TITLE: The Fate of Pesticides and Fertilizers in a Turfgrass Environment

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THE FATE OF PESTICIDES AND FERTILIZERS IN A TURFGRASS ENVIRONMENT

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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 proposed integrated research project has been designed so that all combinations of all treatments can be statistically analyzed. By simultaneously looking at interactions between soils, turfgrasses, irrigation amounts, pesticides, and fertilizers; questions about "best management practices" for turfgrass growth and maintenance will be able to be answered.

The specific objectives of the project are: 1) Compare the leaching characteristics of pesticides and fertilizers applied to two turfgrass treatments; 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; 5) Monitor the effects of different irrigation regimes, fertilizers, and soil types on the quality of the turfgrass.

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' x 12'. 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 5 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. This will allow us to make a quantitative determination of the mass of pesticide leaching through the turfgrass.

Each of the lysimeters was hand-packed to ensure uniformity. 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 packing, 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% 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% crop evapotranspiration (ET_c) and 130% ET_c.

Two different fertilizers will be used on the plots. One-half of the plots will be fertilized with a soluble fertilizer such as urea; the other half will be fertilizer with a slow-release fertilizer product such as sulfur-coated urea.

Early in 1992, background samples will be obtained and analyzed. Differential treatments will begin soon thereafter.

INTRODUCTION

Environmental protection has become a national issue in the past several years. While concerns focused on cleaning up contaminated surface waters in the 1970's, the focus in the 1980's and into the 1990's has been on ground water. Over one-half of the population of the United States relies on ground water for all or part of their potable water. Up to 95% of rural residents obtain their water supplies from wells. Domestic uses account for only 18% of the ground water used in this country, while almost two-thirds of the ground water withdrawn in the U.S. is used for irrigation. In California, up to 20 billion gallons of ground water are used every day for irrigation purposes. The heavy dependence on ground water for both domestic and agricultural uses makes ground water a very valuable resource, which must be protected from contamination.

Widespread use of pesticides has been made during the past 40 years. California alone accounts for 25% of the pesticides applied in the United States. Prior to 1979, little monitoring of ground water for the presence of pesticides was practiced because it was assumed that they were not sufficiently long-lived and mobile to pose a threat to ground water. However, the discovery of a soil fumigant, 1,2-dibromo-3-chloropropane (DBCP) in well water in Lathrop, California triggered widespread ground-water sampling programs. As a result, approximately 10,000 wells in the state have been analyzed for pesticide residues. The monitoring program detected more than 50 different pesticides in 23 California counties. The most commonly detected pesticide was DBCP, which was found in approximately 2500 of the wells.

Public concerns over exposure to toxic chemicals in the environment led to the passage of two pieces of legislation in California that impact ground water: Proposition 65 and Assembly Bill 2021 (AB2021). Proposition 65 requires that the governor publish (and update yearly) a list of chemicals known to the State to cause cancer or reproductive toxicity. One of the provisions prohibits a person in the course of doing business from knowingly discharging a chemical on the list into water or onto or into land where the chemical may pass into a source or potential source of drinking water. Thus, any pesticides which are known to cause cancer or reproductive toxicity will be subject to the provisions of Proposition 65.

AB2021, the Pesticide Contamination Prevention Act, was passed specifically to try to prevent or minimize future ground-water contamination by pesticides. This act states that the use of a pesticide will be restricted if it is detected in the ground water or found in the soil at or below the deepest of the following three depths: 8 feet below the soil surface, below the root zone of the crop, or below the soil microbial zone. As a result of this bill, the use of several pesticides (Table 1) is being restricted in some areas of the state. In addition, the California Department of Food and Agriculture is monitoring the ground waters and soils of the state for the presence of 49 other pesticides (Table 2). If these compounds are detected, their use will be restricted as well.

