

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

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**CLIMATIC REGION:** Cool Arid

**USGA REGION:** Mid-continent/Great Lakes

## I. EXECUTIVE SUMMARY

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 was 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 solute fate in the turfgrass system.

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

Turf/soil cores were excavated to a depth of 24 inches from local field environments one week prior to application and approximately 1, 14, 30, 60 and 120 days after application at the two locations, placed in 8 inch PVC, and transported to the laboratory. Four cores were removed on each sampling date at each location. The cores were sectioned into verdure, thatch, mat and multiple soil depths and prepared for residue analysis. Additional untreated soil columns were encased in cement before removal and transportation 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 15-45 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. A porous plate assembly was designed and constructed such that soil water tension found in the field could be simulated in the greenhouse. The porous plate assembly also would alleviate problems of "perched water tables" which occur in the greenhouse. Soil moisture conditions in the field were related to greenhouse conditions by determining water release curves for samples extracted from the field and by determining soil moisture from several wetting and drying periods in the field. The comparison made it possible to determine the amount of tension to apply to the porous plate assembly. Preliminary evaluation of the system indicated that it could be successfully used in the greenhouse. Full-scale greenhouse experiments are planned for January-March 1992.

An analytical procedure for simultaneous extraction and quantification of residues of isazophos, 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.

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## II. RESEARCH PROGRESS - UNIVERSITY OF NEBRASKA

### A. Undisturbed Soil Cores - Field Monitoring

#### 1. Site

A 30 ft by 30 ft area of 'Huntsville' Kentucky Bluegrass at the Mead Research Farm was selected for the research (Plate 1). The turf area was established in 1988 on a Sharpsburg silty clay loam soil (fine, montmorillonitic, mesic, Typic Argiudoll) and maintained using standard cultural practices. Irrigation and mowing practices comparable to those used on a golf course fairway were implemented during the 1991 growing season.

#### 2. Experimental Design

The research area was divided into four quadrants with 25 one meter square plots per quadrant. One plot per quadrant was randomly selected for each sampling date.

#### 3. Treatments

Targeted fertilizer and pesticides were applied at recommended rates over a four-day period between May 26-29, 1991. Treatments included the following:

##### a. Fertilizer

1. Nitrogen (urea) at 49 kg N/ha (1.0 lb/M).

##### b. Herbicides

1. 2,4-D, mecoprop and dicamba (Trimec Classic<sup>R</sup> EC, 3.32 lb ai/gal) at 1.66 lb ai/acre.
2. Pendimethalin (Lesco<sup>R</sup> 60 DG) at 1.98 lb ai/acre.

##### c. Insecticides

1. Isazophos (Triumph<sup>R</sup> 4E, 4 lb ai/gal) at 2 lb ai/acre.
2. Chlorpyrifos (Dursban<sup>R</sup> 4E, 4 lb ai/gal) at 1 lb ai/acre.

##### d. Fungicide

1. Metalaxyl (Subdue<sup>R</sup> 2EC, 2 lb ai/gal) at 1 lb ai/acre.

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#### 4. Soil Core Sampling

##### a. Sampling Schedule

Soil cores were excavated and removed (Plates 2-6) one week prior to pesticide and fertilizer application and then at 1, 14, 30, 60 and 120 days after application. Four replicate cores were removed at each sampling date.

##### b. Method of Removal

Schedule 80 PVC (8 inch ID polyvinyl chloride), cut to 24-inch lengths, was used to shape and contain the soil cores. One end of the PVC pipe was beveled on the outside to facilitate cutting of the soil. A ring 8 inches in diameter was placed on the turf to mark the perimeter of the top of the column. Soil outside this perimeter was carefully removed to a depth of 24 inches. The PVC pipe was sprayed on the inside with vegetable oil (PAM<sup>R</sup>) to maximize pipe-soil interface shear and carefully pushed over the column of standing soil, cutting away excess soil. The column was cut from the base with a wire and taped at the bottom to prevent soil loss and drying.

#### 5. Analytical Methodology

##### a. Soil Core Preparation

The soils included the Nebraska Sharpsburg (previously described) and an Iowa Nicollet (fine-loamy, mixed, mesic Aquic Hapludoll). Cores collected at the respective dates were received at the laboratory intact. The cores were subsectioned into verdure, thatch, and soil samples at depths of 0-1, 1-2, 2-4, 4-8, 8-12, 12-16 and 16-20 inches. The verdure was clipped from the top and a six-inch diameter sub-core was cut from the center of each core for residue analysis. Soil was sieved with a no. 5 U.S.A. standard testing sieve. All soil and vegetative samples were stored at -20C.

##### b. Pesticide Residue Analysis

Analytical effort to date has focused on determination of residues of pendimethalin, chlorpyrifos, isazophos and metalaxyl, for which a procedure for simultaneous extraction and quantification has been developed. Procedures for dicamba, 2,4-D and mecoprop analysis have yet to be refined to fit the requirements of the project and specific soil and plant media. A brief description of the analytical procedure for measurement of residues of the former group of pesticides in soil follows.

