ANNUAL REPORT - NOVEMBER 1993

MOBILITY AND PERSISTENCE OF TURFGRASS PESTICIDES IN A USGA GREEN

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EXECUTIVE SUMMARY

In previous years, the groundwork was laid for studies on the mobility and persistence of organo-phosphate (OP) pesticides in a USGA green. Lysimeters were installed in a 'Tifdwarf' bermudagrass USGA green at the Ft. Lauderdale Research and Education Center (FLREC), and analytical methods were developed for determining OP pesticides in soil, thatch, plant tissue, and water in the Pesticide Lab at the Everglades-REC in Belle Glade.

During the current reporting year, studies were completed on OP-pesticide losses in percolate, retention in soil and thatch, and removal in clippings. These studies encompassed two applications of fenamiphos (Nemacur), fonofos (Dyfonate), chlorpyrifos (Dursban), isazophos (Triumph), and isofenphos (Oftanol), and one application of ethroprop (Mocap). Generally, less than 0.2% of the applied pesticide was recovered in percolate water, and less than 1% was recovered in clippings. Leaching was considerably greater for the sulfoxide-sulfone metabolite of fenamiphos, and recovery of chlorpyrifos in clippings exceed 7% for a granular application. Most of the applied OP pesticides, however, appeared to be retained in the thatch layer, where they were microbially degraded over time.

Less than 1% of the diazinon, chlorpyrifos, and isazophos applied to a bermudagrass turf surface was dislodged onto cotton cloth immediately after pesticide application. Following 5 mm irrigation, dislodgeability was approximately 15% of the pre-irrigation measurement. Twenty-four hours after application, approximately 3% as much pesticide was dislodged as was measured immediately following application.

Studies were initiated this year on the mobility and persistence of phenoxy-acid pesticides. Leaching of 2,4-D and dicamba totaled 1.6 and 9.7%, respectively, of the applied amounts during a two-month period following treatment.

A pesticide risk assessment analysis was made in cooperation with the University of Florida Center for Environmental and Human Toxicology, based on dislodgeability data collected at the FLREC. The analysis, which was preliminary in nature and was mainly designed to demonstrate risk assessment methodology, nevertheless suggested exposure to diazinon, chlorpyrifos, and isazophos, even in a worst-case-scenario, would be below acceptable limits.

A free-draining version of the lysimeters used at the FLREC was installed in three USGA-type greens on a golf course, in the anticipation that pesticide mobility studies can be continued under true golf course conditions in addition to the FLREC site.

Over a dozen publications and/or presentations based on the USGA-supported research were released in 1993.

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SUMMARY TABLES

SUMMARY TABLE 1*

Loss of pesticide in percolate waters obtained in lysimeters installed in a sand-soil USGA-green with 'Tifdwarf' bermudagrass (Cynodon dactylon X C. transvaalensis) turf, expressed as active ingredient (AI) on a unit area basis and as a percent of that applied.

Application date	Sampling duration	Pcpn.	Percolation	Pesticide	Formulation	Rate (AI)	Pesticide loss	
D/M/Y	days	- - mm - -				$g\ m^{-2}$	$ug\ m^{-2}$	%
13/11/91	75	149	340	Fenamiphos	10G	1.13	701	0.06
				Fen. metabolite		-	199038	17.69**
				Fonofos	5G	0.44	4	< 0.01
27/1/92	85	191	269	Fenamiphos	10G	1.13	419	0.04
				Fen. metabolite		-	12326	1.10**
				Fonofos	5G	0.44	103	0.02
				Chlorpyrifos	1G	0.12	176	0.15
21/4/92	141	841	1370	Chlorpyrifos	2E	0.23	193	0.08
				Isazophos	4E	0.23	204	0.09
				Isofenphos	2E	0.23	53	0.02
15/9/92	112	376	777	Isazophos	4E	0.23	41	0.02
				Isofenphos	2E	0.23	33	0.01
				Ethroprop	10G	2.25	1138	0.05
3/8/93 and 10/8/93	65	451	696	2,4-D	4	0.06	1808	1.55
				Dicamba	4	0.006	1173	9.75

* This Summary Table provides some information presented in previous reports that might not be discussed in the 1993 Annual Report.

** Expressed relative to the parent (fenamiphos) applied.

SUMMARY TABLE 2*

Pesticide in 'Tifdwarf' bermudagrass (Cynodon dactylon X C. transvaalensis) clippings from a USGA green following pesticide application, expressed as a percent of that applied.

Application date	Sampling duration	Pesticide	Formulation	Rate (AI)	Pesticide recovery
D/M/Y	days			$g\ m^{-2}$	%
27/1/92	85	Fenamiphos	10G	1.13	0.38
		Fen. metabolite		-	0.14**
		Fonofos	5G	0.44	1.17
		Chlorpyrifos	1G	0.12	7.87
21/4/92	66	Chlorpyrifos	2E	0.23	0.52
		Isazophos	4E	0.23	0.43
		Isofenphos	2E	0.23	0.79
15/9/92	113	Isazophos	4E	0.23	0.38
		Isofenphos	2E	0.23	0.89
		Ethroprop	10G	2.25	0.44

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** Expressed relative to the parent (fenamiphos) applied

SUMMARY TABLE 3

Effect of time and irrigation on pesticide dislodged onto cotton cloth from bermudagrass turf, reported as the amount on a 10-cm square cloth, and as a percent of the amount dislodged immediately after application.

Treatment	Diazinon		Chlorpyrifos		Isazophos	
	ug	%	ug	%	ug	%
Immediately	13.78	100	1.50	100	15.80	100
After irrigation	1.94	14	0.24	16	1.97	12
End of the day	0.88	6	0.11	7	0.91	6
24 hours after application	0.46	3	0	0	0.08	1

INTRODUCTION

During the first year of the project, six lysimeters were installed and tested in a 'Tifdwarf' bermudagrass USGA-type green at the Ft. Lauderdale Research and Education Center (FLREC), and methods were developed and tested for performing organophosphate pesticide analyses on water, soil, and thatch in the Pesticide Lab at the Everglades Research and Education Center (EREC) in Belle Glade, FL. In the second reporting year, complete results were presented on the mobility and persistence of fenamiphos (Nemacure) and fonofos (Dyfonate). In the current reporting year, all data analysis was completed for two applications of chlorpyrifos (Dursban), isazophos (Triumph), isofenphos (Oftanol), and for a single application of ethroprop (Mocap).