There has also been concern expressed over exposure to pesticides by routes other than drinking water. In California, regulations have been proposed that would list pesticides as potential toxic air contaminants. Thus, consideration

Table 1. Restricted Uses of Detected Leachers

Pesticide	Restriction
Atrazine	all outdoor agricultural, outdoor industrial and outdoor institutional uses prohibited in atrazine PMZs
Bromacil (Hyvar) Diuron (Karmex) Simazine (Princep)	all non-crop uses prohibited in the respective PMZs
Prometon (Pramitol)	all agricultural, outdoor industrial and outdoor institutional uses prohibited in prometon PMZs
Aldicarb	fall applications will be prohibited and rates allowed per acre reduced by 50%

Table 2. Suspected Leachers as Defined by California Department of Food and Agriculture, August 1991

Acephate (Orthene)
Alachlor (Lasso)
Aldicarb (Temik)
Azinphos methyl (Guthion, Gusathion M)
Bensulide (Betasan, Prefar)
Butylate (Sutan)
Chloropicrin
Chlorsulfuron (Glean, Telar)
Cyanizine (Bladex, Fortrol)
Cycloate (Ro-Neet)
2,4-D, dimethylamine salt
Diazinon
Dichlobenil (Casoron, Decabane, Prefix D)
Dicloron (Allisan, Botran)
Diethalyl ethyl (Antor)
Dimethoate (Cygon, Fostion MM, Perfekthion, Rogor, Roxion)
Diquat dibromide (Aquicide, Cleansweep, Pathclear, Reglone, Weedol)
Disulfoton (Disyston, Dithiosystox, Frumin AL, Solvirex)
EPTC (Eptam, Eradicane)
Ethofumesate (Nortran, Tramat)
Ethoprop (Mocap, Prophos)
Fenamiphos (Nemacur)
Fluometuron (Cotoran)
Fonofos (Dyfonate)
Fosetyl-Al (Aliette, Mikal)
Hexazinone (Velpar)
Linuron (Lorox, Afalon)
Metalaxyl (Apron, Fubol, Ridomil)
Metaldehyde
Methiocarb (Mesurol, Draza)
Methomyl (Lannate, Nudrin)
Methyl isothiocyanate (Trapex)
Metolachlor (Dual)
Metribuzin (Lexone, Sencor)
Molinate (Ordram)
Napropamide (Devrinol)
Naptalam, sodium salt (Alanap)
Norflurazon (Evital, Solicam, Zorial)
Oryzalin (Dirimal, Ryzelan, Surflan)
Oxadiazon (Ronstar)
Oxydemeton methyl (Metasystox R)
Parathion (Bladan, Folidol, Fosferno, Niran)
Pebulate (Tillam)
Prometryn (Caparol, Gesagard)
Propyzamide (Kerb)
Sulfometuron (Oust)
Tebuthiuron (Perflan, Spike)
Triallate (Avadex BE, Fargo)
Vernolate (Vernam)

of pesticide volatilization is an important aspect to consider in an environmental fate study, both from a pesticide efficacy and an environmental contamination standpoint.

In addition to pesticides, nitrates have received a great deal of attention. Contamination of ground water by nitrates is one of the major sources of non-point source pollution in the United States. A recent survey by the United States Geological Survey (USGS) suggested that use of fertilizers is a large contributing factor to elevated nitrate levels. In their survey of over 2700 wells in California, the USGS found that over 10% had nitrate levels which exceeded drinking water standards. The State Water Resources Control Board identified increasing nitrate contamination of ground water as one of six general statewide ground-water problems.

PURPOSE

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 proposed integrated research project has been designed so that all combinations of all treatments can be statistically analyzed. By simultaneously looking at interactions between soils, turfgrasses, irrigation amounts, pesticides, and fertilizers; questions about "best management practices" for turfgrass growth and maintenance will be able to be answered.

OBJECTIVES

1) Compare the leaching characteristics of pesticides and fertilizers applied to two turfgrass treatments.
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.
5) Monitor the effects of different irrigation regimes, fertilizers, and soil types on the quality of the turfgrass.

PROGRESS REPORT
APRIL - OCTOBER 1991

Site Construction

During the first six months of this research project, a considerable amount of progress has been made on site construction. The site chosen for this project is the Turfgrass Research Facility at the University of California, Riverside. The site consists of 36 plots, each of which measures 12' x 12'. A plot plan is shown in Figure 1. As shown, all plots that represent green conditions (hereafter referred to as the "green" plots) are located in one area, and are separated from the "fairway" plots by a two-foot-wide border. The fairway area consists of 24 plots, 12 each of two different soil types that have been located randomly in the fairway area. Because the soil types have been distributed

TREATMENT LEGEND:
F=fertilizer
I=irrigation
S=soil

GREEN PLOTS

F1I1	F2I1	F2I2	F1I2
F1I2	F1I1	F2I1	F2I2
F2I2	F1I1	F1I2	F2I1

FAIRWAY PLOTS

F1I1S1	F1I1S2	F2I2S1	F1I2S1	F2I1S2	F2I2S2	F1I2S2	F2I1S1
F1I2S1	F2I1S2	F2I2S2	F1I1S2	F1I1S1	F2I1S1	F1I2S2	F2I2S1
F1I2S2	F1I1S2	F2I1S2	F1I2S1	F2I2S2	F1I1S1	F2I1S1	F2I2S1

Figure 1. Research Plot Plan

randomly in the fairway area, borders have been constructed to contain the soil in its respective plot. In the green area, because there is only one soil type, no borders have been installed between plots.