Fifty-g soil samples were placed in 250-ml polypropylene centrifuge bottles and 100 ml of acetone was added. Bottles were shaken for 45 min at 280 excursions  $\text{min}^{-1}$  and filtered under vacuum through Whatman no.1 filter paper into 250-ml round bottom flasks. Two 25-ml aliquots of acetone were used to wash the centrifuge bottles. One-half ml of 1-octanol was added to the flask. Acetone and water were removed from the extract by rotary evaporation under vacuum in a water bath. Rotary evaporation was continued to near dryness. Three ml toluene were added to each flask and the solution was sonicated to redissolve the residue. An 0.8 ml aliquot of the final extract was transferred to a gas chromatograph autosampler vial and capped in preparation for quantitative analysis.

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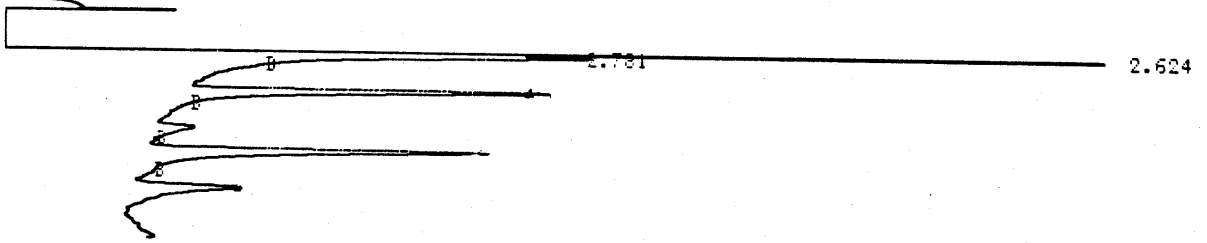
A Perkin-Elmer Sigma 2000 gas chromatograph equipped with a thermionic nitrogen-phosphorus detector was used for quantitative analysis. A 0.53-mm ID wide-bore capillary column containing 1 micron thick bonded methyl 5% phenyl silicone was used for residue separation. Injection port and detector temperatures were 265 C and 300 C, respectively. Oven temperature was isothermal at 205 C for 10 min and was increased to 215 C for 0.5 min between injections. Residues were quantified electronically by comparison with 200 ng/ml (ppb) external standards of isazophos, metalaxyl, chlorpyrifos and pendimethalin. Respective retention times were 3.8, 5.1, 6.1 and 7.5 min (Fig 1). Recovery from the Sharpsburg soil was greater than 94% for the four pesticides. Limits of quantitative detection in soil samples were estimated at 1, 5, 1 and 3 ng/g (ppb) for isazophos, metalaxyl, chlorpyrifos and pendimethalin, respectively.

Analysis of cores excavated and removed prior to pesticide application indicated no detectable residues of isazophos. Compounds corresponding to the other pesticides were detected in a few pretreatment samples, but concentrations did not exceed 4, 14 and 18 ng/g (ppb) for chlorpyrifos, pendimethalin and metalaxyl, respectively. No pattern was apparent in the detections, which are not considered significant at this time. Analysis of soil cores collected following pesticide application in 1991 is continuing.

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FILE 63 RUN 4 STARTED 14:58.4 91/10/29 USGA  
 XS METHOD 1 USGA LAST EDITED 04:02.3 80/01/08  
 SMP AMT 1.0

W\_4 A\_4 C\_4 0\_10



FILE 63 RUN 4 STARTED 14:58.4 91/10/29 USGA  
 XS METHOD 1 USGA LAST EDITED 04:02.3 80/01/08  
 SMP AMT 1.0

RT	HEIGHT	BC	RT/10	RF	NG/G SOIL	NAME
			0.389	4.486221E+00		ISAZOPHOS
			0.503	1.649990E+02		METALAXYL
6.16	1.3685		0.617	6.709533E+00	27.9493	CHLORPYRIFOS
			0.743	1.055820E+02		PENDIMETHALIN

1 MATCHED COMPONENT 4.53% OF TOTAL HEIGHT  
 3 UNKNOWN PEAKS > UNRET PK 95.47% OF TOTAL HEIGHT  
 4 PEAKS > HEIGHT REJECT 30.6596 TOTAL HEIGHT

Fig. 1. Chromatogram of analytical standards for isazophos, metalaxyl, chlorpyrifos and pendimethalin indicating relative retention times of 3.8, 5.1, 6.1 and 7.5 minutes, respectively.

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## B. Cement Encased, Undisturbed Soil Columns - Greenhouse Research

### 1. Excavation, Encasement and Removal of Soil Columns from the Field

Soil columns were obtained by removing the soil outside the perimeter of a 8 inch diameter cylinder to a depth of 24 inches (Plates 7-8). A plywood ring (0.5 inches thick, 14 inches OD and 8.5 inches ID) was placed around the soil column at the bottom of the excavated hole. The plywood ring was used to ensure that a smooth surface would be formed on the bottom of the poured cement which subsequently would facilitate attachment of the porous plate assembly to the soil column. A 12 inch diameter sheet metal heating duct was placed around the cylinder of soil and the space between the soil and the duct was filled with masonry cement (Plate 9). The duct was modified by adding four eyebolts at 90 degree intervals, 8 inches from the bottom. The eyebolts were later used for securing the porous plate assembly to the soil column.

