and leachate).

Golf and Wildlife

In the last thirty years, the importance of protecting plant and animal habitat has been widely discussed by the press and environmental interest groups. Over this same period, the U.S. population has increased by 70 million people. Single family dwellings account for 66% of all housing units, and every year 500,000 new homes are built.

To meet the demands of a growing population, more schools, factories, and parking lots also have been constructed. These factors have forced developers and planners to become increasingly sensitive to the need for conservation, maintenance, and creation of new habitat for plants and animals. The United States Golf Association (USGA) shares this sensitivity.

The previous sections have discussed the USGA programs which address pesticide and nutrient fate, and the impact of golf courses on water quality and the environment. Additional research is underway to better understand these issues, and to guide golf course superintendents as they make decisions that influence the entire community, including wildlife.

New and existing golf courses can be developed and managed to protect and enhance wildlife habitat. The following section describes valuable programs the USGA is funding to achieve these goals.

Audubon Cooperative Sanctuary Program

Ron Dodson

Audubon International, Inc.

Goal:

- *To promote ecologically sound land management and the conservation of natural resources.*

Cooperators:

Jean McKay
Marla Briggs
Neil Gifford
Lee Mangum
Jeff Nickel

A cooperative effort between the United States Golf Association (USGA) and Audubon International, Inc., this program promotes ecologically sound land management and the conservation of natural resources. Its positive impact extends beyond the boundaries of the golf course and helps benefit the community beyond.

There are six different categories in which golf courses apply for certificates of recognition: environmental planning, wildlife and habitat management, member/public involvement, integrated pest management, water conservation, and water quality management. Audubon International provides each golf course with one-on-one assistance in devising an appropriate environmental plan.

1. Environmental Planning

Each course generates a written plan that outlines their goals and proposed projects. It provides a useful tool for golf courses to monitor progress in meeting their goals.

2. Wildlife and Habitat Management

Management of non-play areas is crucial to providing habitat for wildlife on the golf course. Emphasis is given toward maintaining the best possible habitat for the course, considering its location, size, layout, and type of property.

3. Member/Public Involvement

Gaining the support of golfers for an environmental program is an essential ingredient. Focus is placed on generating public awareness through education.

Recognition of well-done tasks continually reinforces the worth of the program.

4. Integrated Pest Management

A comprehensive and responsible program to control pests will ensure a healthy environment for both people and wildlife. Managing turf areas with environmental sensitivity requires educating workers and members about plant management, pesticide application, and use of fertilizers.

5. Water Conservation

Consumption of precious water resources is an issue at most golf courses. Attention is directed toward improving the efficiency of irrigation systems, recapturing and reuse of water sources, maintenance practices, and turfgrass selection. The needs of fish and wildlife are considered throughout the water conservation process.

6. Water Quality Management

Questions abound concerning the impact of golf course chemical use on the water quality of lakes, streams, and groundwater sources. Strategies are devised to monitor water quality, protect wetlands, reduce erosion, filter runoff, and, if warranted, improve conditions.

No restrictions are placed on the property as a condition of participation in the Audubon Cooperative Sanctuary Program. All decisions concerning the implementation of program suggestions remain with the golf course superintendent and course officials.

Each course pays a $100 annual fee to participate in the program. Among the benefits golf courses receive are a resource inventory handbook that helps develop an environmental plan, and a one-year subscription to Field Notes, the Cooperative Sanctuary newsletter.

Audubon International is one of more than 500 Audubon Societies in the United States. It is not affiliated with the National Audubon Society. Audubon International is completely independent, separately incorporated, and is guided by its own Board of Directors.

More than 1,800 golf courses from around the country have joined this program, including more than 55 facilities receiving full certification by fulfilling requirements in all six categories. Some of these sanctuaries include:

- *The Links at Spanish Bay, Pebble Beach, California*
- *Collier's Reserve, Naples, Florida*
- *St. Charles Country Club, St. Charles, Illinois*
- *Prairie Dunes Country Club, Hutchinson, Kansas*
- *Applewood Golf Course, Golden, Colorado*

Inquiries about the Audubon Cooperative Sanctuary Program for Golf Courses are always welcome. Contact the Audubon Cooperative Sanctuary Program at:

Audubon International, Inc.
6 Rarick Road
Selkirk, NY 12158
(518) 767-9051

Table 19. Number of active courses in each state and Canada that participate in the Audubon Cooperative Sanctuary Program for Golf Courses (as of December 31, 1996).

State	Number	State	Number
Alaska	1	Nebraska	7
Alabama	16	Nevada	9
Arkansas	8	New Hampshire	8
Arizona	36	New Jersey	55
California	115	New Mexico	3
Colorado	40	New York	102
Connecticut	32	North Carolina	39
Delaware	7	North Dakota	2
Florida	192	Ohio	65
Georgia	29	Oklahoma	11
Hawaii	12	Oregon	39
Idaho	4	Pennsylvania	63
Illinois	120	Rhode Island	5
Indiana	38	South Carolina	31
Iowa	17	South Dakota	2
Kansas	17	Tennessee	26
Kentucky	19	Texas	74
Louisiana	5	Utah	4
Maine	24	Vermont	7
Maryland	24	Virginia	31
Massachusetts	58	Washington	35
Michigan	102	West Virginia	35
Minnesota	52	Wisconsin	57
Mississippi	4	Wyoming	4
Missouri	28	District of Columbia	2
Montana	6	Canada	149
Total			1822

Restoration Design Handbook

Gary Libby

Donald Harker

Hal Bryan

Kay Harker

Goals:

- *Consolidate concepts and techniques in a useful and practical reference book.*
- *Transmit a summary of the scientific literature on ecological restoration to persons who may not otherwise encounter such information.*

The *Restoration Design Handbook* is designed to consolidate concepts and techniques in a useful and practical reference book. While the hands-off attitude is a form of natural area management, ecological deterioration can result from this approach. There are many opportunities to restore devastated or derelict lands. But for areas in between, where change has occurred but has been less pronounced - that's where we still have an opportunity to get a very big payoff from a minimum amount of effort.