CHLORPYRIFOS, ISAZOPHOS, ISOFENPHOS, AND ETHROPROP MOBILITY AND PERSISTENCE

MATERIALS AND METHODS

Chlorpyrifos (Dursban) was applied to the green as a 1G material at 0.117 g A.I. m^{-2} on 27 Jan. 1992, and again on 21 April 1992 as a 2E liquid at 0.229 g A.I. m^{-2}, along with isazophos (as Triumph 4E) at 0.229 g A.I. m^{-2} and isofenphos (Oftanol 2E) at 0.229 g A.I. m^{-2} (Table 1). The latter two materials, along with ethroprop (Mocap 10G) at 2.245 g A.I. m^{-2}, were applied on 15 Sept. 1992. Soil, water, and clipping samples were taken and processed as has been described in the previous reports.

Table 1. Pesticides used on the USGA green in persistence and mobility studies.

TRADE NAME	COMMON NAME	DATES APPLIED	FORM	RATE g AI m^{-2}
Dursban	chlorpyrifos	27 Jan. 1992	1G	0.117
		21 April 1992	2E	0.229
Triumph	isazophos	21 April 1992	4E	0.229
		15 Sept. 1992	4E	0.229
Oftanol	isofenphos	21 April 1992	2E	0.229
		15 Sept. 1992	2E	0.229
Mocap	ethroprop	15 Sept. 1992	10G	2.245

RESULTS AND DISCUSSION

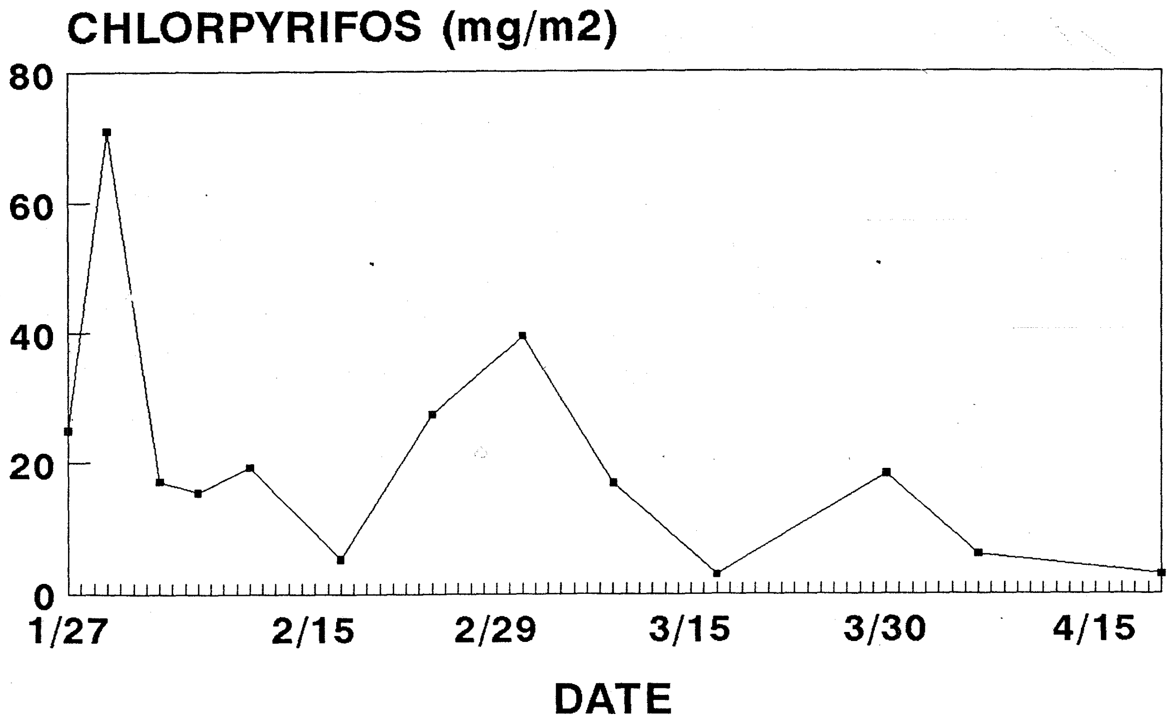
PESTICIDE IN THATCH AND SOIL. Chlorpyrifos was detected in the thatch/soil profile for several months after the 27 January application, although there was a general trend for decreasing concentration with time (Fig. 1). Most of the chlorpyrifos was located in the thatch throughout this period (Fig. 2). Concentrations of chlorpyrifos, isazophos, and isofenphos in the thatch/soil profile decreased rapidly following application on 21 April (Fig. 3), although in the latter part of this study period somewhat more chlorpyrifos was detected than was observed for the other two pesticides. Most of each of these three pesticides was located in the thatch, rather than in the soil (Fig. 4). Following application on 15 Sept., ethroprop concentration in the thatch/soil profile also was observed to decline with time (Fig. 5), and to largely reside in the thatch layer (Fig. 6). Several weeks after the 15 Sept. application, the portion of these pesticides in the thatch appeared to decreased somewhat. This may have been due to actual migration into the soil layer, but the observation also may simply be an artifact of making percentage calculations on very low, and therefore somewhat imprecise, values of pesticide concentration.

PESTICIDE LEACHING. Chlorpyrifos leaching following application on 27 Jan. 1992, was small (Table 3), and was little more following the second application (21 April 1992), even though the application rate was doubled and percolation increased five-fold.

Table 3. Summary of hydrological data and Chlorpyrifos leaching for applications on 27 Jan and 21 April 1992.