Currently, 30 cores have been excavated and removed from the field for greenhouse research (Plates 10-12).

### 2. Porous Plate Assembly for Simulating Field Conditions

Soil columns encased by concrete lined heating ducts have been useful in evaluating nitrogen movement under greenhouse conditions. However, there is a limitation in using the encased soil columns to simulate field conditions. As soil water moves downward through the column, water accumulates at the bottom, creating a "perched water table" which does not occur in the field. The perched water table occurs because the tension by which the soil holds the water must be reduced to near atmospheric pressure before soil water can drain from the core to a collection vessel. A reduction in soil water tension is needed when the soil becomes saturated near the soil-air interface.

The perched water table can be alleviated by attaching a porous, ceramic plate to the bottom of the soil column (Plates 13-15) and applying a vacuum (tension). The ceramic plate is fastened inside a heating duct, 12 inches in diameter and 3.5 inches in length, and attached to the bottom of the soil column. Soil water tension comparable to field capacity (the water content after 24 hours of drainage) can be simulated by adjusting the vacuum (water tension) at the bottom of the ceramic plate. The appropriate vacuum can be determined from water release (soil moisture vs water tension) curves developed from undisturbed soil cores in the laboratory and soil moisture data from field plots.

### 3. Greenhouse Simulation of Soil Moisture Conditions

As water is removed from a field soil (by internal drainage or evapotranspiration) the tension by which the remaining water is held in the soil increases. The water tension/water content relationship (referred to as the "water release characteristic") is unique for a given soil. The water release characteristic is best illustrated by a curve of the soil water content versus the soil water tension. Based on the "water release curve", the water tension corresponding to the water content of the field soil at field capacity can be determined. If the appropriate tension can be applied to the bottom of the greenhouse soil columns, the field capacity water content should be closely simulated in the greenhouse.

Undisturbed soil cores, taken from the surface soil, were placed in a pressure plate apparatus (Tempe Cell) and increasing pressure steps (tension) was applied. The effluent from each pressure step was collected and the percent water content (volume basis) held at each tension was calculated. The soil moisture content at each tension is given in Table 1 for four depths and the average of the first two depths.



Table 1. Percent soil moisture (volume basis) at various tensions for undisturbed cores sampled at four depths.

TENSION	DEPTH (CM)				AVERAGE (2.5-25.4)
	2.5-10.0	17.5-25.4	33.0-43.2	48.3-55.9	
0	50.00	54.70	48.30	49.70	52.35
10	43.00	39.90	39.60	38.20	41.45
50	41.30	37.50	36.60	35.20	39.40
100	40.80	36.70	35.70	34.40	38.75
250	39.80	36.10	35.00	33.60	37.95
500	39.10	35.20	34.20	33.00	37.15
750	38.50	34.70	33.70	32.80	36.60
1000	38.00	34.30	33.30	32.70	36.20

Table 2. Percent soil moisture of field turf grass plots.

DATE	WATER (%) WT. BASIS	BULK DENSITY	WATER (%) VOL. BASIS
8/19	25.95	1.265	32.83
8/21	23.75	1.265	30.04
*8/22	27.64	1.265	34.97
8/23	30.13	1.265	38.11
*8/26	26.69	1.265	33.76
8/27	24.21	1.265	30.63
*8/29	26.72	1.265	33.80
*9/01			
9/03	29.31	1.265	37.08
*9/04	28.79	1.265	36.42
9/06	29.38	1.265	37.17
*9/07 <sup>1</sup>			
9/10	21.38	1.265	27.04
*9/11 <sup>2</sup>			
*9/14			
9/18	26.70	1.265	33.78

\* Irrigated 2.54 cm

<sup>1</sup> Rainfall of 1.27 cm, <sup>2</sup> Rainfall of 4.80 cm

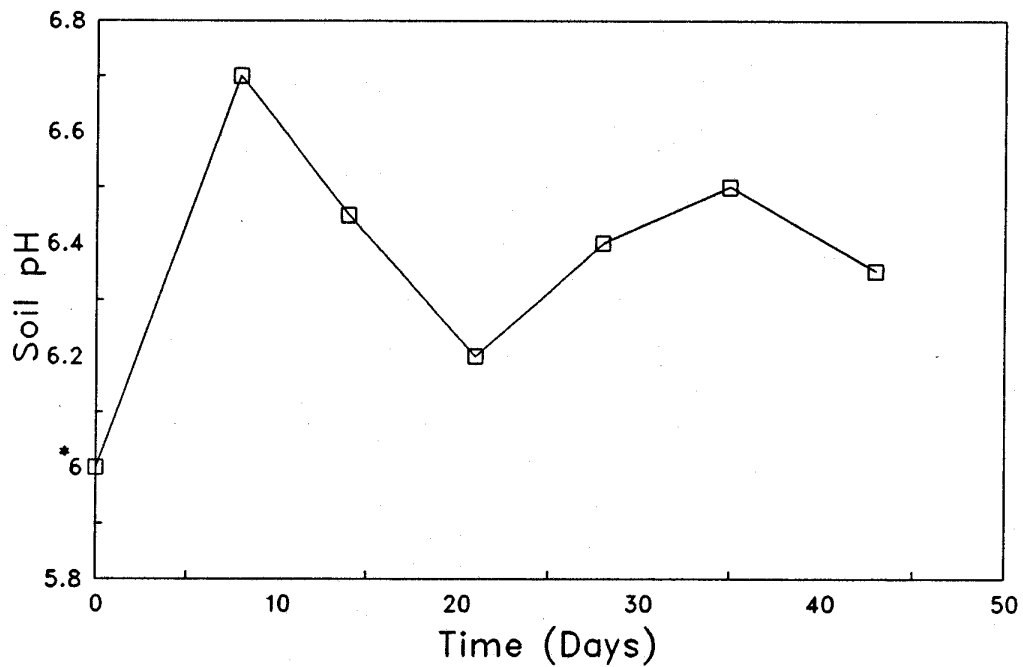
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Soil samples were taken from the field over a four-week period and their moisture contents determined. Moisture contents (Table 2) represent several wetting and drying cycles.

