GOLF KEEPS AMERICA BEAUTIFUL

USGA GREEN SECTION

1991 ENVIRONMENTAL RESEARCH SUMMARY

Cover Photos:

During 1991, the first year of a 3-year study on golf courses and the environment, work on sponsored projects involved setting up facilities, developing experimental methods, and running preliminary trials. Construction of a lysimieter - under construction (left) and ready for use (right) - will allow researchers at Michigan State University to investigate the fate of pesticides and fertilizers applied to golf course turf.

1991
ENVIRONMENTAL RESEARCH SUMMARY

SUBMITTED BY:

United States Golf Association
Golf House
Far Hills, New Jersey 07931

United States Golf Association
Green Section

National Director
JAMES T. SNOW

USGA
DAVID B. FAY
Executive Director

Golf House
PO Box 708
Far Hills, NJ 07931-0708
(908) 234-2300
FAX: (908) 234-9488

March 1992

TO: THE READERS OF THE 1991 ANNUAL ENVIRONMENTAL RESEARCH REPORT

No issue will have a greater effect on the way golf courses are built and maintained than peoples' concern about the environment. Golf courses have been heralded as wildlife sanctuaries and condemned as toxic waste sites, depending on your point-of-view. What's the truth? The truth is, we need more scientific information on the role of golf courses in our environment before a clear determination can be made.

In 1990, the USGA Executive Committee approved a 3-year, $3.2 million study to investigate the effects of golf courses on the environment. Based upon a report commissioned by the USGA Turfgrass Research Committee from Spectrum Research, Inc., the committee identified the following subject areas as priorities for investigation: 1) the fate of pesticides and fertilizers applied to golf courses; 2) the development of alternatives to the use of chemical pesticides for control of certain golf course pests; and 3) the impacts and benefits of golf courses on people and wildlife. From a pool of more than 80 proposals from land-grant universities, the Research Committee selected 21 projects for funding.

What follows in this Annual Report is a summary of what was accomplished on these 21 projects during 1991, the first year of this 3-year program. For most projects, 1991 was a year of constructing facilities, developing and testing experimental procedures, and collecting preliminary data. It also should be pointed out that an ambitious quality assurance/quality control program was established for all of the pesticide and nutrient fate studies, ensuring data that can be validated under the closest of scrutiny.

From people involved in the golf industry who have been aware of the Environmental Research Program, the most frequently asked question has been "When will we have the answers to these questions?" For the most part, definitive information will not be available until the end of the study,

in late 1993 or early 1994. And if this research work follows the form of most research, there will be questions raised that may require even more investigation. Nevertheless, useful preliminary information should be available by the end of 1992.

USGA

Not all projects funded in this program involve 3-year studies. Several are nearing completion and important publications are forthcoming. Everyone in golf and many outside of golf should have an interest in these publications.

Golf Course Management and Construction: Environmental Issues - A thorough review of the scientific literature on this topic. 900+ pages. Due out June 1, 1992.

Naturalizing the Human Landscape - A book detailing natural vegetation zones in the United States, including information on native plants and how to use them for the benefit of wildlife on golf courses. Due out in late 1992 or early 1993.

Quantification and Validation of the Beneficial Contributions of Golf Courses and Turfgrasses - A seminal article on the environmental benefits of golf courses; to be submitted to a major, peer-reviewed, scientific journal. It also will be published in more "popular" form as an extension bulletin or similar format. Due late 1992 or early 1993.

In funding environmental research, the USGA Executive Committee has gone on record as declaring itself an honest broker on the issue of environmental effects of golf courses. If the research results suggest potential problems with golf courses, the USGA will endeavor to find solutions acceptable to all. By the end of 1993, we shall know more clearly what the next step will be.

Sincerely,

Jim Snow

James T. Snow
National Director, Green Section
Chairman, Environmental Research Committee

in late 1993 or early 1994. And if this research work follows the form of most research, there will be questions raised that may require even more investigation. Nevertheless, useful preliminary information should be available by the end of 1992.

USGA

Not all projects funded in this program involve 3-year studies. Several are nearing completion and important publications are forthcoming. Everyone in golf and many outside of golf should have an interest in these publications.

Golf Course Management and Construction: Environmental Issues - A thorough review of the scientific literature on this topic. 900+ pages. Due out June 1, 1992.

Naturalizing the Human Landscape - A book detailing natural vegetation zones in the United States, including information on native plants and how to use them for the benefit of wildlife on golf courses. Due out in late 1992 or early 1993.

Quantification and Validation of the Beneficial Contributions of Golf Courses and Turfgrasses - A seminal article on the environmental benefits of golf courses; to be submitted to a major, peer-reviewed, scientific journal. It also will be published in more "popular" form as an extension bulletin or similar format. Due late 1992 or early 1993.

In funding environmental research, the USGA Executive Committee has gone on record as declaring itself an honest broker on the issue of environmental effects of golf courses. If the research results suggest potential problems with golf courses, the USGA will endeavor to find solutions acceptable to all. By the end of 1993, we shall know more clearly what the next step will be.

Sincerely,

Jim Snow

James T. Snow
National Director, Green Section
Chairman, Environmental Research Committee

United States
Golf Association

Golf House
P.O. Box 708
Far Hills, NJ 07931-0708
(908) 234-2300
FAX: (908) 234-9687

USGA

DAVID B. FAY
Executive Director

March 25, 1992

To the Readers of the 1991 Annual Environmental Research Summary:

Little the USGA does, or is likely to do, will have more effect on the future of golf than funding and monitoring environmental research.

That effort has one aim--to investigate the effects of golf course activities on the environment.

We must address environmental concerns head-on if the game is to continue to thrive. For example, reducing the use of potable water for irrigation is essential in many parts of the country.

The funding of this program is controlled by the USGA's Executive Committee, and administered by an Environmental Research Committee of 16 members with distinguished careers as academics, agronomists from the USGA Green Section, golf course superintendents, and representatives of the turfgrass industry.

The Research Committee not only recommends how the money will be spent, but its members monitor the progress of the work as well. A quality control program will help ensure that the highest standards are maintained as the research work is carried out.

The 1992 budget calls for 21 grants totaling $930,000 to be distributed to 18 universities and research centers. The USGA has every hope and expectation that these investigations will answer important questions for the benefit of the game of golf and the environment.

Sincerely,

David Fay

David Fay
Executive Director

United States Golf Association

USGA

DAVID B. FAY
Executive Director

Golf House
P.O. Box 708
Far Hills, NJ 07931-0708
(908) 234-2300
FAX: (908) 234-9687

March 25, 1992

To the Readers of the 1991 Annual Environmental Research Summary:

Little the USGA does, or is likely to do, will have more effect on the future of golf than funding and monitoring environmental research.

That effort has one aim--to investigate the effects of golf course activities on the environment.

We must address environmental concerns head-on if the game is to continue to thrive. For example, reducing the use of potable water for irrigation is essential in many parts of the country.

The funding of this program is controlled by the USGA's Executive Committee, and administered by an Environmental Research Committee of 16 members with distinguished careers as academics, agronomists from the USGA Green Section, golf course superintendents, and representatives of the turfgrass industry.

The Research Committee not only recommends how the money will be spent, but its members monitor the progress of the work as well. A quality control program will help ensure that the highest standards are maintained as the research work is carried out.

The 1992 budget calls for 21 grants totaling $930,000 to be distributed to 18 universities and research centers. The USGA has every hope and expectation that these investigations will answer important questions for the benefit of the game of golf and the environment.