Item	27 Jan - 20 April	21 April - 8 Sept
Hydrologic data (mm)		
Rainfall	191	841
Percolation	269	1370
Chlorpyrifos leaching		
ug M^{-2}	176	193
% of applied	0.15	0.08

TOTAL CHLORPYRIFOS IN THATCH AND SOIL



1992

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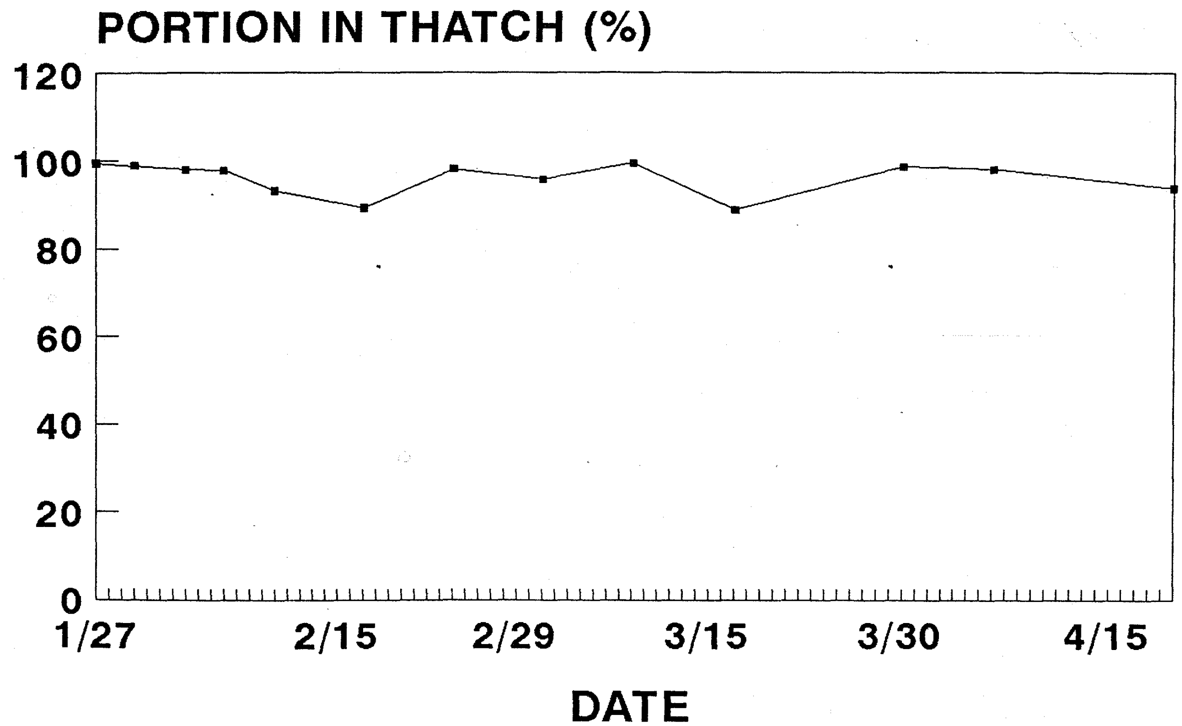
Figure 1. Total chlorpyrifos in the thatch/soil profile following application on 27 January, 1992.

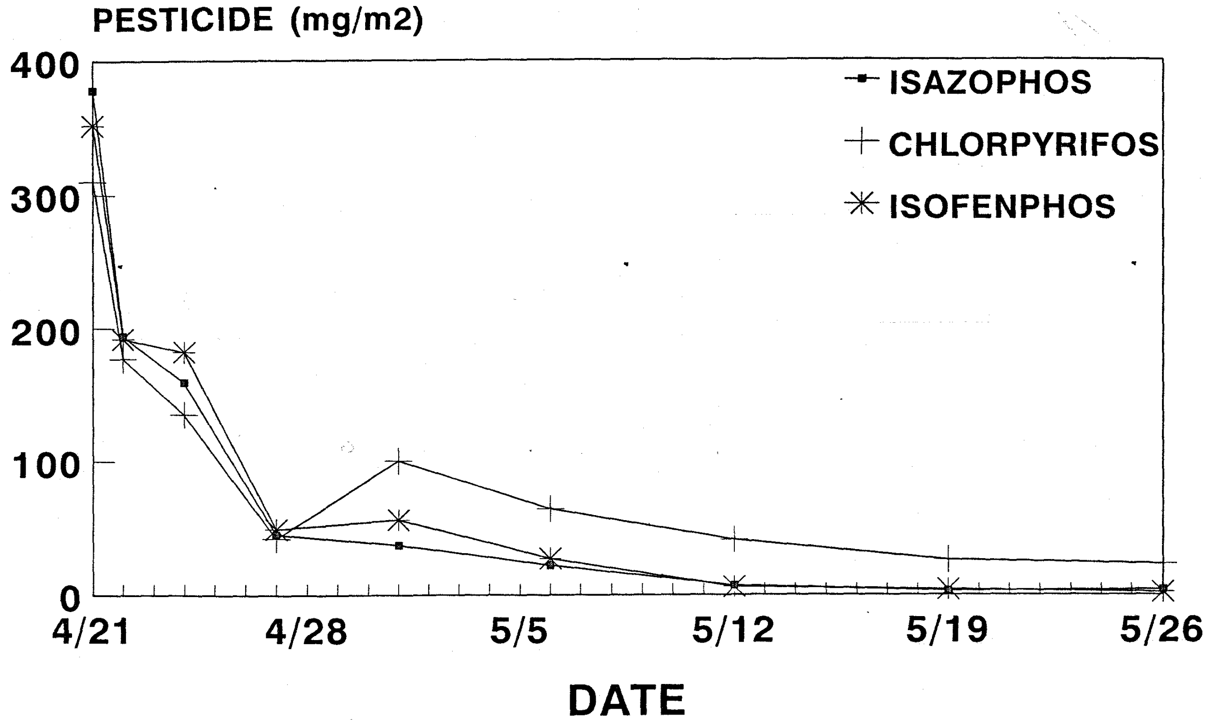
PORTION OF CHLORPYRIFOS IN THATCH



1992

Fig. 2. Chlorpyrifos in the thatch layer as a percent of the total amount in the thatch/soil profile, following application on 27 January, 1992.