Based on irrigation, rainfall and evapotranspiration data, it is estimated from Table 2 that the field soil was at or near field capacity on August 23 and September 3, 4 and 6. The field capacity is thought to be between 36 and 38 percent moisture by volume. From Table 1 it appears that the water tension of the field soil at field capacity would be near 500 cm of water. Therefore, by saturating the greenhouse soil columns and letting them drain for 24 hours while applying 500 cm of water tension, the soil water content of the columns will be very close to the true field capacity. Thus the moisture regimes for the beginning of the greenhouse experiment should be very close to that in the field. The movement of any agrichemicals should simulate that under field conditions provided the field evapotranspiration rates are also simulated in the greenhouse.

#### 4. Effect of Cement Encasement on Soil pH

Changes in soil pH due to the process of encasing soil columns in cement was recognized as a potential problem. Soil pH below 6.0 or above 7.0 could influence the results of experiments by affecting processes of pesticide dissipation in the soil. A cement encased soil column, 12 inches in diameter and 12 inches in length, was excavated, removed from the field, and transported to the greenhouse. Soil pH was determined at the time of excavation and at one week intervals for six weeks. An increase in soil pH occurred during the first week (Fig. 2) but stabilized at 6.2-6.5 at 2-6 weeks. The fluctuation in soil pH was not expected to significantly affect pesticide degradation.



\*pH 6.0 was the initial sample from the field.

Fig. 2. Effect of cement encasement on soil core pH.

### 5. Greenhouse Testing

Greenhouse procedures for executing pesticide fate/movement studies on cement-encased soil columns are currently being evaluated. A high intensity lighting system, racks to hold the columns, and a vacuum system have been constructed. Methodologies for irrigation, determination of evapotranspiration, and soil saturation currently are under investigation.

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## II. RESEARCH PROGRESS - IOWA STATE UNIVERSITY

### A. Undisturbed Soil Cores- Field Monitoring

#### 1. Site

A 60 ft by 60 ft area at the Iowa State University Horticultural Research Station was used for this research. The area consisted of a blend of four Kentucky Bluegrass cultivars (Parade, Adelphi, Glade, and Rugby). The soil was a Nicollet, as previously described.

#### 2. Design, Treatments, Soil Core Sampling, and Analysis

Experimental design, treatments, methods of sampling soil cores, and analysis were similar to the University of Nebraska research.

### B. Cement Encased, Undisturbed Soil Columns - Greenhouse Research

#### 1. Introduction

Various chemicals and nutrients are widely used by the turfgrass industry to maintain a high quality stand of turf. Runoff and leaching of fertilizers and pesticides from golf courses, recreational, agricultural, municipal, and industrial operations are perceived to be an important environmental problem. In this study we are trying to answer the following question: How much of the nitrogen, phosphorus, Trimec®, pendimethalin, isazophos, chlorpyrifos, metalaxyl and chlorothalonil applied to a turf area maintained as a golf course fairway moves past the root system to the groundwater?

#### 2. Methodology

For the first year of the project, the fate of nitrogen and phosphorus was studied. The soil used was excavated from the Horticulture Farm from an established stand of turf cut at fairway height. Undisturbed soil columns were brought into the greenhouse in November, 1990 and testing started in February, 1991.

The one week testing procedure started with application of nitrogen and phosphorus in a liquid form to the turf. The source of nitrogen was urea and the phosphorus source was calcium phosphate. To distinguish between nitrogen that was stored in the soil and nitrogen that was applied, the urea was labeled with N-15 which is only present in extremely low levels in nature. To determine the effects of irrigation rates, two watering schemes were used. One was an application of 1 inch immediately after nutrients were applied and the other included four separate 0.25-inch applications distributed throughout the one week test period. Volatilized nitrogen was measured (Fig. 3). Soil water that leached through the column was collected and tested for nutrients at the end of the test period. Soil and vegetative materials were dried and sent to the analytical lab for testing.