Sincerely,

David Fay

David Fay
Executive Director

Table of Contents

Statement of Intent

It is the intent of the United States Golf Association (USGA) Turfgrass Research Committee, through the USGA Foundation, to collect and disseminate substantial amounts of money for support of research to: 1) improve turfgrasses, specifically, to substantially reduce water 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 turf scientists to become leaders in 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 presently intends to return any income received from royalties to the support of turfgrass research. Institutions which accept these research grants will be asked to engage in a free exchange of information with other investigators.

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 helped to provide better playing areas for golf, they 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 uses have been improved by developments which were pioneered by the USGA.

The USGA expects to support research at numerous institutions. In some cases, several 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 that they will engage in a free exchange of information with other investigators.

Overall Objectives

The purpose of this field research project is to quantify and document the impact of turfgrass management on the environment. The overall objectives of the project are to:

1. Understand the effect of turfgrass pest management and fertilization on water quality and the environment.

2. Evaluate valid alternative methods of pest control to be used in integrated turf management systems.

3. Determine the human, biological, and environmental factors that golf courses influence.

Understanding and quantifying the degradation and fate of turfgrass pesticides and fertilizers is required for accurate prediction or simulation of environmental impacts of managed turfgrass systems. Given the current status of research on environmental impacts of turfgrass, a higher priority was assigned to basic and applied research to examine degradation and fate of turfgrass chemicals, rather than directed toward modeling efforts. Once water, pesticide, and nutrient processes have been characterized, development or modification of existing computer models can proceed.

Alternative methods of pest control have a promising future managing turfgrass systems. However, these methods will need field testing under realistic golf course conditions in order to receive widespread acceptance by golf course superintendents. Once the scientific documentation of alternative methods of pest control has been completed, they can be incorporated in integrated pest management systems.

Golf courses provide beautiful greenbelts within our urban and suburban landscapes. However, the human, biological, and environmental factors that golf courses influence need to be scientifically addressed. The future of golf will depend on the development of environmentally sound management practices, in conjunction with the development of public information on why "Golf Keeps America Beautiful."

1991 Environmental Research Committee

James T. Snow, Chairman

Raymond Anderson
Chairman, Green Section Committee
USGA Executive Committee
1506 Park Avenue
River Forest, IL 60305

Dr. Bruce Branham
Department of Crop & Soil Sciences
Michigan State University
East Lansing, MI 48824

Thomas Burton
Sea Island Golf Club
100 Retreat Avenue
P.O. Box 423
St. Simons Island, GA 31522

Thomas T. Chisholm
Vice-Chairman, Green Section Committee
26101 Northwestern Highway
Southfield, MI 48076

Ron Dodson
Audubon Society of New York State
Hollyhock Hollow Sanctuary
Route 2, Box 131
Selkirk, NY 12158

David B. Fay
Executive Director, USGA
Golf House
P.O. Box 708
Far Hills, NJ 07931-0708

Dr. Victor A. Gibeault
Batchelor Hall Extension
University of California
Riverside, CA 92521

Dr. Peter Hayes
The Sports Turf Research Institute
Bingley, West Yorkshire
BD16 1AU, England

Rees Jones
Rees Jones, Inc.
P.O. Box 285
Montclair, NJ 07042

Howard E. Kaerwer
Turfgrass Breeding and Genetics
12800 Gerard Drive
Eden Prairie, MN 55346

Dr. Michael P. Kenna
Director, Green Section Research
P.O. Box 2227
Stillwater, OK 74076

Dean L. Knuth
Director, Green Section Administration
Golf House
P.O. Box 708
Far Hills, NJ 07931-0708

Ann R. Leslie
U.S. EPA - Office of Pesticide Programs
401 M Street, S.W.
Washington, DC 20460

Charles Passios, CGCS
Hyannisport Club
218 Camelback Road
Martons Mills, MA 02648

Jaime Ortiz-Patino
Valderrama Golf Club
54-56 Route de Vandoeuvres
1253 Vandoeuvres
Geneva Switzerland

Dr. Paul Rieke
Dept. of Crop & Soil Sciences
Michigan State University
East Lansing, MI 48824

James T. Snow
National Director, Green Section
Golf House
P.O. Box 708
Far Hills, NJ 07931-0708

Dr. James R. Watson
Vice President, Toro
8111 Lyndale Avenue
Minneapolis, MN 55420

1991 Research Budget Summary

PROJECT	SUBPROJECT	UNIVERSITY/INVESTIGATOR	1991 ACTUAL	1992 BUDGET	1993 BUDGET	TOTAL BUDGET
PESTICIDE AND NUTRIENT:						
	LEACHING	CORNELL/PETROVIC	104,245	72,000	72,000	248,245
	LEACHING	MI STATE UNIV./BRANHAM	90,000	130,000	95,000	315,000
	LEACHING/VOLATILIZATION	UC RIVERSIDE/YATES	55,000	95,000	150,000	300,000
	LEACHING/VOLATILIZATION	UNL-ISU/HORST-CHRISTIANS	126,585	133,000	140,488	400,073
	NITROGEN LEACHING	WA STATE/BRAUEN	20,000	25,000	25,000	70,000
	NITROGEN LEACHING	UNIV. NE-RENO/BOWMAN	20,000	20,000	20,000	60,000
	PESTICIDE LEACHING	UNIV. FL/SNYDER-CISAR	45,000	45,000	45,000	135,000
	PESTICIDE LEACHING/RUNOFF	UNIV. GA/SMITH	40,000	55,000	55,000	150,000
	RUNOFF	PENN STATE/WATSCHKE	36,961	53,100	55,722	145,783
	VOLATILIZATION	UNIV. MASS/COOPER	40,000	40,500	40,500	121,000
	QA/QC	INDEPENDENT/WALKER	20,000	20,000	20,000	60,000
		SUBTOTALS:	597,791	688,600	718,710	2,005,101
GOLF COURSE BENEFITS:						
	QUANTIFICATION/VALIDATION	TEXAS A&M/BEARD	45,000	0	0	45,000
	WILDLIFE TOXICOLOGY	TIWET-CLEMSON/KENDALL	50,000	50,000	50,000	150,000
	ON COURSE WITH NATURE	EARTH FUND/HARKER	25,000	25,000	0	50,000
	HUMAN BENEFITS	TEXAS A&M/ULRICH	25,000	50,000	0	75,000
		SUBTOTALS:	145,000	125,000	50,000	275,000
ALTERNATIVE PEST MANAGEMENT:						
	BIOCONTROL-DISEASE	UC RIVERSIDE/CASALE	13,000	13,000	20,000	46,000
	BIOCONTROL-DISEASE	UNIV. OF FL/ELLIOTT	16,000	20,000	20,000	56,000
	BIOCONTROL-DISEASE	CORNELL/NELSON	25,186	27,000	28,000	80,186
	BIOCONTROL-DISEASE	IOWA STATE/HODGES	20,000	20,000	25,000	65,000
	BIOCONTROL-INSECT	UNIV. OF KENTUCKY/POTTER	20,000	20,000	20,000	60,000
	BIOCONTROL-INSECT	USDA/KLEIN	20,000	20,000	20,000	60,000
		SUBTOTALS:	114,186	120,000	133,000	367,186
		GRAND TOTALS:	856,977	933,600	901,710	2,647,287

The concern over the environmental impact of applications of pesticides and fertilizers to golf course turfgrass has been growing steadily. The information on the fate of pesticides and nutrients applied to turfgrass, however, is encouraging but somewhat limited. The downside of previous studies is that they were conducted under a limited set of conditions (i.e., climates, soils, irrigation, pesticides, turfgrass species, etc.), leaving much room for speculation.

The purpose of these research projects is to evaluate the mobility, persistence, and ultimate fate of parent compounds and transformation products of commonly applied pesticides and nutrients. These studies will cover a wide range of golf course management factors, climates, and sampling methods which include: a) putting green soil mixtures (sand, sand/peat) and fairway soil textural classes (sand, loam, clay loam); b) thatch development; c) soil profile sampling depths; d) turfgrass species maintained under golf course conditions; and e) irrigation regimes.