TOTAL PESTICIDE IN THATCH AND SOIL



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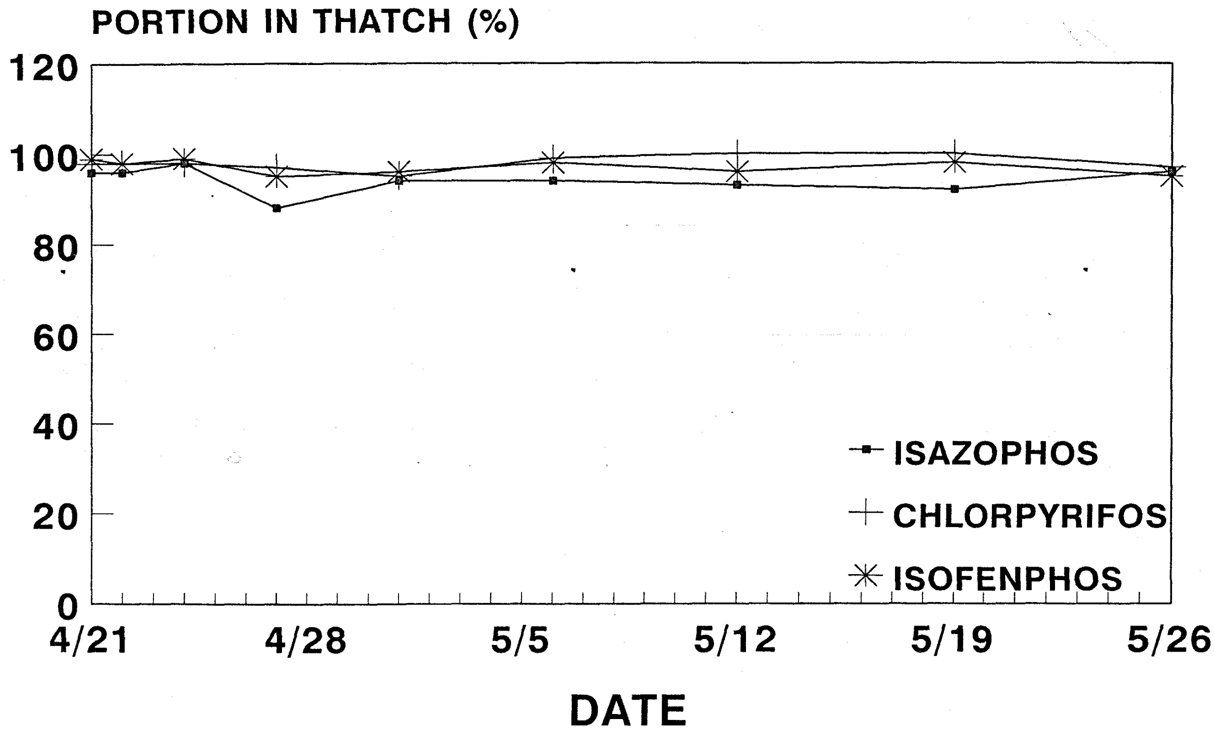
1992

Fig. 3. Total isazophos, chlorpyrifos, and isofenphos in the thatch/soil profile following application on 21 April, 1992.

PORTION OF PESTICIDE IN THATCH



1992

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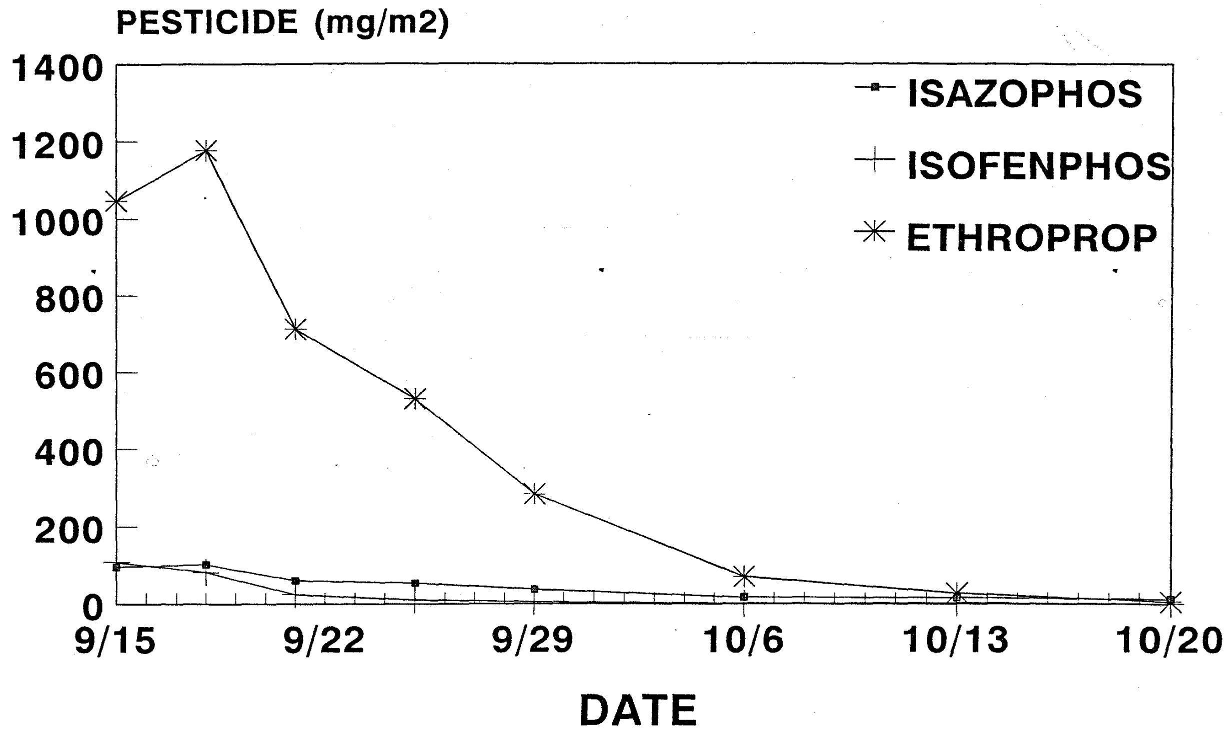
Fig. 4. Isazophos, chlorpyrifos, and isofenphos in the thatch layer as a percent of the total amount in the thatch/soil profile, following application on 21 April, 1992.