#### 3. Results

Analysis of N-15 samples was completed in early October 1991 and results are being compiled. Figures 4-7 present preliminary data on the distribution of nitrogen in the 14 soil columns. Denitrification occurred during the seven day test period in various amounts depending on the condition of each soil layer.

There was a greater loss of volatilized nitrogen from columns that received four 0.25 inch applications than from columns receiving a single 1 inch application (Fig. 4 and Fig. 5).

Applied nitrogen moved to greater depths from a single 1 inch application, with 6.6% moving below 30 cm versus 1.0% for the four 0.25 inch applications. Leachate contained 0.7% of applied nitrogen for the 1 inch applications and 0.1% for the four 0.25 inch applications.

More nitrate was found at greater depths in columns receiving a single 1 inch application. Leachate sample analysis was incomplete at date of this report (Fig. 5 and Fig. 6).

#### 4. Summary

The methods used for determining the fate of nitrogen were found to be successful. The second set of columns was collected in October 1991. Pesticides will be included in the work of 1991-1992.

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### Schematic of Volatilizing Nitrogen Collection

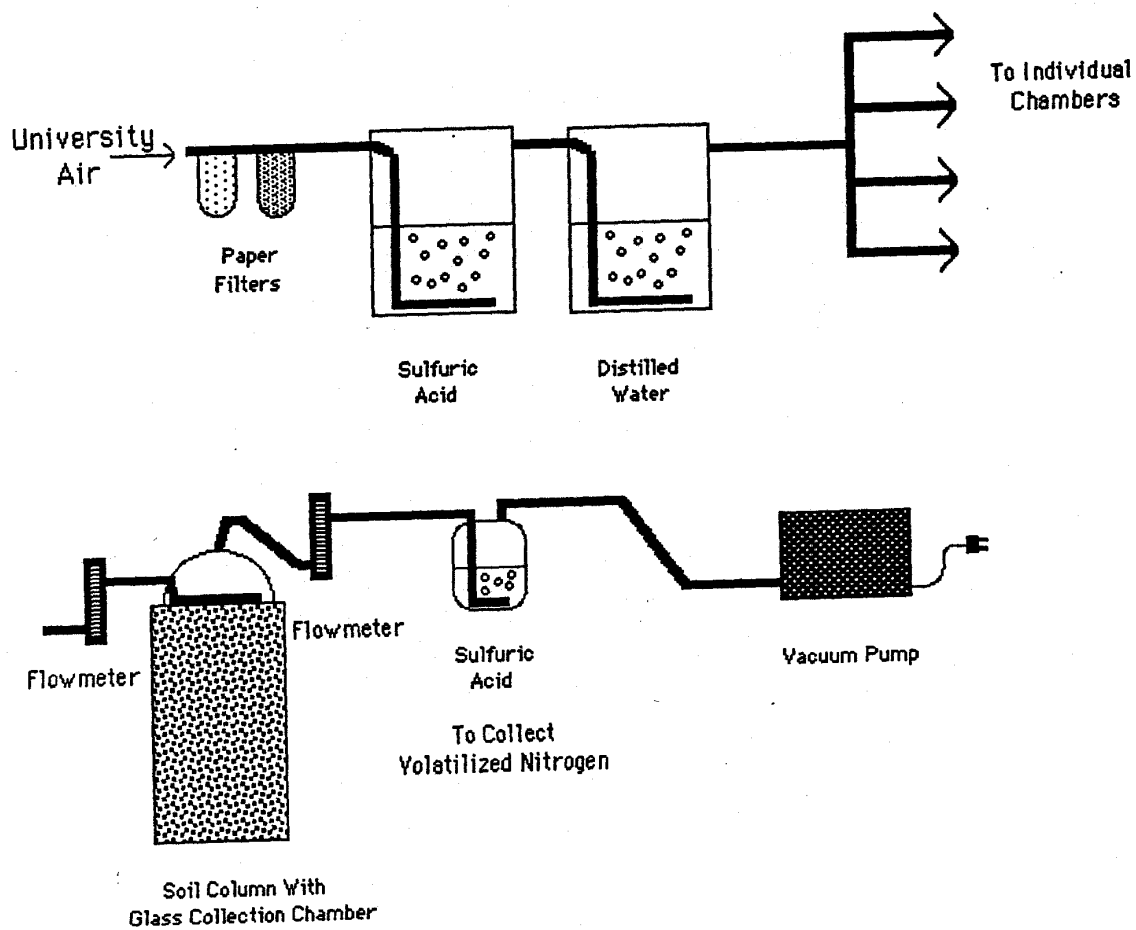


Fig. 3. Schematic diagram of the system used to trap volatilized nitrogen.