Lysimeter Installation

Prior to installation of the lysimeters, the site was graded and leveled. The lysimeter assembly, consisting of 5 metal cylinders, were pre-assembled and then transported to the plots. One assembly was placed in the center of each of the 36 plots. A plan view of one plot is shown in Figure 2. The lysimeter assemblies were placed on the graded surface, and then leveled so that all of the assemblies are at the same elevation.

Each of the lysimeters has a metal drain pipe at the bottom that extends the length of the field (terminating at the retaining wall on the south side), enabling us to collect the leachate. The leachate can be collected from a single lysimeter or from the entire assembly, which will allow us to assess any variation among lysimeters.

The lysimeter assembly and drain system has been fabricated using only metal so that there is no potential for pesticide adsorption. This will allow us to make a quantitative determination of the mass of pesticide leaching through the turfgrass.

Each of the lysimeters was hand-packed to ensure uniformity. Profile views of the lysimeter assembly for the green and fairway plots are shown in Figures 3 and 4, respectively. 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 packing, 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.

After the lysimeters were filled, the remainder of the plot was mechanically filled with the appropriate soil.

The soil used in the green area is a Caltega IV green sand containing 10% sphagnum peat that meets the USGA specifications. A mechanical analysis of this soil is shown in Table 3. 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, which has a relatively low permeability. This soil has been classified as a fine sandy loam and contains 67.3% sand, 19.8% silt, and 12.9% clay. The other soil is a top soil that has been brought to the site. This soil is a fine sand which has a relatively high potential for leaching; its mechanical analysis is shown in Table 3.

A soil suction cup device will be installed in the center lysimeter of each plot. The suction cup devices will be constructed of a porous stainless steel cup and teflon tubing. These materials will be utilized to minimize pesticide adsorption to the sampling devices. The suction cup devices will be placed in the soil during the construction process, if possible, to minimize disruption of the turfgrass after it has been established.