Research projects (studies) specific to pesticides will produce results concerning: a) degradation rates for commonly used pesticides in several important turfgrass environments; b) conditions which enhance microbial degradation and which, in turn, decrease pesticide loads; c) adsorption coefficients for organic and inorganic materials as a function of residence time in the turfgrass environment; and d) a mass balance assessment of the fate of applied pesticides that takes into account the initial distribution among different turfgrass components (i.e., canopy, thatch, roots), drift, volatilization, soil, water, runoff, and leachate.

Nitrogen fertilizer studies will produce information on: a) the importance of factors which influence volatilization, denitrification, mobilization, immobilization, adsorption, plant uptake, and fixation, as well as b) the loss by surface runoff and leaching. Similar experiments are being conducted to determine the fate of phosphorous in the turfgrass environment.

Cornell University

Mass Balance Assessment of Pesticides and Nutrients Applied to Golf Turf

The objective of this project is to more fully understand the fate of pesticides and fertilizers applied to golf turf evaluated over a wide range of conditions.

Evaluated in this study were applications of mecoprop (applied in September, 1991) and triadimefon (applied in September and October, 1991) to a simulated creeping bentgrass fairway. A urea/methylene urea fertilizer containing phosphorus was also applied (1 lb N/1000sq. ft.) in September and October, 1991. These experiments are being conducted at the ARESTS facility (Automated Rainfall Exclusion System for Turfgrass Studies) which is composed of 27 draining lysimeters (12 ft. x 12 ft.), a rainout shelter, and irrigation and drainage collection systems. Factors evaluated were three soil textures (acid sand, sandy loam and silt loam) and two simulated growing season precipitation patterns (average and wetter-than-normal). In this case, rainfall patterns for 1950 and 1917 were used.

Measurements taken thus far include: clipping harvests on 12, 16, 18, 20, 23, 25, 27, 30 of September, and 2, 4, 7, 11, 16, 18 and 23 of October, 1991; and leachate from all or part of the lysimeters on 18, 19, 26, 30 of September and 2, 4, 5, 8, 10, 11, 12, 15, 20 of October, 1991. The leachate samples are being analyzed for the concentration of nitrate, ammonium, phosphate, mecoprop and triadimefon.

Dr. A. Martin Petrovic

Michigan State University

Groundwater Contamination Potential of Pesticides and Fertilizers Used on the Golf Course

This project is designed to examine the leaching potential of nitrogen, phosphorus, and pesticides under realistic field conditions.

Four lysimeters (devices for the collection of soil water) have been installed at the Hancock Turfgrass Research Center on the Michigan State University Campus. These lysimeters are 10.8 $ft.^2$ in surface area and are 4 ft. deep. The soil within the lysimeters are intact cores that were not disturbed during the construction of the lysimeter. We believe that the data from these lysimeters will reflect conditions that occur naturally in the field, and that the data will give a clear picture of the

leaching potential of the soil (Owosso sandy loam) used in this study.

The project consists of three separate areas. First, the leaching of nitrate from late-fall versus early spring applications will be studied using ^{15}N labeled urea. This study will also examine the fate of nitrogen over a three year period and will focus on the cycling and forms of nitrogen in the soil. As a second approach to the study, pesticides will be applied to the lysimeters and leachate will be tested for the presence of these pesticides over the next three years. A total of five fungicides, two herbicides, and one insecticide will be applied. In August, the insecticide isazofos and the fungicide chorothalonil were applied to the lysimeters, and in September, the herbicides 2,4-D and mecoprop were applied. The other four fungicides will be applied in 1992.

The last objective of the study is to examine the mobility of phosphorus in putting green soil mixes. Phosphorus has little mobility in soils with appreciable clay content; however, movement can occur in soils that are mostly sand. This study will collect samples from recently constructed greens throughout the USA, and will test these mixes for phosphorus adsorption capacity. Also, phosphorus mobility on pure sand greens will be examined at the Hancock Turfgrass Research Center.

Results from our first summer of monitoring are not available at this time due to the intensive nature of the laboratory analysis required to determine ^{15}N quantities. Preliminary data on the quantity of leachate is interesting since it demonstrates that under periods of high ET demand, little leaching occurs. From May 1 through August 28, the lysimeters received a total of 24 inches of rainfall plus irrigation. Only 1.6 inches of leachate, however, were collected from the lysimeters. From August 29 through September 16, an additional 3.1 inches of rainfall plus irrigation were received while the lysimeters leached 1.9 inches of water. Thus, as ET demand decreases, the soil moisture level throughout the whole core rises and rain or irrigation will cause leaching. These data indicate the importance of irrigation management to reduce the potential for leaching. Data will be available in 1992 on the ^{15}N and pesticide content of the leachate and data on the cycling and movement of ^{15}N through soil.

Dr. Bruce Branham

University of California, Riverside

The Fate of Pesticides and Fertilizers in a Turfgrass Environment

The purpose of this research project is to study the fate of pesticides and fertilizers applied to turfgrass in an environment which closely resembles golf course conditions. The goal is to obtain information on management practices that will result in healthy, high quality turfgrass while minimizing detrimental environmental impacts. The specific objectives of the project are to: 1) compare the leaching characteristics of pesticides and fertilizers applied to two turfgrasses; 2) study the effects of the soil type and irrigation regime on the leaching of pesticides, nitrates and phosphorus; 3) compare the leaching and volatilization characteristics of nitrates from different fertilizers; 4) measure the volatilization rate of pesticides from turfgrasses into the atmosphere as a function of time since application; and 5) monitor the effects of different irrigation regimes, fertilizers, and soil types on turfgrass quality.

During the first six months of this research project, a considerable amount of progress has been made on site construction. The site consists of 36 plots, each of which measures 12 ft. x 12 ft. The fairway area consists of 24 plots, 12 each of two different soil types that have been located randomly in the fairway area. A lysimeter assembly, consisting of five metal cylinders, was placed in the center of each of the 36 plots. The lysimeter assembly and drain system has been fabricated using only metal so that there is no potential for pesticide adsorption. Gravel was placed in the bottom of each lysimeter for drainage. The appropriate soil was then added to the lysimeters. In order to ensure uniform soil conditions, the soil was hand packed to the same bulk density in each of the barrels. This was accomplished by weighing the soil and adding it to a measured depth of the lysimeter.

The soil used in the green area is a Caltega IV green sand containing 10 percent sphagnum peat that meets the USGA specifications. Two different soils are being used in the fairway area to represent the ends of the spectrum in terms of leaching potential, while still being representative of actual golf course soils. One of these is the native soil at the site, a fine sandy loam. The other soil is a fine

sand that has been brought to the site. The irrigation system is being designed so that each of the 36 plots can be irrigated individually. The irrigation will be controlled electronically; scheduling will be determined based on the evapotranspiration requirements of the turfgrass. All turfgrass-soil type combinations will be subjected to two irrigation regimes: 100 percent crop evapotranspiration (ET_C) and 130 percent ET_C.

Fertilizer (urea and sulfur-coated urea) and pesticide treatments will begin early 1992. The volatilization and leaching of the products applied will be characterized for the putting green and fairway plots.