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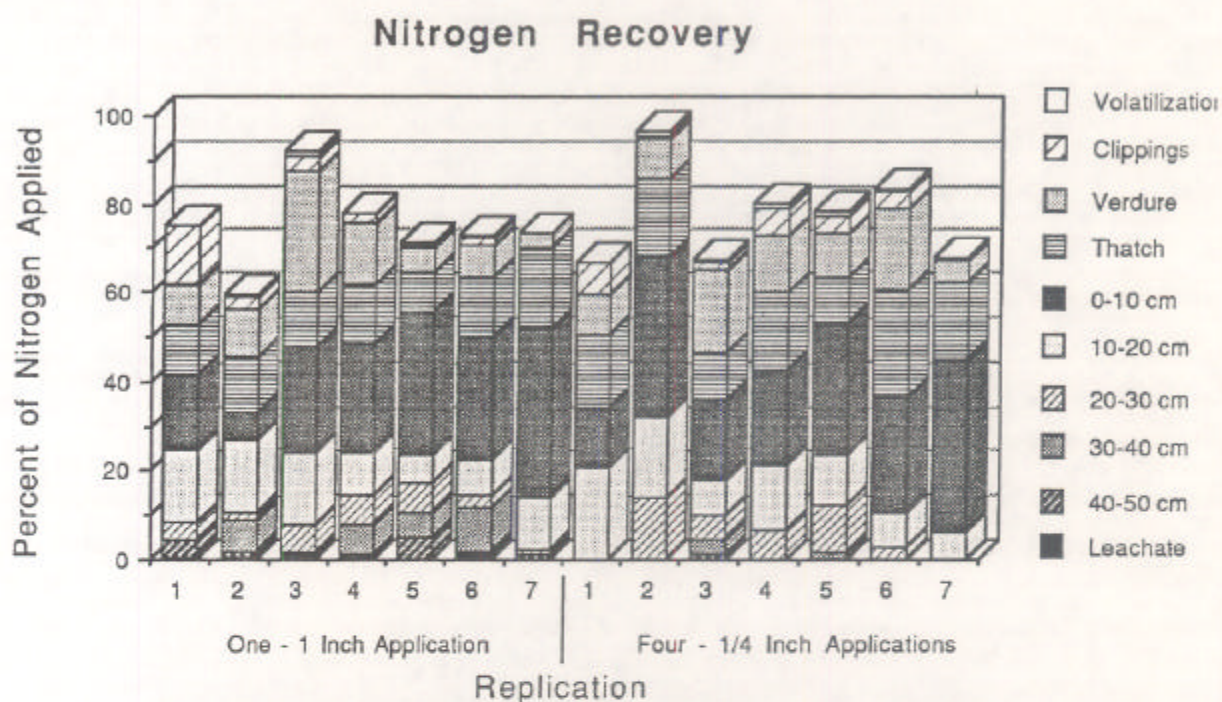


Fig. 4. Nitrogen recoveries from turf/soil column subfractions following a single 1-inch application or four 0.25-inch applications of water (individual column measurements).

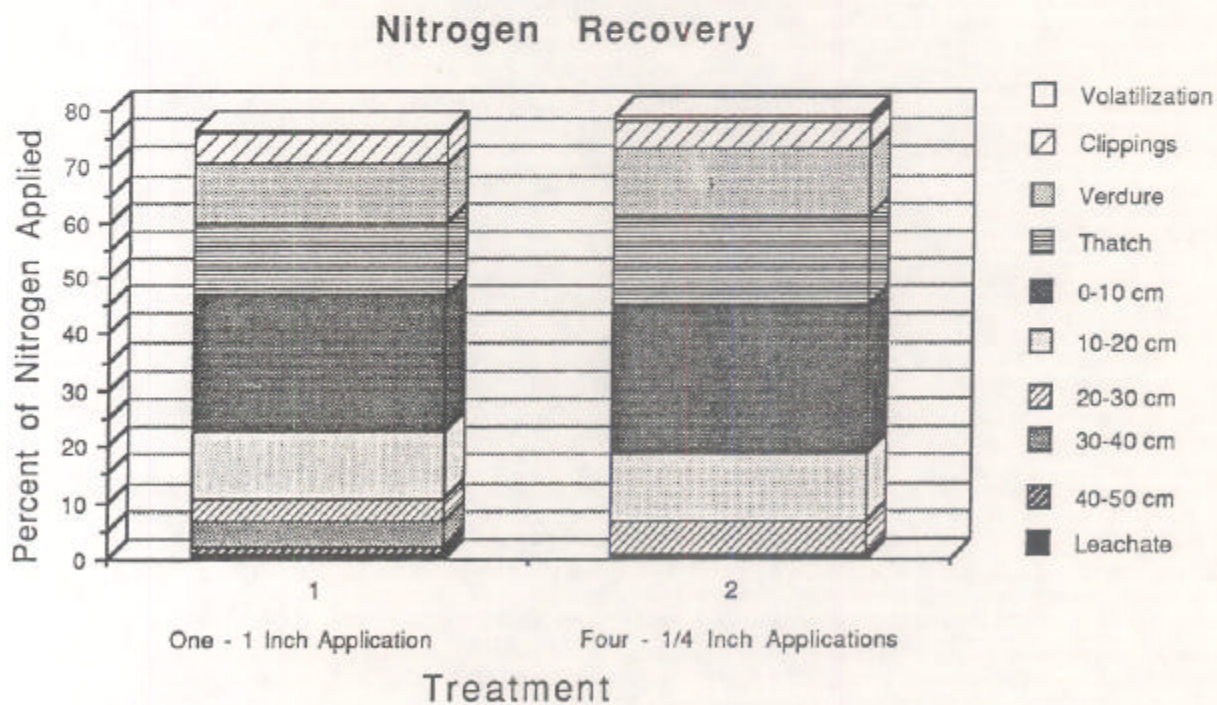


Fig. 5. Mean nitrogen recovery from turf/soil column subfractions following a single 1-inch application or four 0.25-inch applications of water.



