

AN ASSESSMENT OF THE RISKS ASSOCIATED WITH PESTICIDES VOLATILIZED AND DISLODGED FROM GOLF TURF

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EXECUTIVE SUMMARY

A series of pesticide dislodgeability studies were conducted to evaluate the risks associated with golfer exposure to pesticides. The work was performed by Mr. Raymond H. Snyder as part of a master of science degree program at the University of Florida. The pesticides 2,4-D and Dicamba were applied as liquids to a cv. Tifgreen bermudagrass USGA green with and without *Poa trivialis* overseeding, and to a cv. Tifdwarf USGA green. Isazofos, chlorpyrifos, and fenamiphos were spray-applied to the Tifdwarf green. Pesticides were dislodged with damp cheesecloth rubbed on the turf surface, damp cotton cloth pressed on the surface, damp leather pressed, by putting a golf ball over the surface, by rolling golf grips on the surface, and in a short rough off to the side of the green by swinging a golf club through the grass and wiping the club surface with damp cheesecloth.

Generally, the amount of pesticide dislodged decreased with time after application, and was greatly reduced following irrigation. By combining the data, risk assessment calculations could be made for various scenarios. For example, exposure to chlorpyrifos on 18 greens one hour after application every day for a lifetime was calculated to provide a Hazard Quotient of 0.31. Hazard quotients less than 1.00 are considered to pose little risk. A similar calculation for exposure after irrigation was 0.02. Chlorpyrifos has a rather high Reference Dose, i.e., acceptable amount of exposure, which reduces the Hazard Quotient. Calculations for the other pesticides, some of which have higher Reference Doses, will be made at a later date.

A stabilized organic polymer (SOP) coated on USGA-sized sand for reducing pesticide leaching was field evaluated twice. Accumulated fenamiphos leaching was reduced up to 100% (Fig. 1) and fenamiphos metabolite up to 76% (Fig. 2) by inclusion of the SOP-sand at the rate of 20% by volume in the lower 10 cm of the 30 cm USGA soil profile.

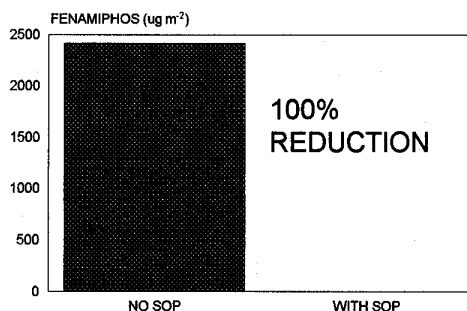


Fig. 1. Effect of SOP on fenamiphos leaching seven weeks after pesticide application.

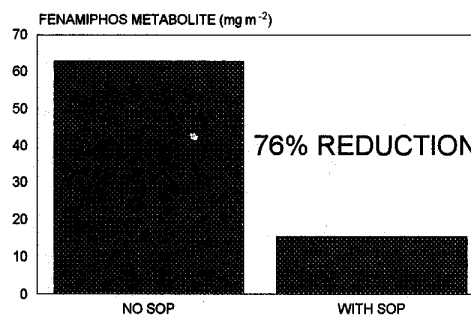


Fig. 2. Effect of SOP on fenamiphos metabolite leaching seven weeks after pesticide application.

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VOLATILIZED AND DISLODGED FROM GOLF TURF

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ABSTRACT

A series of pesticide dislodgeability studies were conducted to evaluate the risks associated with golfer exposure to pesticides. The work was performed by Mr. Raymond H. Snyder as part of a master of science degree program at the University of Florida. The pesticides 2,4-D and Dicamba were applied as liquids to a cv. Tifgreen bermudagrass USGA green with and without *Poa trivialis* overseeding, and to a cv. Tifdwarf USGA green. Isazofos, chlorpyrifos, and fenamiphos were spray-applied to the Tifdwarf green. Pesticides were dislodged with damp cheesecloth rubbed on the turf surface, damp cotton cloth pressed on the surface, damp leather pressed, by putting a golf ball over the surface, by rolling golf grips on the surface, and in a short rough off to the side of the green by swinging a golf club through the grass and wiping the club surface with damp cheesecloth.

Generally, the amount of pesticide dislodged decreased with time after application, and was greatly reduced following irrigation. By combining the data, risk assessment calculations could be made for various scenarios. For example, exposure to chlorpyrifos on 18 greens one hour after application everyday for a lifetime was calculated to provide a Hazard Quotient of 0.31. Hazard quotients less than 1.00 are considered to pose little risk. A similar calculation for exposure after irrigation was 0.02. Chlorpyrifos has a rather high Reference Dose, i.e., acceptable amount of exposure, which reduces the Hazard Quotient. Calculations for the other pesticides, some of which have higher Reference Doses, will be made at a later date.