Figure 2. Plot Close-up

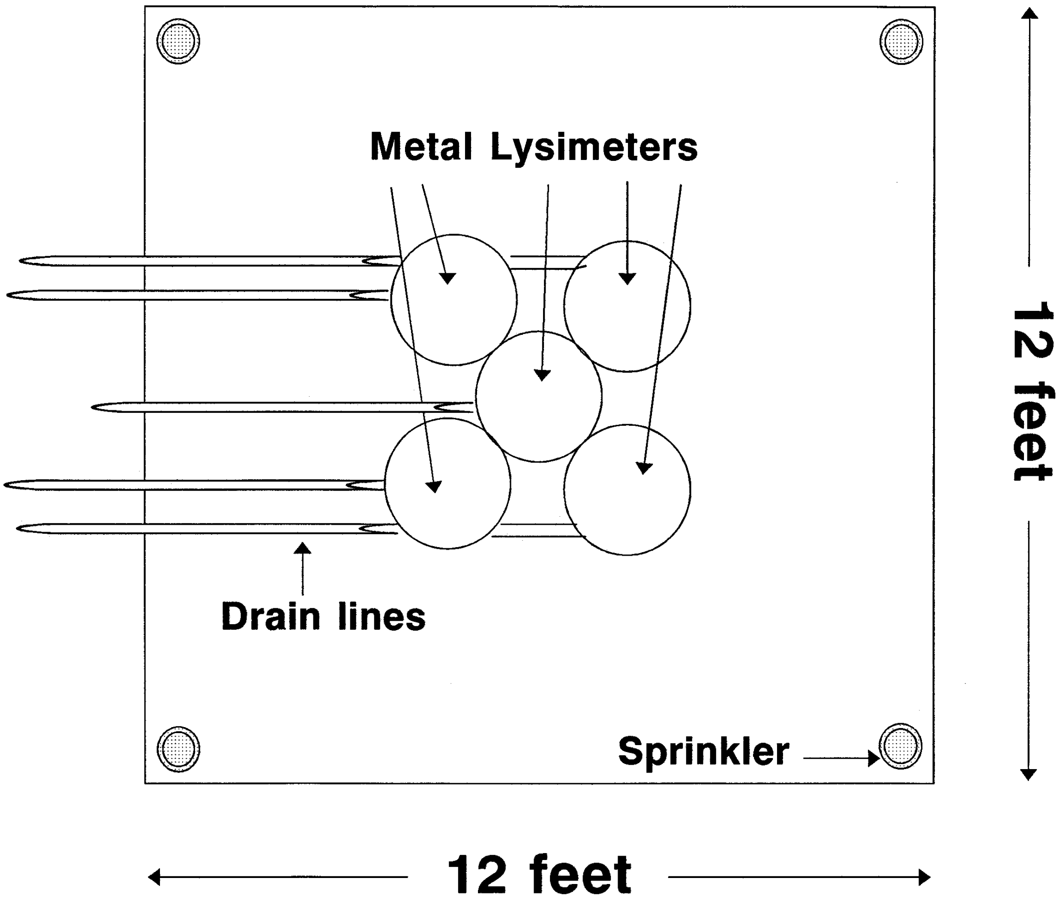

Figure 3. Green Plot Profile

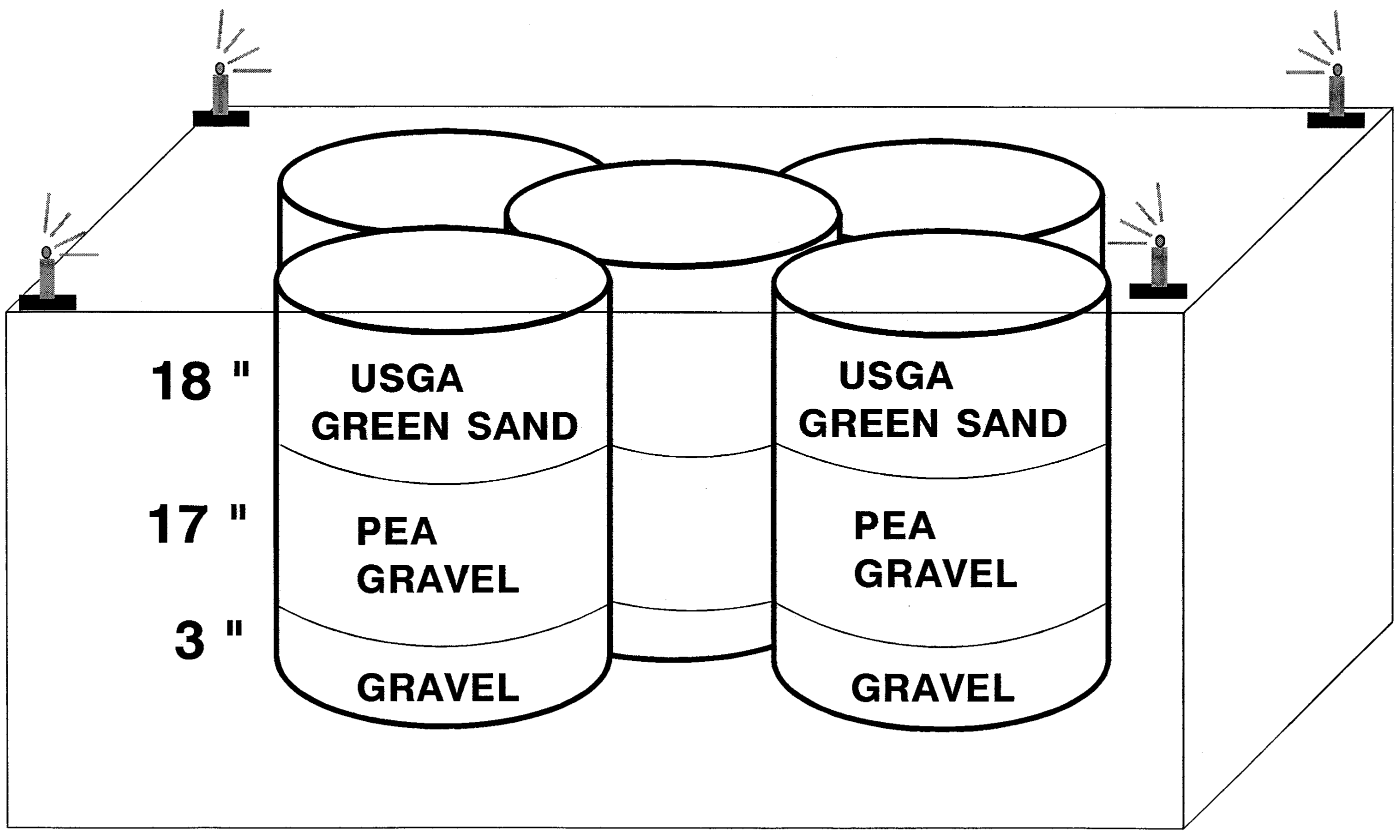

Figure 4. Fairway Plot Profile

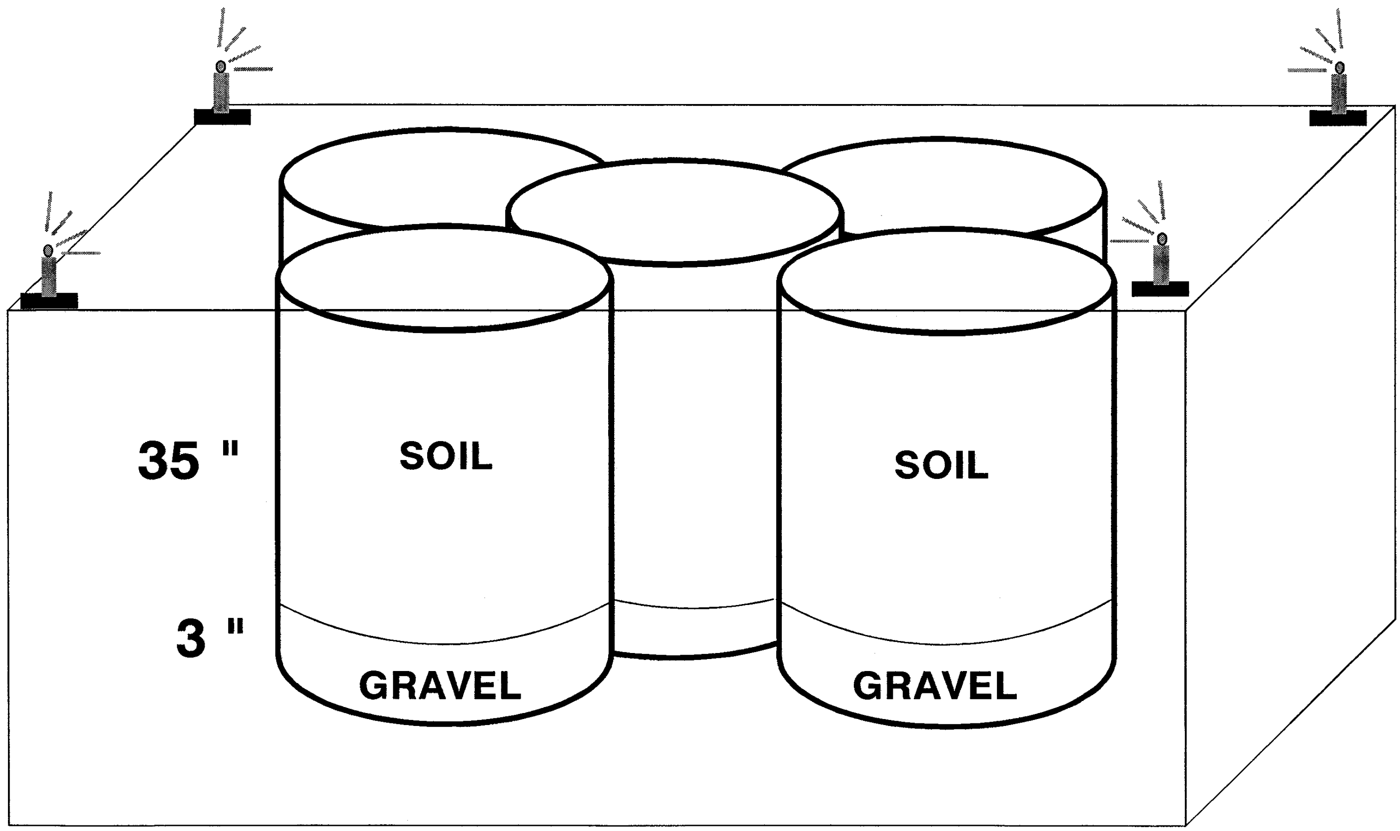

Table 3. Mechanical Analyses of Soils Used in Turfgrass Plots

Sieve Size	USDA Ratings	Percent Retained	
		Green Sand	Fairway Sand
10	fine gravel	1.20	0.10
18	very coarse sand	8.80	0.50
35	coarse sand	21.00	0.50
60	medium sand	36.40	24.00
140	fine sand	30.00	58.00
270	very fine sand	1.20	15.30
	silt & clay	1.40	1.60