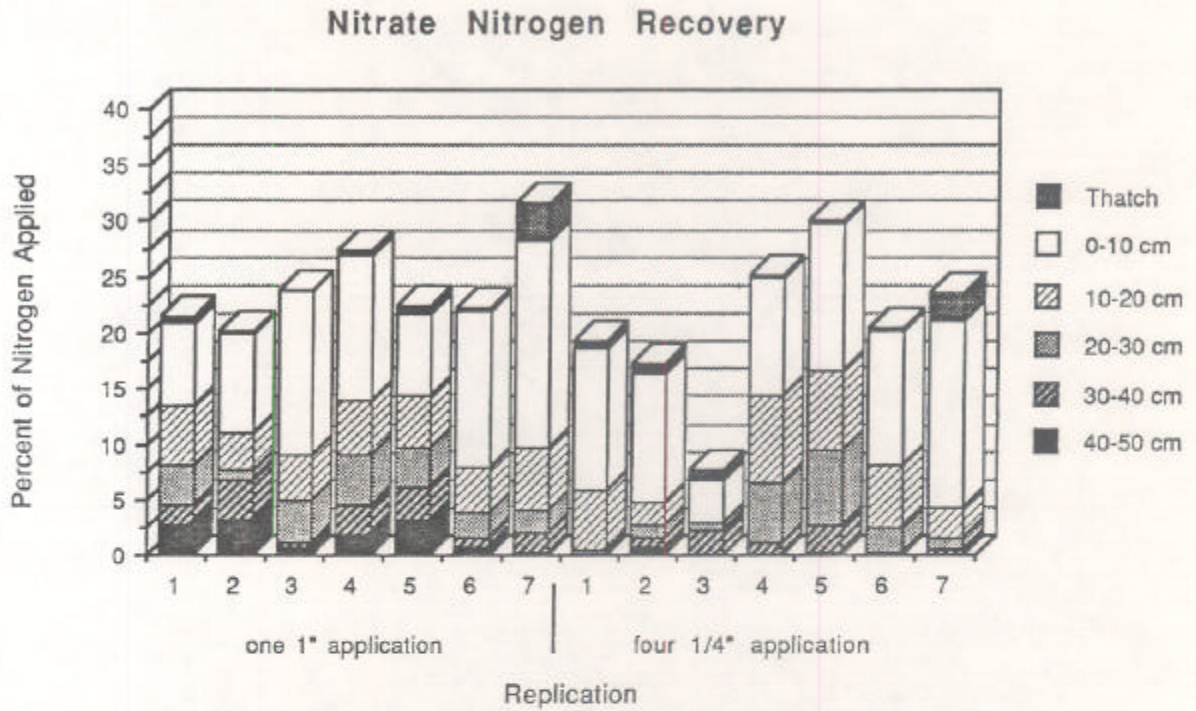


Fig. 6. Nitrate nitrogen recoveries from turf/soil column subfractions following a single 1-inch application and four 0.25-inch applications of water (individual column measurements).