Dr. Marylynn Yates

University of Nebraska
Iowa State University

Pesticide and Fertilizer Fate in Turfgrasses Managed Under Golf Course Conditions in the Midwestern Region

Research addressing movement and fate of fertilizer and pesticides in turfgrasses managed under golf course conditions was initiated at the University of Nebraska and Iowa State University during 1991. The objective of the research is to determine the influence of pesticide, fertilizer and irrigation management practices on the persistence and mobility of nitrogen and selected pesticides in turfgrass systems. Intact, undisturbed soil columns were used to reliably monitor pesticide and nitrogen movement in the field, and effectively simulate the turf-soil environment in controlled greenhouse studies. The columns in controlled greenhouse studies will allow measurement of nitrogen and pesticide residue in column leachate for a balance-sheet of their fate in the turfgrass system.

Research sites with established stands of Kentucky bluegrass were selected at the John Seaton Anderson Turfgrass Research Facility at the Agricultural Research and Development Center near Mead, Nebraska, and at the Iowa State University Horticulture Farm, Ames, Iowa. The experimental areas were treated with recommended rates of urea fertilizer; Trimec® (2,4-D, mecoprop and dicamba) and pendimethalin herbicides; isazofos and chlorpyrifos insecticides; and the fungicide metalaxyl.

Eight-inch turf-soil cores were excavated to a depth of 24 inches from local field environments and transported to the laboratory one week prior to application and approximately 1, 14, 30, 60 and 120 days after application. Four cores were removed on each sampling date at each location. The cores were sectioned into verdure, thatch, mat and multiple soil depths, and then prepared for residue analysis. Additional untreated soil columns were encased in cement before being moved to the greenhouse for controlled experiments.

Experiments addressing the fate of nitrogen and phosphorus were initiated at Iowa State University. Fourteen soil columns were encased in cement, extracted from the field, and transported to the greenhouse. Nitrogen and phosphorus were applied to the columns and two watering regimes (1 inch immediately following nutrient application and four 0.25-inch applications during a one-week period) were used to determine the effects of irrigation rates. Nitrogen volatilization was greater from columns receiving the lower irrigation rate. Nitrogen moved to greater depths in the profile under the higher irrigation rate.

Protocols developed at Iowa State for soil column preparation and greenhouse research were modified for pesticide and fertilizer studies at the University of Nebraska. A concern regarding the effect of cement encasement on soil pH was addressed. The pH of a Sharpsburg soil increased from 6.0 to 6.7 after 10 days of contact with the cement, but declined and remained between 6.2 and 6.5 at 15 to 45 days after encasement. The pH fluctuation would not be expected to have a significant effect on the fate of the pesticides included in the study. In addition, a porous plate assembly was designed and constructed such that soil water tension found in the field could be simulated in the greenhouse.

An analytical procedure for simultaneous extraction and quantification of residues of isazofos, metalaxyl, chlorpyrifos and pendimethalin has been developed, and analysis of turf/soil cores removed from the Nebraska and Iowa field sites is in progress. Additional methodology development will be required for analysis of 2,4-D, dicamba and mecoprop in the samples.

Dr. Garald Horst
Dr. Nick Christians

Washington State University

Quantification and Fate of Nitrogen from Amended Sand Putting Green Profiles

The Pacific Northwest has a history of constructing sand greens from pure sand, some with coarse particle sizes and without amendment in order to reduce the cost of construction. A major concern is whether nitrate nitrogen in the leachate from putting green profiles constructed of sand alone, or peat/soil amended sand, can be prevented through efficient irrigation practices, efficient nitrogen fertilizer application, reduction in total nitrogen fertilization rate, or use of deeper sand profiles. This research project will evaluate the susceptibility of these systems to nitrate nitrogen leaching and provide guidance for its correction, reduction or elimination. Lighter, more frequent applications of fertilizers from slow-release sources may be helpful. In addition, frequent, light, liquid application of ammonium sulfate, from a portion of the nitrogen supplied, may improve nitrogen uptake efficiency and improve turf quality and playability without promoting excessive thatch development.

Lysimeters were constructed during 1991 from local funds and labor. Thirty-six of the lysimeters were seeded in early October to 'Putter' creeping bentgrass (*Agrostis palustris* Huds.) and will be overseeded to local ecotypes of annual bluegrass (*Poa annua* L.) in the spring of 1992. The turf is managed as a putting green and traffic will be applied with a Brinkman traffic simulator equipped with golf cleats.

With these lysimeters, an amended sand by nitrogen rate by nitrogen application timing study was established. The field lysimeters, built similarly to USGA green specifications, are 4 ft. x 8 ft. and were constructed with a plastic reinforced liner, and each was fitted with perforated drain tube. The drain tubes are overlaid by 3 inches of pea gravel and 3 inches of coarse sand. Lysimeters are fitted with PVC suction water samplers placed at 8 to 11 inches in the profile. Irrigation timing and quantity is computer logged in each group of 12 lysimeters. The irrigation system is controlled by computer monitoring of moisture sensors located at 3 to 4 and 10 to 12 inches below the putting surface to provide optimum water management.

The growing medium consists of 12 inches of USGA specification sand, either alone or amended with ten percent sphagnum peat and two percent fine sandy loam soil. Nitrogen applications consist of three nitrogen rates (38.7, 58.1 and 77.4 g N m^{-2} annually) and two application methods (granular slow release/soluble N fertilizer in four-week applications and biweekly granular slow release N with liquid ammonium sulfate).

Leachate data collection was begun the last week of October with the beginning of fall rains on the weekend of October 20, 1991. Soil-water percolate from each lysimeter is monitored and quantified on 24-h intervals during leachate production periods. Leachate samples are analyzed by nitrate and ammonium ion sensitive electrodes and ion analyzer.

Dr. Stanton Brauen
Dr. Gwen K. Stahnke

University of Nevada, Reno

The Effect of Salinity on Nitrate Leaching from Turfgrass

This project was initiated in March of 1991, and consists of both a field component (Las Vegas) and a greenhouse component (Reno) to examine the effects of saline irrigation water on nitrate leaching from a soil root zone and on nitrogen uptake by turfgrasses.

Las Vegas: The irrigation system and sampling hardware (lysimeters, tensiometers, neutron probe access tubes, ceramic extraction cups, associated plumbing, etc.) were installed at Horseman's Park in southeast Las Vegas during the spring and summer. Plots were then seeded with either 'NuMex Sahara' bermudagrass or 'Monarch' tall fescue at rates of 45 and 357 lbs./acre, respectively. Each turf was established under typical fairway management conditions. Bermudagrass plots were overseeded with Palmer/Prelude perennial ryegrass in October. The saline irrigation treatments will be initiated in January of 1992, after which time data collection will begin. It is anticipated that the first full season's data will be available by November 1992.

Reno: Seventy-two soil columns (6 inches diameter by 24 inches deep) were equipped with

ceramic extraction cups embedded in diatomaceous earth and backfilled with a loamy sand. Each extraction cup is connected by tubing to individual collection bottles, which are in turn connected to a common vacuum line. The 36 columns were then seeded with either 'NuMex Sahara' bermudagrass or 'Monarch' tall fescue at the rates discussed above. Establishment and growth has been rapid in the greenhouse for both species, and a dense sward has developed. Columns are fertilized once each month with ammonium nitrate (NH_4NO_3) at a rate of 45 lbs. N/acre. Supplemental iron (Fe-EDDHA) has been added regularly to correct some incipient chlorosis in the young bermudagrass. Salinity by leaching fraction treatments were started in January and samples will be collected weekly and analyzed for nitrate and ammonium.

In addition to setting up the column experiment, an experiment was conducted in nutrient solution culture to examine the effects of salinity on nitrogen uptake. Briefly, two cultivars of tall fescue were grown in solution culture for four months. 'Monarch' was chosen as a relatively salt tolerant and 'Finelawn' as a salt sensitive cultivar. Nitrogen treatments were imposed to produce N-replete turf (no N stress) and moderately N-deficient turf (daily additions of nitrate at suboptimal rates to mimic the more typical turf condition). Rootzone salinity was imposed incrementally over four weeks to final salt concentrations of 0, 20, 40, and 80 mM using a combination of NaCl and $CaCl_2$ at a molar ratio of 8:1. Nitrogen uptake was measured for either nitrate and ammonium nitrogen over a 24 hour period and these results are currently being analyzed.