Irrigation System

The irrigation system is being designed so that each of the 36 plots can be irrigated individually. Each plot will have 4 sprinklers, one at each corner. The entire irrigation assembly will be outside of the lysimeter assembly so that there is no potential for adsorption of the pesticides to the PVC pipe.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% crop evapotranspiration (ET_c) and 130% ET_c. The 100% ET_c treatment is the optimal amount of water required by the turfgrass to grow and maintain itself in a healthy state. Thus, 130% ET_c is above the optimum water requirement, but is well within the range of standard practice within the industry. ET_c is calculated using the formula: $ET_c = ET_o \times K_c$. ET_o is the reference evapotranspiration, and represents the amount of water required by 4 to 6" tall fescue. The ET_o is calculated based on several factors including solar radiation, temperature, wind speed, and humidity. The ET_o is measured at over 80 CIMIS (California Irrigation Measurement Information System) weather station locations in the state, one of which is located at the University of California, Riverside turfgrass research facility. K_c is the crop coefficient, which must be known for the particular crop of interest, in this case, turfgrass. The crop coefficients for several different turfgrass varieties have been determined at the turfgrass facility over the past several years.

Fertilizer Treatments

Two different fertilizers will be used on the plots. One-half of the plots will be fertilized with a soluble fertilizer such as urea; the other half will be fertilizer with a slow-release fertilizer product such as sulfur-coated urea. All plots will be fertilized with the same total amount of nitrogen and phosphorus calculated on a yearly basis. The applications will be made according to recommendations made by USGA Green Section personnel. It is anticipated that the yearly rate of nitrogen applied will be between 8 and 10 pounds of nitrogen per 1000 ft^2, based on the advice of Paul Vermeulen (Agronomist, USGA Green Section, Western Region).

Pesticide Application

The pesticides to be used in this study will be chosen based on several factors including widespread use in the golf course industry, chemical and physical properties, safety considerations, and analytical capabilities. Pesticides exhibiting as wide a range of volatilization and leaching characteristics as possible (within the constraints listed above) will be used. The herbicides to be used will be chosen from the following group: 2,4-D, MCPA, Betasan (bensulide), Balan (benefin), and Dacthal (DCPA). At least one application per year of an insecticide (carbaryl, bendiocarb, or Oftanol) will be made to the plots. Fungicides (such as PCNB or Subdue) will also be applied as necessary. All pesticide applications will be made at rates and intervals typical of those used in the golf course industry. Applications will be determined based on consultation with USGA Green Section Western Region personnel and University of California cooperators.

Quality Assurance Plan

A quality assurance plan for this project is currently being written. We are following the guidelines for quality assurance project plans established by the U.S. Environmental Protection Agency. Thus, the plan contains the 16 elements listed in Table 4.

EXPECTED ACCOMPLISHMENTS - NOVEMBER 1991-OCTOBER 1992

The project is currently proceeding according to the original time schedule. We expect to complete site construction (including backfilling plots and irrigation system installation) by January and to obtain samples of the soil and water for baseline nitrogen and pesticide concentrations by February. Differential treatments (irrigation and fertilizer) will be started as soon as possible after that time.

Samples to be collected will include total leachate from the lysimeter assemblies, leachate from the soil suction devices, and air samples for volatilization measurements. Samples will be analyzed for nitrates and pesticides as appropriate.

Table 4. U.S.EPA Quality Assurance Project Plan Elements

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II. Table of Contents
III. Project Description
IV. Project Organization and Responsibilities
V. Quality Assurance Objectives
VI. Sampling Procedures
VII. Sample Custody
VIII. Calibration Procedures and Frequency
IX. Measurement Procedures
X. Data Reduction, Validation, and Reporting
XI. Internal Quality Control Checks
XII. Performance and System Audits
XIII. Preventive Maintenance
XIV. Calculation of Data Quality Indicators
    - Precision
    - Accuracy
    - Completeness (Sampling and Analytical)
    - Completeness (Statistical)
    - Comparability
    - Method Detection Limit
XV. Corrective Action
XVI. QA/QC Reports to Management