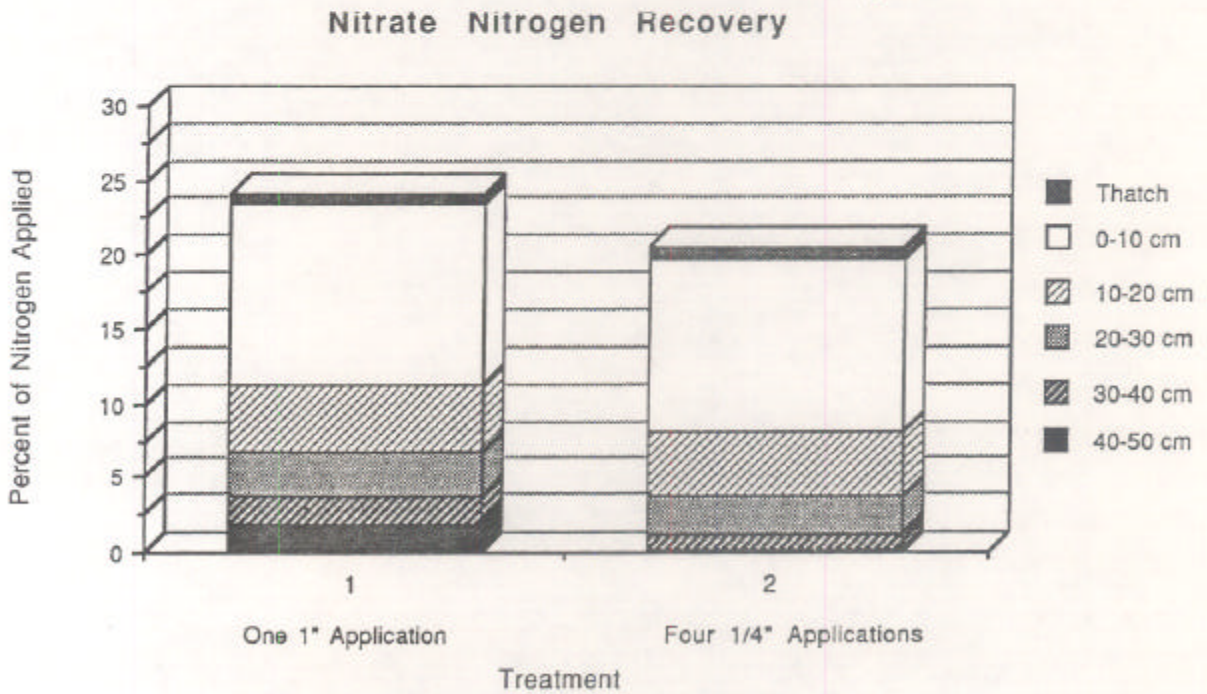


Fig. 7. Mean nitrate nitrogen recovery from turf/soil column subfractions following a single 1-inch application or four 0.25-inch applications of water.





Plate 1. Field monitoring site at the University of Nebraska turfgrass facility.



Plate 2. Excavation of turf/soil cores.

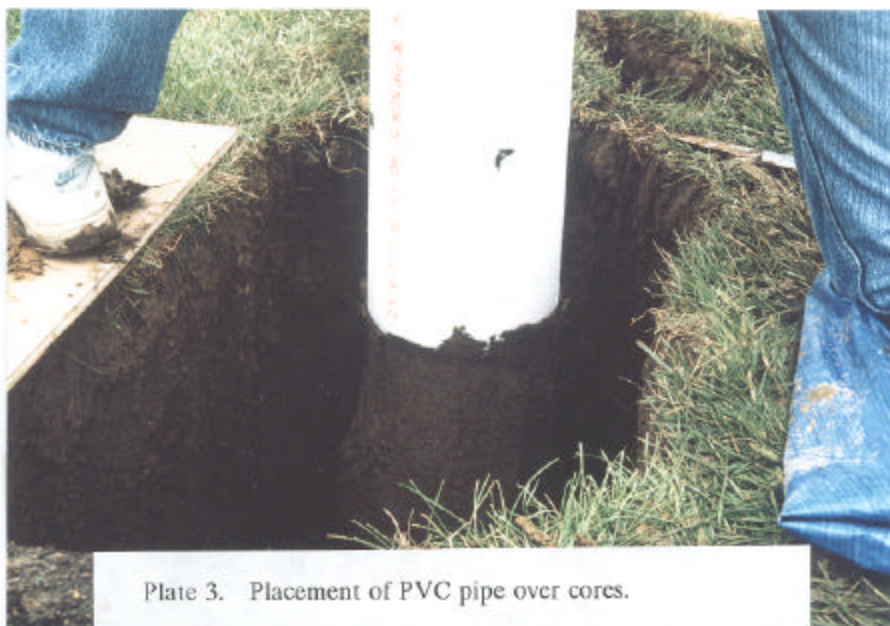


Plate 3. Placement of PVC pipe over cores.



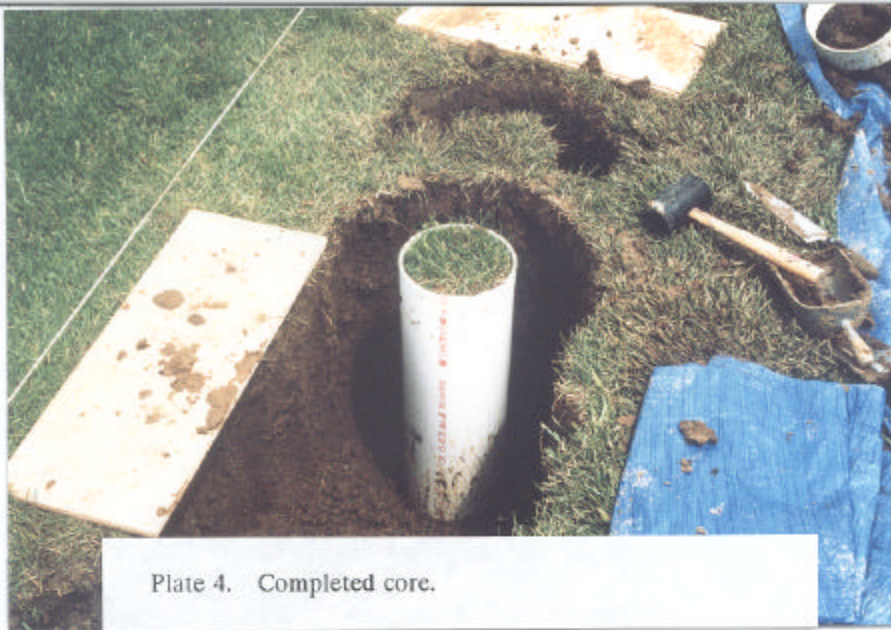


Plate 4. Completed core.



Plate 5. Core removal.



Plate 6. Core and site after removal.