Dr. Daniel Bowman
Dr. Dave Devitt
Dr. Wally Miller

University of Florida, IFAS

Mobility and Persistence of Turfgrass Pesticides in a USGA Green

The first-year project objectives were to construct, install, and test lysimeters for collecting percolate water in a USGA-specification green; evaluate various methodology practices for pesticide analysis; develop a quality assurance and control (QA/QC) program; and to engage in preliminary data collection. These objectives have been completed.

Stainless-steel lysimeters were installed in a USGA-specification green at the University of Florida, IFAS, Ft. Lauderdale Research and Education Center. They were fitted with stainless-steel lines for off-site collection of percolate water. Lysimeter performance was tested in three ways to determine the completeness of sample recovery and to investigate the effect of sample residency time. It was determined that recovery equaled or exceeded 97 percent. The concentration of fenamiphos remained virtually unchanged after 4 days residency in the collection reservoir, whereas after 1 and 4 days residency, diazinon was only 94 and 0 percent, respectively, of that injected.

A 19-section, 33-page quality assurance/quality control plan was developed to delineate field and laboratory protocols for such items as sampling, calibration, error determinations, chemical analyses, data reduction and validation, corrective actions, and reporting.

Methods were validated for determining certain organo-phosphate pesticides in percolate water, thatch, soil, and grass clippings.

In a preliminary field study, fenamiphos applied to bermudagrass (*Cynodon* spp.) turf was observed primarily in thatch over a 7-day period. Fenamiphos in the underlying soil generally was only 10 percent of the amount found in the thatch, and seven days after application, fenamiphos in thatch was only 10 percent of the amount observed two days after application.

Dr. George H. Snyder
Dr. John L. Cisar

Pennsylvania State University

Surface Runoff of Pesticides and Nutrients Applied to Golf Turf

This year was dedicated to the establishment and characterization of the runoff plots. Plots were established with creeping bentgrass and perennial ryegrass. Shortly after germination, irrigation was used to produce steady-state runoff, and hydrographs were generated from the runoff data.

Ten weeks after seeding, fertilizer was applied at a rate of 1 lb N/1000 sq. ft. and plots were irrigated to produce runoff. Runoff and lysimeter samples were taken and frozen for analyses of nutrient content during the winter.

The hydrographs for the initial runoff show relatively high peak runoff rates and short time to peak flow. Hydrographs generated after turf establishment and fertilization show an increase in the time to runoff and a lowering of peak flows. Hence, it would appear that even young turfgrass areas can significantly reduce total runoff when compared to the early seedling stage.

Dr. Thomas Watschke

University of Massachusetts

Volatilization and Dislodegeable Residues of Pesticides and Nutrients Applied to Golf Turf

The objective of this study is to determine the gaseous losses and dislodgeable foliar residues of pesticides applied to golf course turf. To date, limited work has shown that volatile loss of some pesticides applied to turf approaches 15 to 25 percent of the total applied.

In the past 9 months, this laboratory has been responsible for the hiring, training (both academic and technical) and quality control for a full-time Ph.D. graduate student (Casey Murphy), a 1/2-time residue chemist (M.W. Brooks) and a 3/4-time work study technician (B. Chase). Relevant literature was reviewed concerning the environmental monitoring of mecoprop, triadimefon and trichlorfon. Procedures for the analysis of these three pesticides, both as airborne volatile and dislodgeable residues, were evaluated, modified, developed and implemented. Detection levels, extraction efficiencies, linearity of standard curves, interference due to environmental contaminants, mass balance recoveries from sampling devices and storage ability have been determined.

Upon method verification for triadimefon and trichlorfon, these materials were applied to turf (8/23/91-triadimefon and 9/28/91-trichlorfon). Airborne residues were assessed using the high-volume/theoretical profile shape method (i.e., high volume suction fan sampling air above the turfgrass area). Dislodgeable residue samples are determined by vigorously wiping cheese cloth over several one-square-foot areas. Volatile and dislodgeable samples were collected over a two week sampling period. Samples were extracted and prepared for storage. Quantification of these samples is now under way at the Massachusetts Pesticide Analysis Laboratory (MPAL).

Evaluation of a new derivatization method to analyze mecoprop is currently being carried out, and method verification for the analysis of isazofos will be initiated in 1992. Once concluded, these two pesticides will be applied to our experimental turf plot during the 1992 growing season.

Dr. Richard Cooper

University of Georgia

Evaluation of the Potential Movement of Pesticides Following Application to a Golf Course

The objectives of our project are to: 1) determine the potential movement of pesticides from treated bermudagrass and bentgrass greens through effluent entry into surface runoff and groundwater, and 2) determine the potential movement of pesticides from treated bermudagrass fairways by surface runoff and leaching.

The initial funding of this project was received during the spring of 1991 and work accomplished includes the development of greenhouse and field lysimeter installations, and laboratory methods for accurately quantifying the pesticides according to Good Laboratory Practice Standards. Analytical methods were developed to accurately determine 2,4-D, mecoprop, and dicamba at levels of 1, 100, and 20 ppb, respectively, in aqueous solution using partition extraction and electron-capture gas-chromatography analysis.

The greenhouse lysimeter facility has been constructed to simulate golf course greens with 'Penncross' bentgrass and 'Tifgreen' bermudagrass turf. Thirty-six individual lysimeters were constructed by mounting a turfgrass growth-box on a PVC column containing a soil profile developed according to USGA specifications. An automatic track-irrigation system was developed for controlling the rates and time for irrigation. The watering nozzles traverse a horizontal track located above the growth boxes at a speed of 10 ft./min. The

flow rate of the water was adjusted to a rate of 0.06 fl. oz./sec at 20 psi. The daily irrigation of 0.25 inch of water and a weekly rain event of 1 inch are controlled by an automatic timer. The coefficients of variation for water distribution were less than 0.08 across the boxes laterally and over the length of the track. The first pesticide treatments were conducted during the last week in October, 1991.

The field lysimeter facility consists of small bermudagrass and bentgrass greens with lysimeters (22 inches diam.) installed below the sod. The 20 lysimeters are plumbed in the bottom for collection of aqueous effluent from the soil profile developed according to USGA specifications. Bentgrass was seeded during the last week in October, 1991 and bermudagrass will be sodded in April, 1992.

Dr. Albert Smith
Dr. David C. Bridges

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

1. Biological control;
2. Nonchemical control including cultural and mechanical practices;
3. Allelopathy;
4. Selection and breeding for pest resistance;
5. Ecological balance of turfgrass species; and
6. Application of integrated turf management practices utilizing IPM and low cultural inputs.

University of California, Riverside

Investigation of Turf Disease Decline for Potential Development of Biological Control Methods

Increasing restrictions on the use of chemical pesticides demands a shift in emphasis from chemical control to alternative disease control methods. One alternative is the biological control of plant disease through the use of "beneficial" microorganisms that are antagonists of disease-causing microorganisms. This is the first year of a project to investigate sites, where disease has declined naturally, as potential sources of microorganisms for the development of biological control methods. Increased activity of antagonistic microorganisms may be associated with disease decline expressed at a site over several seasons, or within the green, recovered central areas that often appear within brown, symptomatic patches of turf as the disease spreads.