TOTAL PESTICIDE IN THATCH AND SOIL

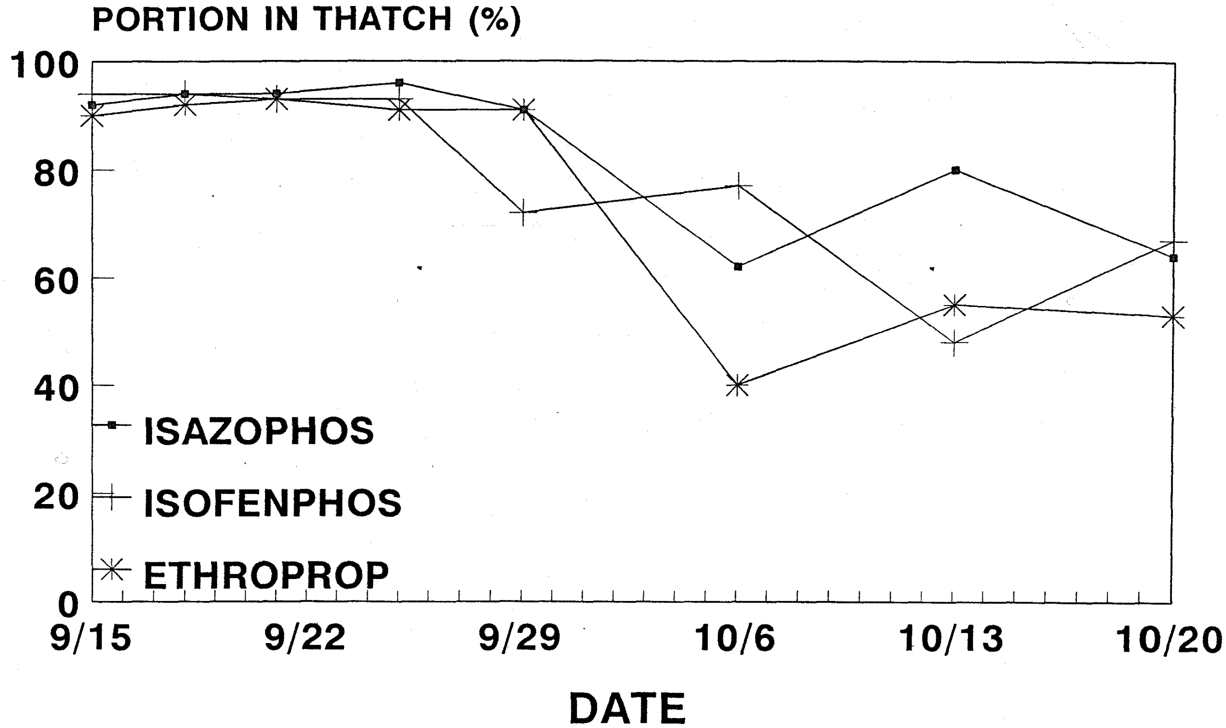


1992

00240

Fig. 5. Total isazophos, isofenphos, and ethroprop in the thatch/soil profile following application on 15 September, 1992.

PORTION OF PESTICIDE IN THATCH



00242

1992

Fig. 6. Isazophos, isofenphos, and ethroprop in the thatch layer as a percent of the total amount in the thatch/soil profile, following application on 15 September, 1992.

Leaching of isazophos and isofenphos following the 21 April and 17 Sept. 1992 application also was very small (Table 4). A larger amount of ethroprop leaching was observed. However, ethroprop was applied at nearly 10 times the rate used for the other two pesticides (Table 1). Thus, when calculated as a percent of the application rate, ethroprop leaching also was quite small (Table 4).

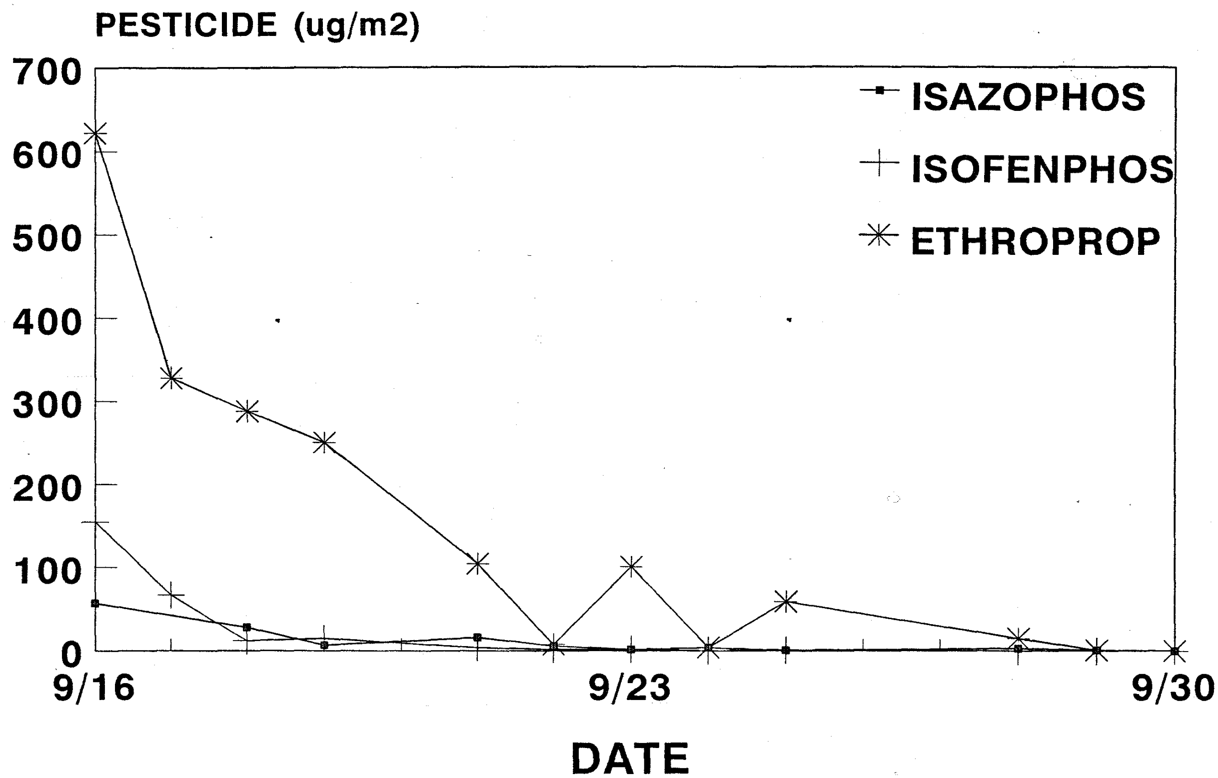
The leaching data are consistent with the data for thatch and soil. Since most pesticide was found in the thatch, and little appeared to move into the underlying soil, it is reasonable that only small quantities were detected in the percolate waters.

Table 4. Summary of hydrological data and pesticide leaching for applications on 21 April and 1992.