To achieve ecosystems which 1) work the first time, 2) are self-sustaining, 3) are developed economically, and 4) possess the species and structure desired, it is clear that a large number of different operations have to be carried out correctly so that properly functioning ecosystem processes will occur. There is no single over-riding principle to be observed. It is important to use research findings to guide restoration projects. At the same time, major restoration sites and funding mechanisms are needed by scientists to test new methods of restoring ecosystems. The purpose of this book is to compile useful and practical information for those designing, evaluating, or planning a restoration project.

The *Restoration Design Handbook* will attempt to transmit findings on ecological restoration to persons who may not otherwise encounter such information. The recommendations in the book will be based upon existing scientific literature pertaining to ecological restoration.

Wildlife Links Program

Dr. Peter Stangel

National Fish and Wildlife Foundation

Goal:

Advisory Panel:

Dr. Peter Stangel
National Fish and Wildlife

Jim Felkel
U.S. Forest Service

Dr. Mike Lennartz
U.S. Forest Service

Dr. Dan Petit
U.S. Fish & Wildlife Service

Ron Dodson
Audubon International

Jim Snow
USGA Green Section.

The Wildlife Links Program represents golf's first comprehensive investigation of the game's relationship with wildlife and its habitat. It was established in early 1995 to fund research, management, and education projects needed to provide the game of golf with state-of-the-art information on wildlife management issues. The USGA will contribute $100,000 for 1997, with additional amounts allocated for 1998 and beyond.

The program is administered by the National Fish & Wildlife Foundation (NFWF), which is headquartered in Washington, DC. Congress established NFWF in 1984 as a non-profit organization dedicated to the conservation of natural resources—fish, wildlife, and plants. Among its goals are species habitat protection, environmental education, public-policy development, natural resource management, habitat and ecosystem rehabilitation and restoration, and leadership training for conservation professionals. It meets these goals by forging partnerships between the public and private sectors.

This track record of forging alliances between various groups remains crucial to the underlying philosophy of the Wildlife Links Program. Environmental and golf organizations are encouraged to participate and lend their expertise and financial support. In that manner, it is hoped the program will grow to become recognized as a golf industry effort.

The first step in implementing Wildlife Links was the creation of an advisory panel of experts representing federal and state

agencies, non-governmental conservation organizations, and universities. Dr. Peter Stangel, director of the NFWF's Neotropical Migratory Bird Conservation Initiative, chairs the panel. Other members include: Jim Felkel, of the U.S. Forest Service; Dr. Mike Lennartz, of the U.S. Forest Service; Dr. Dan Petit, of the U.S. Fish & Wildlife Service; Ron Dodson president of Audubon International; and Jim Snow, national director of the USGA Green Section.

This panel undertakes various tasks under the banner of the Wildlife Links initiative. Refining research priorities, requesting and reviewing proposals from qualified researchers, and monitoring and evaluating the approved projects head the list. NFWF will take the leadership role in ensuring that research projects address golf's highest priorities, and complement associated projects underway with other agencies and organizations.

The program's overall goal is to protect and enhance—through proper planning and management— the wildlife, fish, and plant resources found on golf courses. This aim includes providing golf course designers and superintendents with information to promote the wildlife on their golf facilities, while still providing quality playing conditions for the game of golf.

Certain issues will receive research priority. Some of them include determining how golf courses can be maintained as biologically productive sites for wildlife; providing solid recommendations regarding wildlife issues that can be incorporated into long-term management strategies; and educating golfers and the general public about these issues.

Examination of individual golf courses within the context of their surrounding landscape is a focus of Wildlife Links. Obviously, an urban golf course may have different obstacles to overcome versus a rural course. A desert course presents a much different landscape for wildlife than a wetlands venue. Regardless of their climatic orientation, however, the loss or fragmentation of wildlife habitat and its effect on wildlife, especially birds, will be a major factor in research projects.

Two initial publications are being developed through the Wildlife Links Program: 1) *Golf Courses and Bird Conservation: A Management Manual* under the direction of Scott Gillihan, Colorado Bird Observatory, and 2) *Wetlands Management Manual for Golf Courses* under the direction of Dr. Donald Harker. The first manual is targeted for golf course superintendents and will provide guidance on how to enhance the habitat for bird species on golf courses. The second manual will be dedicated to wetland issues, including ponds, streams, and wetland areas. This manual will provide recommendations about how to protect wetlands and enhance the wildlife habitat around them.

A third project underway is the development of a data management system using information from the Audubon Cooperative Sanctuary Program for golf courses. This system will be used to determine wildlife management, research and educational program needs for golf courses and to improve conservation management practices on existing and future courses.

Golf courses, especially in more developed regions, hold great potential as hospitable areas for many species of animals and plants. The Wildlife Links Program represents golf's best mechanisms to examine these issues and develop appropriate strategies.

The user of the 1996 Turfgrass and Environmental Research Summary is responsible for determining that the intended use of pesticide information is consistent with the label of the product being used. Use pesticides safely. Read and follow the label directions. The information given herein is for research and educational purposes only. Reference to commercial products or trade names is made with the understanding that no discrimination is intended and no endorsement by the United States Golf Association is implied.

This report is prepared each year by the USGA Green Section. Dr. Michael P. Kenna, research director, and James T. Snow, national director, assemble and edit the annual progress reports submitted by USGA-sponsored researchers. If you would like a copy of the entire annual progress report for one of the research projects in this summary, please write to:

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