The study was initiated with a bermudagrass field plot previously inoculated with *Leptosphaeria korrae* (cause of spring dead spot) at the University of California at Riverside (UCR) Experiment Station. Disease had spread sufficiently so that green, symptomless patches were obvious in the center of brown, diseased areas; hence, a comparison of microbial profiles from each of these areas could be performed. Thus far, 135 different bacteria and fungi have been isolated from this UCR field plot. These microorganisms are being tested for the ability to reduce growth of several turfgrass pathogens (*Leptosphaeria korrae, Sclerotium rolfsii*, and *Rhizoctonia solani*) in culture. Experiments are also underway to test the most promising microorganisms for their ability to reduce disease in the greenhouse.

Identification of disease decline sites in California, studies to determine the disease-suppressiveness of turf samples from these sites, and a comparison of virulence of pathogens from these sites are planned for the next project year.

Dr. William Casale
Dr. Howard Ohr

University of Florida

Pathogenicity and Biological Control of Gaeumannomyces-like Fungi

The two objectives of this project are to: 1) develop a model system for determining the relationship between melanization of fungal structures and pathogenicity (ability to cause disease) of *Gaeumannomyces* species and related fungi, and 2) determine the biological control potential of non-pathogenic mutant strains of *Gaeumannomyces* fungi for control of turfgrass patch diseases.

At least five turfgrass patch diseases are caused by soilborne fungi with dark-pigmented (melanized) hyphae and an ectotrophic growth habit on roots. These diseases include summer patch and necrotic ring spot of Kentucky bluegrass, spring dead spot and bermudagrass decline of bermudagrass, and take-all patch of bentgrass. The causal agents of these diseases are *Magnaporthe poae, Leptosphaeria korrae, L. narmari, Ophiosphaerella herpotricha, Gaeumannomyces graminis var. graminis,* and *G. graminis var. avenae*. DHN (1,8-dihydroxynaphthalene) melanin is the most common fungal cell wall melanin. Inhibition of the production of DHN melanin has been demonstrated to be a disease control method, primarily with the plant pathogens *Pyricularia oryzae* and *Colletotrichum* spp. In addition, melanin deficient mutants of these species are capable of colonizing plant tissue, but can not penetrate the plant tissue.

Compounds which inhibit DHN melanin were

evaluated in the laboratory for their ability to inhibit the growth of the fungi and to inhibit disease expression. The results indicate that the melanin in *G. graminis* var. *graminis, G. incrustans* and *Magnaporthe poae* is DHN melanin. However, inhibition of melanin production does not appear to inhibit their ability to cause disease.

Seventy-five mutant strains of *G. graminis* var. *graminis* have been obtained. Twenty-nine have been evaluated for their ability to cause disease. All strains were still pathogenic; however, their ability to produce the sexual spores of this fungus and a structure called a hyphopodia were severely impaired. The remaining strains must be evaluated before we will know if this will be a viable method for obtaining biological control of patch diseases.

Dr. Monica Elliott

Cornell University

Microbial Basis of Disease Suppression in Composts Applied to Golf Course Turf

The goal of this project is to develop more effective biological control strategies with compost-based organic fertilizers by understanding the microbial ecology of disease-suppressive composts. The specific objectives of this study are to: 1) determine the spectrum of turfgrass pathogens suppressed by compost applications, 2) establish relationships between overall microbial activity, microbial biomass, and disease suppression in composts, 3) identify microorganisms from suppressive composts that are capable of imparting disease-suppressive properties to conducive composts or those rendered conducive by heat treatment, and 4) determine the fate of compost-derived antagonists in golf course putting greens following application of individual antagonists or composts fortified with these antagonists.

The suppressiveness of various composts to turfgrass disease caused by two different *Pythium* species and *Typhula incarnata* has been established. This extends the range of turfgrass pathogens already known to be suppressed by compost applications. In field studies, some composts are as effective as standard fungicides in suppressing *Pythium* root rot and *Typhula* blight on creeping bentgrass putting greens.

Laboratory studies have focussed on *Pythium* incited disease of creeping bentgrass. We have shown that disease suppression in some composts is a result of microbial activity, whereas suppression in other composts is due to non-microbiological factors. In general, immature composts (less than 1 yr old) are less suppressive to *Pythium* than mature composts (greater than 1.5 yr old). Sterilization of some composts eliminates disease-suppressive properties. These results further indicate a microbiological nature to disease suppression in these composts. In examining a number of suppressive and conducive composts, we have shown direct relationships between microbial activity and disease suppression.

In preliminary experiments with a poultry manure compost, populations of fungi and actinomycetes were quite low, whereas populations of bacteria ranged from 4.4 to 7.5 million cells per gram of compost. Current studies are focussing on the qualitative microbiological differences between suppressive and conducive composts, and the interactions of specific microorganisms with turfgrass pathogens. Our goal is to determine the key microorganisms inhabiting composts so that their physiology and ecology might be better understood. This information will be important in predicting whether composts, at particular stages of maturity, will be suppressive under a set of environmental conditions.

Dr. Eric Nelson

Iowa State University

Potential for Physiological Management of Symptom Expression by Turfgrass Infected by Bipolaris sorokiniana

Ethylene has been found to contribute substantially to the loss of chlorophyll in leaves of *Poa pratensis* infected by *Bipolaris sorokiniana* (leaf spot). The physiological basis of the elevated endogenous ethylene levels is unknown, however. This research project was initiated to determine if the endogenous ethylene, or its mode action, could be manipulated to prevent the loss of chlorophyll in infected leaves and thereby prevent yellowing. The ultimate objective is to develop a means of controlling disease symptom expression. Infection would not be prevented, but yellowing would not

occur and normal mowing procedures would remove infected leaves. The use of fungicides for diseases of this type could be substantially reduced or eliminated.

Initial studies with aminooxyacetic acid (AOA) have provided some positive results. AOA blocks the enzymatic conversion of S-adenosyl-L-methionine (SAM) to 1-aminocyclopropane-1-carboxylic acid (ACC) in the biosynthetic pathway of ethylene in higher plants. This action ultimately reduces the total ethylene produced. Leaves of inoculated plants showed elevated levels of endogenous ethylene at 24, 48, 72, and 96 hr after inoculation; peak endogenous ethylene production occurred at 48 hr (1000 u1 1^{-1}). Plants inoculated and treated with AOA (10^{-3}M) produced less endogenous ethylene at all sampling times than untreated inoculated plants. At 48 hr, the leaves of inoculated plants treated with AOA produced 642 μl l^{-1} of endogenous ethylene compared to 1000 μl l^{-1} produced by untreated inoculated plants.

Chlorophyll loss was initiated after peak endogenous ethylene production (48 hr) and became progressively more severe with time. Chlorophyll content of leaves of untreated inoculated plants was 57 percent of that in healthy control leaves at 96 hr after inoculation; chlorophyll content of leaves of AOA treated and inoculated plants was 81 percent. The decrease in endogenous ethylene in infected leaves of AOA treated plants clearly decreased the chlorophyll loss associated with the disease. No phytotoxic effects were observed to be associated with AOA.

These initial observations are encouraging and suggest that manipulation of symptom expression (yellowing) by leaves infected with *B. sorokiniana* may be feasible. Several additional substances that interfere with ethylene biosynthesis, or with the mode of action of ethylene, will be examined during the next year.

Dr. Clinton Hodges

USDA, Rutgers University, University of California

Biological Control of Turf Pests: Isolation and Evaluation of Nematode and Bacterial Pathogens

White grubs are chronic and often serious problems for golf course and other turfgrass managers throughout the United States. In the Eastern States, the Japanese beetle alone is responsible for over $230 million in control and turf replacement costs. Turf managers are seeking alternatives to the conventional chemical insecticides now available for grub control due to concerns about effectiveness, groundwater contamination, chemical trespass, and adverse effects on nontarget organisms. The development of effective and reliable biological control agents will provide options for use in managing turf pests. Two groups of organisms, insect parasitic nematodes (microscopic worms) and bacteria, have shown promise in controlling a variety of insects. A team of federal and university researchers in Ohio, New Jersey, and California are searching for new isolates of nematodes and bacteria with increased effectiveness against white grubs in turf.