Item	21 April - 8 Sept	15 Sept - 5 Jan(1993)
Hydrologic data (mm)		
Rainfall	841	376
Percolation	1370	777
Isazophos leaching		
ug M^{-2}	204	41
% of applied	0.09	0.02
Isofenphos leaching		
ug M^{-2}	53	33
% of applied	0.02	0.01
Ethroprop leaching		
ug M^{-2}	-	1138
% of applied	-	0.05

PESTICIDE REMOVAL IN CLIPPINGS. Figures relating removal of chlorpyrifos in clippings following the 29 Jan. application, and of chlorpyrifos, isazophos, and isofenphos removal following the 22 April application were presented in the Nov. 1992 Annual Report, and will not be repeated here. These data are consistent with the later findings presented herein (Fig. 7). As would be expected, the quantity of pesticide removed with the clippings was greatest for the first clipping after application, and

PESTICIDE IN CLIPPINGS



00245

1992

Fig. 7. Isazophos, isofenphos, and ethroprop recovered in clippings following application on 15 September, 1992.

decreased rapidly thereafter. In one case, an appreciable amount of pesticide was removed in the clippings over the sampling period following pesticide application (Table 5). The higher value for the first application of chlorpyrifos may have been the result of granules having been removed with the clippings. Chlorpyrifos was applied as a liquid on the second application (21 April). Clippings removed the day after application of chlorpyrifos as granules contained 1.82 mg kg^{-1} of chlorpyrifos, expressed on a dry weight basis, whereas following application of chlorpyrifos as a liquid the next-day clippings contained 0.12 mg kg^{-1} of chlorpyrifos. Less than 1% of the applied amount of the other pesticides was recovered in clippings during any of the study periods (Table 5).

Table 5. Accumulative quantity of pesticide removed with clippings during two application cycles.

Study period	Pesticide	Application rate	Amount removed
		g A.I. m^{-2}	% of applied
27 Jan. - 21 Apr.	Chlorpyrifos	0.117	7.87
21 Apr. - 5 June	Chlorpyrifos	0.229	0.52
	Isazophos	0.229	0.43
	Isofenphos	0.229	0.79
15 Sept. - 4 Jan.	Isazophos	0.229	0.38
	Isofenphos	0.229	0.89
	Ethroprop	2.245	0.44

CONCLUSIONS DRAWN FROM STUDIES ON ORGANOPHOSPHATE-PESTICIDE MOBILITY AND PERSISTENCE. For each of the organophosphate pesticides studied, generally less than 0.2% of the applied pesticide was recovered in the percolate water. Less than 1.0% was recovered in the clippings, except for granular application of chlorpyrifos. Little if any pesticide was observed in the soil underlying the thatch. By far, most of the applied pesticide remained in the thatch layer and disappeared with time, presumably by microbial degradation. The only exception was the metabolites of fenamiphos (Nemacure), discussed in an earlier report (November, 1992).

PESTICIDE DISLODGEABILITY FROM BERMUDAGRASS TURF

METHODS AND MATERIALS

The effect of time and irrigation on pesticide dislodgeability was investigated in a study at the FLREC conducted on cv. Tifgreen bermudagrass adjacent to, but not on, the USGA green. Diazinon, chlorpyrifos, and isazophos were sprayed at the rate of 0.458, 0.057, and 0.229 g A.I. M^{-2} at approximately 11 A.M. on 24 November, 1992. Duplicate 10-cm squares of dry cotton cloth were pressed on the treated surface with a pressure of 10 kPa for 10 sec. immediately after pesticide application, immediately after approximately 0.5 cm irrigation, four hours after the irrigation (i.e., at the end of the day), and 24 hours after application. The cloths were placed in 500 ml (1 pint) glass jars which were capped, transported to the laboratory in Belle Glade, and placed in a freezer (-20 C) prior to analysis.

For each sample, the cloth and foil were removed from the glass container, sliced with scissors into pieces approximately 1 cm square, and returned to the container. Pesticides were extracted from the cloths with three portions of a methanol-sulfuric acid solution, and the combined extracts were themselves extracted three times with methylene chloride. The combined methylene chloride extract was roto-evaporated to 10 ml volume and analyzed for chlorpyrifos and isazophos by gas chromatography.

RESULTS AND DISCUSSION

Dislodgeability immediately following pesticide application amounted to only 0.30, 0.26, and 0.69% of the diazinon, chlorpyrifos, and isazophos applied to a turf area equal to that of the cloth. Following irrigation, approximately 15% of that amount was dislodged (Table 6). The amount dislodged at the end of the first day was less than half that dislodged immediately after irrigation, and the amount dislodged 24 hours after application was no more than half of that dislodged at the end of the first day.

Table 6. Effect of time and irrigation on pesticide dislodged onto cotton cloth from bermudagrass turf, reported as the amount on a 10-cm square cloth, and as a percent of the amount dislodged immediately after application.

Treatment	Diazinon		Chlorpyrifos		Isazophos	
	ug	%	ug	%	ug	%
Immediately	13.78	100	1.50	100	15.80	100
After irrigation	1.94	14	0.24	16	1.97	12
End of the day	0.88	6	0.11	7	0.91	6
24 hours after application	0.46	3	0	0	0.08	1

RISK ASSESSMENT STUDY

For more than a year, we made repeated attempts to interest Dr. Raymond D. Harbison, Director of the University of Florida Center for Environmental and Human Toxicology, in our pesticide studies, because we believed his Center could help us determine the significance of our data relative to human and environmental toxicology. Finally, on 1 April, 1993, he had a post-doctoral student, Dr. Chris J. Borgert, visit our study site at the FLREC as part of another visit he was making in south Florida. Dr. Borgert became interested in some data we had collected on pesticide transferred to golf balls, cotton cloth, and leather. Working in collaboration with us, he prepared a poster that was presented at the 7th International Turfgrass Research Conference in Palm Beach, in July 1993, and he prepared a manuscript for future publication in the USGA Green Section Record. These presentations outline the procedure that can be used for an assessment of certain chemical hazards on golf courses, and verified our contention of the worthiness of a joint collaboration. Subsequently, we have met with Drs. Borgert and Harbison at their Center to plan future collaboration and joint efforts at securing funding.

Using a conservative approach to avoid underestimation of exposure risk, the presentations evaluated the potential exposure to three pesticides applied to a putting green for a golfer who plays 18 holes of golf every day of his life, always playing 24 hours after a pesticide application. For each day of his life, the golfer is assumed to receive dermal exposure to the pesticides through kneeling on the green to align putts, handling golf-club grips what have been placed on the green, and by cleaning the soles of his golf shoes after playing the round of golf. He is further assumed to ingest pesticide by cleansing his golf ball by licking it. Data we had collected for dislodgeability of diazinon, chlorpyrifos, and isazofos on cotton, leather, and golf balls were used in this assessment. The Hazard Quotients calculated for each pesticide, using the stated assumptions, were less than one, indicating that the dosage is safe. This risk assessment is somewhat limited in scope and is based on preliminary data, but it illustrates the usefulness of a close collaboration among turfgrass scientists, analytical chemists, and toxicologists.