Initial efforts have been placed on the isolation of new strains of insect parasitic nematodes from golf courses and other turf areas. In New Jersey, nearly 300 sites across the state have been examined and more than 50 new isolates have been collected. Representatives from the two major genera of insect parasitic nematodes have been recovered. New strains of a nematode originally isolated from Japanese beetle larvae in the 1930's were found. Field tests demonstrated that new strains of two different species of nematodes were more effective than strains now used in commercial production, and were as effective in controlling Japanese beetle larvae as a chemical insecticide standard. Efforts in Ohio and California have resulted in the isolation of new strains of both genera of insect pathogenic nematodes from soil, as well as from natural field infections of white grubs. Strains from grubs may be adapted to these hosts and offer promise for controlling these pests.

Efforts to identify bacterial pathogens of white grubs have located the organism responsible for causing "amber disease" in New Zealand. These bacteria are commercially available there, but their strains have no effect on white grubs in the USA. We have isolated several bacteria from the Japanese beetle in Ohio and New Jersey, and from masked chafer larvae in California on media that is selective for the amber disease organisms. One isolate from California has been identified as similar to the New Zealand bacteria, thus indicating real promise for finding effective bacterial pathogens in the United States. Additional iso-

lates of both nematodes and bacteria will be obtained in the future, and the effectiveness of all isolates against white grubs will be established.

Dr. Michael Klein
Dr. Randy Gaugler
Dr. Harry Kaya

University of Kentucky

Damaged Thresholds, Risk Assessment, and Environmentally Compatible Management Tactics for White Grub Pests of Turfgrass

The objectives of this project are to: 1) field test a pheromone-based risk assessment system for predicting white grub densities, 2) evaluate the compatibility of turfgrass insecticides with beneficial predators, and 3) establish damage thresholds for white grubs on cool-season turfgrasses.

For the first objective, an inexpensive trap system, which could be easily used by golf course superintendents, was developed and field tested. Female masked chafers produce a volatile sex pheromone that is highly attractive to night-flying males. In 1990, we placed sticky traps at 30 sites in the roughs surrounding three fairways at the Lexington Country Club, Lexington, KY. The traps were baited with 3 female-equivalents of the pheromone extract, and set out on the turf surface to capture beetles. We repeated this procedure on two nights, July 3 and July 9. In early August, we returned to the golf course and took 12 turf core samples at each site. Grubs were returned to the laboratory where they were identified and counted. We plotted and analyzed the data to determine if there was a predictive relationship between the trap captures of adults and subsequent grub populations.

While we had hoped for a strong correlation between the number of adult beetles caught and the subsequent grub density, no such relationship was evident in the golf course test. We could not predict the local grub population based on pheromone trap captures. Our efforts on this project will now be mainly directed at identifying the chemical sex pheromone. This would enable large quantities of synthetic pheromone to be produced at relatively low cost. The pheromone could be formulated in dispensers which discharge it slowly over a period of several weeks, making extended trapping more practical.

The second objective of the project is to determine the importance of predators in reducing populations of pest insects in turf, and to identify those turfgrass insecticides that are least disruptive to this process. Improper timing of insecticide applications, or use of certain insecticides that are particularly harsh on predators, could result in peak resurgences because of interference with natural predation on eggs and other life stages of pest species. Large plots (0.25 acre) of Kentucky bluegrass were treated in June 1991 with either carbaryl, isazofos, cyfluthrin, or left untreated. Impact of the insecticides on predators was monitored with pitfall traps for up to 10 weeks post-treatment. Eggs of the Japanese beetle and pupae of the fall armyworm were implanted into the treated plots at 1 and 3 weeks after treatment, and the incidence of natural predation that occurred in 48 hours was determined. Last fall, grub populations were sampled in treated and untreated plots to determine if the June treatments could indirectly affect grub populations by eliminating predators.

Preliminary counts suggest that all of the insecticides resulted in significant reductions in predator abundance. Their effects, however, were not equally severe, and analysis of the full data set is expected to reveal significant differences in impact on beneficial insects. Initial results document the high rate of predation in the control plots (more than 50%) and is the first experimental verification that predators are important in natural regulation. There were high rates of predation on fall armyworm pupae in all plots, including those treated with insecticides. Perhaps the most striking and significant result from these 1991 studies was the finding that fall grub populations were significantly higher in some pesticide treated plots than in untreated control plots.

The third objective is to quantify relationships between grub density, root damage, foliar growth, and aesthetic quality of different cool-season turfgrasses to establish damage thresholds for making management decisions. Interactions between grass species, grub species, and management tactics on the expression of grub feeding injury will be measured. Large, replicated plots of Kentucky bluegrass, creeping bentgrass, hard fescue, perennial ryegrass, and endophyte-infected and endophyte-free tall fescue were established in 1989. In spring 1991, we implanted 12 galvanized

steel enclosures (1 ft.^{2})into each plot. In addition, 204 wooden rooting boxes, each consisting of a 1 ft.^{2} wooden frame with a nylon screen bottom, were implanted into a Kentucky bluegrass turf. These were divided among two studies, one to measure effects of irrigation and fertilization on expression of grub damage, and the other to consider grass species effects.

Because white grubs do the most damage during late summer and fall, the above experiments were run until mid-October, and harvesting was completed just one week before this report was written. We have begun the time-consuming task of separating the formerly living (green) and dead (brown) grass tissue before weighing the hundreds of samples.

Dr. Daniel A. Potter
Dr. Andrew Powell

The purpose of this project is to document and quantify the influence of golf courses on people, other biological organisms, and environmental factors. The studies include research pertaining to the influence of golf courses on:

1. Local soil and climate regarding gaseous and particulate pollutants that affect air quality; temperature, humidity, and wind modification; soil stabilization and watershed management; and noise modification;

2. Biological diversity of flora and fauna in urban, urbanizing, and urban-agriculture fringe areas;

3. Psychological and physical well-being of people, and the importance of landscape aesthetics to humans due to the interaction between people and plants.

Spectrum Research, Inc.

Golf Course Management and Construction: Environmental Issues

The final manuscript for the book *Golf Course Management and Construction: Environmental Issues* was submitted to Lewis Publishers, Inc. on October 4, 1991. The book is a summary and assessment of the technical and scientific research on the environmental effects of turfgrass management and, to a smaller extent, golf course construction. The book is intended as an introduction to the concepts of the non-point source environmental impacts of turfgrass management for turfgrass scientists and specialists, landscape and golf course architects, developers of turfgrass systems and golf courses, golf course superintendents, environmental scientists, and land use regulators.

The manuscript is organized into eight chapters. The introduction provides an overview and historical perspective regarding turfgrass management and environmental quality. The second chapter discusses the relationship of turfgrass management to the critical issues of water resources. This chapter focuses on the issues of water use, water quality, soil and water conservation, and movement within the water cycle. Chapters three and four provide a state-of-the-art scientific review and assessment of the literature regarding the environmental effects of nutrient and pest management practices. The fifth chapter provides an introduction to concepts necessary for development of integrated management systems for turfgrass. Chapter six covers the direct and indirect effects of golf course management and construction on wildlife and aquatic organisms. The seventh chapter is an introduction to the critical issues of conservation and protection of wetlands which is emerging as a critical environmental concern of the 1990's. Chapter eight contains tables of toxicity tests related to the effect of chemicals used for turfgrass management. Each of the chapters includes a section on research and information needed to resolve the issues surrounding the positive and potentially adverse effects of turfgrass management.