MOBILITY AND PERSISTENCE OF PHENOXY-ACID PESTICIDES

METHODS AND MATERIALS

The phenoxy-acid herbicides 2,4-D and dicamba were applied as liquids to the USGA green on 24 Feb. and 6 March, 1993, and in a separate study on 3 Aug. and 10 Aug. 1993. For each application, the rate was 0.0582 and 0.006 g A.I. M^{-2} for 2,4-D and dicamba, respectively. In contrast to the organophosphate experiments, no irrigation was applied immediately following treatment with the phenoxy-acid herbicides. Soil, thatch, percolate, and clipping samples were taken in the manner described for the organophosphate studies, except that only the 0-10 cm soil layer was sampled in the phenoxy-acid experiments.

RESULTS AND DISCUSSION

Data for the percolate water following the August applications are complete at the time of this writing. Fifty three g NaCl and 10 ml 2.25 M H_2SO_4 were dissolved in 150 ml portions of percolate sample. Then 50 ml of 70:30 hexane:ether was added, followed by 15 min shaking on a reciprocal shaker. After phase separation, the upper (organic) phase was transferred by pipeting to a 500 ml round bottom flask. The extraction process was repeated with two 40 ml additions of hexane:ether solvent and the extracts were combined in the round bottom flask. The extract was evaporated to near dryness with a rotoevaporator. The residue was transferred to a 10 ml volumetric flask in 3 aliquots of ether totaling approximately 5 ml, and the volumetric flasks were placed in a 40 C water bath until their contents reached near dryness. The 2,4-D and dicamba in the flasks were derivatized to their methyl esters by addition of 0.25 ml diazomethane-ether solution, which was synthesized in-house from 1-methyl-3-nitro-1-nitrosoguanidine in a Wheton micro-diazomethane generator. After 20 min, the samples were diluted to volume with hexane and analyzed by gas chromatography using an electron capture detector. Phenoxy-acid herbicide recovery from lysimeter water exceeded 90%.

Although approximately 10% as much dicamba as 2,4-D was applied, nearly 65% as much dicamba as 2,4-D was recovered in the percolate water over a 2-month period following the first August application (Table 7). Clearly, dicamba was much more mobile

Table 7. Summary of hydrological data and herbicide leaching for applications on 3 and 10 August, 1993.

Item	3 Aug - 7 October
Hydrologic data (mm)	
Rainfall	451
Percolation	696
2,4-D leaching	
ug M^{-2}	1808
% of applied	1.6
Dicamba leaching	
ug M^{-2}	1173
% of applied	9.7

than 2,4-D in the USGA green. Nevertheless, considering that 696 L percolate M^{-2} was recovered, the average concentration of dicamba in this percolate was less than 1.7 ug L^{-1} (ppb).

FACILITIES EXPANSION

Sufficient experience had been obtained with using stainless-steel lysimeters for collecting percolate from a USGA green at the FLREC that we wished to install a modified version of these lysimeters in greens on a golf course. We found such an opportunity during a rebuilding program at the Breakers West Golf Course in Palm Beach County, Florida. Through Mr. Larry Webber, LAW Horticultural Services, Inc., contact was made with Mr. John Baute, golf superintendent at the Breakers West. He made the construction crew available for us to install lysimeters on greens 2, 14, and 17 during their construction. The lysimeters were modified to provide passive drainage from the bottom of the collection chamber to a percolate-collection station on the back slope of each green (Fig. 8). The lysimeters were fitted with an air-return line, as was done at the FLREC, and stainless steel

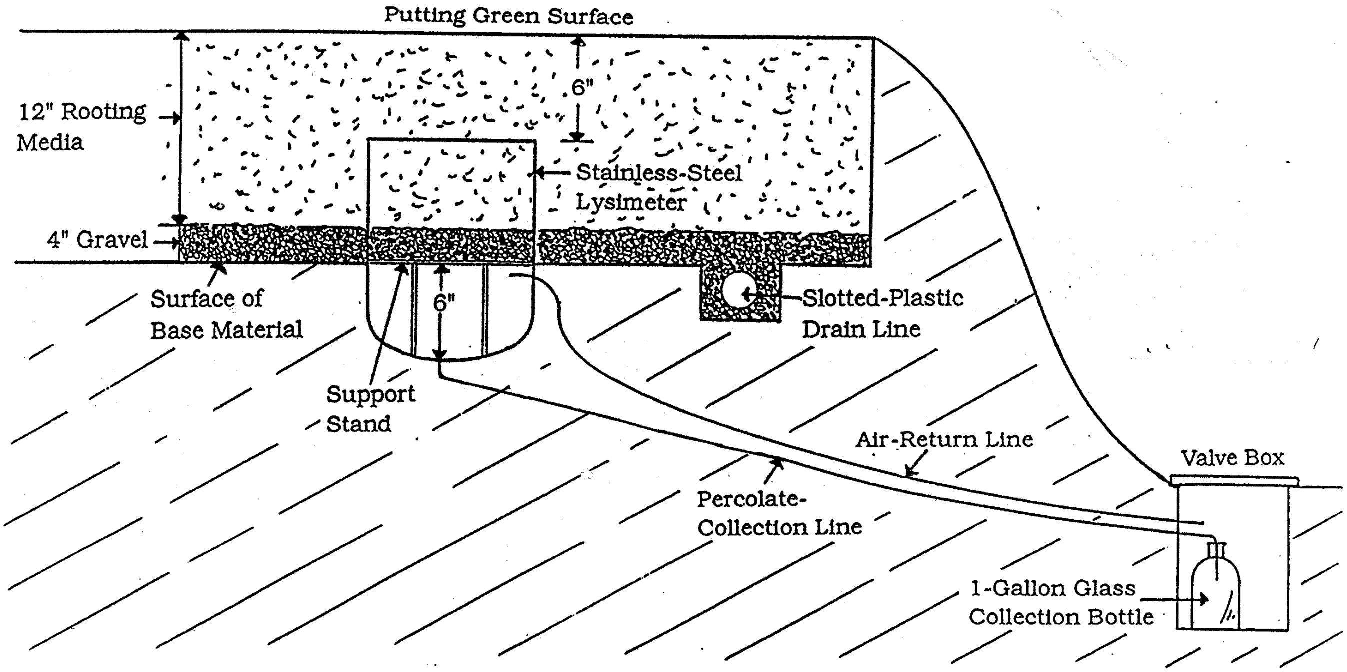

Putting Green Surface
12" Rooting Media
6"
Stainless-Steel Lysimeter
4" Gravel
Surface of Base Material
6"
Slotted-Plastic Drain Line
Support Stand
Air-Return Line
Valve Box
Percolate-Collection Line
1-Gallon Glass Collection Bottle

Fig. 8. Schematic of the free-draining stainless-steel lysimeter installation used in three greens at the Breakers West Golf Course in Palm Beach County, Florida.

was used throughout to minimize pesticide absorption. The "rooting mix over gravel" greens-construction combination in use at each location was reproduced in each lysimeter, thereby preserving the hydrological integrity of the percolate-collecting system. Installation was completed in July, 1993. Collection of percolate water by Breakers West personnel was initiated in September. These samples are being analyzed for NH_4-N, NO_3-N, P, and K. We hope that funding can be secured for conducting pesticide analyses as well, since this was the main purpose for the lysimeter installation.

PUBLICATIONS AND PRESENTATIONS

A number of publications and presentations were made in 1993 based on the studies receiving USGA Environmental Research Program funding.

Cisar, J. L., and G. H. Snyder. 1993. Mobility and persistence of pesticides in a USGA-type green. I. Putting green facility for monitoring pesticides. Int. Turfgrass Soc. Res. J. 7:971-977.

Snyder, G. H., and J. L. Cisar. 1993. Mobility and persistence of pesticides in a USGA-type green. II. Fenamiphos and fonofos. Int. Turfgrass Soc. Res. J. 7:978-983.

Giblin-Davis, R. M., J. L. Cisar, G. H. Snyder, and C. L. Elliott. 1993. Effects of fenamiphos or fenamiphos sulfone on the survival of the sting nematode, Belonolaimus longicaudatus, in vitro. Int. Turfgrass Soc. Res. J. 7:390-397.

Cisar, J. L., and G. H. Snyder. 1993. Mobility and persistence of pesticides applied to a USGA-type green. III. Isazophos and isofenphos. 1993 Agron. Abstracts, pg. 156. To be presented as a poster at the 1993 ASA meetings. Manuscript in preparation for submission to a refereed journal.

Cisar, J. L., and G. H. Snyder. 1993. Fate of pesticides applied to golf greens. 2. Fenamiphos and fonofos. In J. L. Cisar and J. J. Haydu (eds.) Turfgrass Research in Florida - A technical report. Univ. Fla., IFAS, Gainesville. p. 37-45.

Snyder, G. H., and J. L. Cisar. 1993. Fate of pesticides applied to golf greens. 3. Organophosphates in clippings. In J. L. Cisar and J. J. Haydu (eds.) Turfgrass Research in Florida - A technical report. Univ. Fla., IFAS, Gainesville. p. 47-50.

Borgert, C. J., S. M. Roberts, R. D. Harbison, J. L. Cisar, and G. H. Snyder. 1993. Assessing chemical hazards of golf courses. Submitted by request for publication in the USGA Green Section Record.

PUBLICATIONS AND PRESENTATIONS (Continued)

Zaneski, C. T. 1993. Water hazard? Tests track golf course toxins. The Miami Herald, August 16, p. 1A, 13A. A front-page article featuring the USGA-sponsored pesticide research at the FLREC.

Cisar, J. L. 1993. Fate of pesticides applied to a USGA green. Invited presentation at the Golf Course Superintendents Association of America conference, Anaheim, CA, Jan. 25.

Cisar, J. L. 1993. Environmental fate of agrochemicals applied to turf. Invited presentation at the Florida Turfgrass Association Conference and Trade Show, Sept. 27.

Jacoby, C. 1993. Turfgrass Research. The USGA-sponsored study was included in a 30-minute video shown several times on the cable TV program "Growing Together", Channel 20, West Palm Beach, Florida.

Cisar, J. L. 1994. Pesticide dislodgeability. Invited presentation to be given at the Golf Course Superintendents Association of America conference, Dallas, TX, Feb. 4.

The USGA-sponsored facilities for pesticide fate and mobility studies located at the FLREC were shown, along with a brief discussion of results, at the Turfgrass Field Day, April 1, 1993, and at the International Turfgrass Research Conference mid-week tour, July 21, 1993. An estimated 700 persons visited the facility in 1993.

CURRENT PROJECT STATUS AND FUTURE PLANS

Because of funding by the USGA Environmental Research Project, facilities have been installed at the FLREC and at the Breakers West Golf Course for assessing the persistence and mobility of pesticides applied to USGA-type golf greens. A pesticide analysis lab has been developed at the Everglades Research and Education Center (EREC) in Belle Glade, FL, dedicated to cost-effective in-house analysis of samples obtained from turfgrass projects. The services of an excellent project-funded analytical chemist have been secured. Three support personnel have become experienced in pesticide sample collection and analyses procedures, including GLP requirements. Methods have been developed for conducting turfgrass pesticide-fate studies. The attention and interest of toxicologists has been obtained. The authors (Snyder and Cisar) have achieved a degree of visibility in the field of turfgrass-pesticide environmental issues through their published papers and oral presentations. These accomplishments represent an investment by the USGA that is ripe for exploitation. The facilities will deteriorate, and the project-funded personnel who have been trained with project money will go elsewhere if funding for turfgrass-pesticide environmental studies is interrupted. To prevent these losses, we hope that funding can be continued.

Considerable work has been conducted on the organophosphate class of pesticides applied to a USGA green. Studies on replicated applications of six organophosphates have demonstrated that relatively little pesticide is carried by percolate waters or is removed in clippings. Approximately 99% of the applied pesticides of this class was held in the thatch layer until it was microbially degraded. The only exception was a sulfone-sulfoxide metabolite of fenamiphos, which was demonstrated to be leached from the thatch layer.

Studies have begun using phenoxy-acid herbicides (2,4-D, dicamba). The same concentrated effort that was made for the organophosphate materials should be undertaken for other classes of turfgrass pesticides, such as the phenoxy-acids, until generalized conclusions can be drawn for each pesticide group. Studies on pesticide dislodgeability and its toxicological significance should be continued. The pesticide-fate studies should be expanded to include actual golf-course environments, in addition to the more controllable Research Center site. Pesticide volatilization has yet to be addressed in our studies.

A number of solid accomplishments have been realized as a result of funding by the USGA. The opportunity exists for uninterrupted and expanded work in the field of turfgrass-pesticide environmental issues.