Dr. James Balogh

Texas A&M University

Quantification and Validation of the Beneficial Contributions of Golf Course Turfgrasses

This progress report represents a summary of the ongoing research activities for the first nine months of a project entitled "Quantification and Validation of the Beneficial Contributions of Golf Course Turfgrasses." The objectives of this project were to: 1) conduct a detailed assessment of the literature to obtain and validate scientifically based sources of information supporting the benefits of turfgrass to our environment via golf courses, and 2) conclude with a manuscript that will be submitted to a major, peer-reviewed, scientific journal as a seminal article on the environmental benefits of golf courses. Also, there would be the opportunity to publish a Texas Agriculture Experiment Station bulletin or report which could be in press sooner than the scientific paper.

Considerable time and effort has been spent toward achieving our objectives since fall 1990. Over 282 papers have been collected, organized, and assessed (many are not useful for our needs). Over 84 personal inquiries have been made for specific information concerning the benefits of golf course and turfgrass. These numbers will be increased substantially before our objectives are

achieved. A tentative outline for a position paper, to be submitted to Science, was completed in June 1991. Currently we are writing a preliminary draft which should be completed in early 1992. A final draft of the manuscript will be submitted to the USGA Green Section on or before May 1, 1992.

This has been a rewarding and enlightening project because there is a need for it, and because our perspective has evolved concerning the environmental issues challenging the golf course industry. This position paper, and other USGA projects, are needed first steps. We agree, however, that the lasting solution will be achieved from the golf course industry and environmental groups working together to achieve common goals and objectives.

Dr. James Beard

The Earth Fund

On Course with Nature

This project will adapt information on eco-regions across the United States for use in naturalizing landscapes around golf courses. By increasing the natural areas around the golf course, it is hoped to increase or preserve wildlife habitat.

Earth Fund researchers look at golf courses as valuable green space within the urban environment. Golf courses, however, are not regularly cited in scientific literature concerning wildlife habitat, and more often receive negative attention in popular press. This project has surveyed the literature on natural areas and established woodland size, vegetation structure, and other information to encourage wildlife usage of golf courses. The United States is already divided into natural eco-regions and the book developed from the project will describe how to recreate or manage the natural vegetation previously on the site.

An outline of the book contents was developed and an extensive literature review was completed during the last three to four months. Lists of native plant species and nurseries in the United States that produce these materials will be incorporated into the book. The landscape side of the problem, or the "how to do it" principles, will be a major portion of the book. Careful attention to recommendations on adapted plant materials for a region will be emphasized. A detailed map of the United States indicating the natural ecoregions and plant communities was developed in 1991. Landscape architects and horticulturalists can use this map and then go to a nursery to select suggested plant species. Currently, native plant species do not have something similar to this approach, and the project will help a great deal to meet this need.

The Green Section will help select photographs of golf courses that are already utilizing some of the principles the book will develop. From an urban planning perspective, the book could help develop scenarios for natural corridors through urban areas by linking golf courses, parks, and larger tracks of land. The concept of 'sustainable development' and 'quality of life' will be covered.

Dr. Donald Harker

Institute of Wildlife and Environmental Toxicology

The Effects of Golf Course Activities on Wildlife

The Institute of Wildlife and Environmental Toxicology (TIWET) at Clemson University has conducted numerous studies on the environmental effects of pesticides used on golf courses. TIWET, with USGA funding, initiated research in golf course management practices to institute environmentally sound approaches based on knowledge of chemical use, fate and effect. Attempts will be made to determine those products and management procedures which reduce non-target wildlife exposure to pesticides. Resulting information will aid in the development golf course management practices that provide satisfactory playing surfaces, without damage to the environment.

The pilot study on the Ocean Course, Kiawah Island, began in July, 1991. This investigation has focused on two areas: 1) developing a thorough water sampling program to measure the quantity of pesticides reaching adjacent marshes; and 2) assessing the potential for exposure of wildlife on the Ocean Course and adjacent habitats.

The development of Kiawah was conducted with environmental foresight, resulting in a residential and resort community endowed with diverse habitat and abundant wildlife. The Ocean course, constructed with an innovative drainage

system that captures runoff from rainfall and irrigation, is situated in a sensitive ecosystem of sand dunes and tidal marsh. Chemicals used on the course are deterred from entering adjacent wetlands and the water can be recycled.

TIWET efforts during the first year have concentrated on gathering background information on the Ocean Course and on substantiating irrigation and chemical application procedures. Maps and diagrams were developed and used to describe the flow of irrigation and drainage water on the course. Turf management practices and pesticides used on the Ocean Course were documented. Chemical application records were collated and the irrigation schedule was recorded. Water samples have been collected for preliminary analysis of pesticide residues.

Dr. Ron Kendall

Texas A&M University

Human Benefits of Golf Course Views: Emotional Well-Being, Stress and Performance

While golf courses are an important type of land use in most American cities and suburban areas, there is little scientific evidence regarding the human benefits that golf courses make possible. More specifically, there is virtually no sound, convincing research regarding the "influence of golf courses on the psychological and physical well-being of people." The absence of research on these issues is not a problem for the avid golfer, for whom the benefits of golf courses and the game are intuitively self-evident. The great majority of Americans, however, are not golfers, and accordingly lack the direct experience that is probably necessary for an intuitive appreciation of the benefits of golf courses and the game.

The lack of research on golf course benefits can be a major problem both from the standpoint of communicating or marketing the benefits of the game to the non-golfing public, and/or conveying the benefits of a proposed golf course to either a planning commission, a zoning board, a city council, or a group of environmentalists. The reality is that intuitively-based arguments about the human benefits of golf courses, however commonsensical to golfers, carry little or no weight in the face of the more publicized or tangibly documented issues such as pesticide runoff, consumption of scarce water resources in semi-arid areas, or membership polices based on racial or ethnic criteria.

A major feature of the two proposed studies is the emphasis placed on state-of-the-art *physiological* and *behavioral* measurement techniques, in combination with self-report techniques such as questionnaires, for examining the effects of golf courses on human well-being and cognitive performance. For reasons related to scientific validity, we strongly favor using a combination of physiological, behavioral, and self-report measurement instruments in the assessment of human responses. Such a research strategy avoids relying solely on widely-used verbal measures such as "aesthetic preference" and "satisfaction" and thus circumvents a potential criticism of such measures based on recent empirical demonstrations that preference ratings for natural environments may neither be correlated with improved emotional well-being, nor be consistently linked with such human benefits as recovery or restoration from stress or mental fatigue.

The specific objectives of these studies are to: 1) identify and measure the physiological and emotional effects of off-site views of golf courses, and compare these effects with those resulting from viewing other common types of urban land uses (i.e., commercial strips, residential areas and parks, etc.); and 2) identify and measure the effects of viewing golf courses (relevant, for instance, to views from workplace windows) on the performance of cognitive tasks relevant to the productivity of administrators and other employees. Performance on these tasks will be diagnostic of our capacity to either monitor or reject incoming information and to either analyze or synthesize diverse information. For example, a significant part of the project will focus on whether viewing a golf course elicits a positive mood, that in turn enhances performance on tasks related to creative thinking.

The anticipated benefits of the research will include: 1) the potential positive consequences of golf course location for off-site users will be identified, assessed, and made accessible for practitioners involved in land use decisions; 2) a precedent will be established for the training of graduate students in landscape architecture on the indirect health

consequences of golf course design and location; 3) peer reviewed publications in established scientific journals; and 4) continued theory development in an ongoing basic research effort by the investigators to more fully characterize the dynamic relationship between humankind and the natural landscape.

Dr. Louis Tassinary
Dr. Roger Ulrich