A stabilized organic polymer (SOP) for reducing pesticide leaching was field evaluated twice. Accumulated fenamiphos leaching was reduced up to 100% and fenamiphos metabolite up to 76% by inclusion of the SOP at the rate of 20% by volume in the lower 10 cm of the 30 cm USGA soil profile.

In the coming year, we anticipate completing the risk assessment calculations on a number of golfing scenarios for all of the pesticides studied. We also anticipate conducting volatilization studies and performing risk assessments on the data obtained.

INTRODUCTION

The project was designed to be in collaboration with a project headed by Dr. John Clark, University of Massachusetts. However, that project was not funded by the USGA, so our project has and will continue to undergo appropriate modification.

In 1998, studies on pesticide dislodgeability were conducted with assistance from Mr. Raymond Snyder, a University of Florida graduate student working on an M.S. degree in the Soil and Water Science Department. Drs. Cisar and Borgert, and Dr. Jerry Sartain of the Soil and Water Science Department in Gainesville, form Mr. Snyder's graduate committee and have participated to varying degrees in the work reported herein. Some field work conducted prior to USGA funding is included in this report because analytical work and data interpretation were accomplished later with the aid of the USGA grant. The field work on pesticide dislodgeability from Mr. Snyder's project has been completed and will be summarized in this report along with some conclusions on the implication for risk assessment. Upon completion of this thesis, more detailed risk assessment analysis will be included in the 1999 Annual Report along with the full thesis containing tables and other information beyond the scope of the current report.. Although not specifically the subject of this project, this report also contains the final work on developing a stabilized organic polymer for reducing pesticide leaching which was conducted in our lab in conjunction with prior USGA-funded studies.

PESTICIDE DISLODGEABILITY STUDY

MATERIALS AND METHODS

A. Experimental Site

1. Putting Green

Part of the study was conducted on a 'Tifgreen'/'Tifdwarf' bermudagrass (*Cynodon dactylon* L. X *C. transvaalensis*) United States Golf Association (USGA) putting green located at the University of Florida's Ft. Lauderdale Research and Education Center (FLREC). The putting green consisted of two sections: 1.) Three-quarters 'Tifdwarf' 2.) One-quarter 'Tifgreen'. Both sections were utilized in this study. The putting green was maintained at 5 mm cutting height. Maintenance of the putting green was similar to that of putting greens located at golf courses throughout Florida; mowing every morning (except during experimental sampling periods), and watering and pesticide application (i.e., pesticides of non-interest to this study) as needed.

In order to determine and compare dislodgeable residues from overseeded and non-overseeded bermudagrass, five 1 x 12 m plots randomized with five non-overseeded plots were overseeded with *Poa trivialis* (Cypress) on January 9, 1997 at a rate of 45 g m⁻² and maintained

as described above.

2. Rough

In order to determine dislodgeable residues from a club face (chip and wipe), part of the study was conducted on a 'Tifway' (*Cynodon dactylon* L. X *C. tranvaalensis*) bermudagrass stand located adjacent to the USGA putting green described above. This area was maintained at a height of 8.5 cm. This area was mowed three times a week; water and pesticide applications (i.e., pesticides of non-interest to this study) were made as needed.

B. Application of Pesticides to Turfgrass

All pesticide applications were carried out using a 1 m width, two nozzle, CO₂ backpack sprayer. Applications were made using labeled rates. Total application time never exceeded 15 min.

a. 2,4-D and Dicamba

On the morning of 11 March 1997, 2,4-D and dicamba were applied at the following rates: 2,4-D = 0.058 g(a.i.)m⁻² and dicamba = 0.006 g(a.i.)m⁻². Additional studies were conducted on 29-30 January 1998, 5-6 March 1998, and 7-8 April 1998 using the same application rates.

b. Isazofos, Chlorpyrifos, and Fenamiphos

On 3 June 1997, isazofos, chlorpyrifos, and fenamiphos were applied at the following rates: isazofos = 0.229 g(a.i.)m⁻², chlorpyrifos = 0.229 g(a.i.)m⁻², fenamiphos = 1.125g(a.i.)m⁻². On 29 October 1997, these pesticides were reapplied at the same rate in order to conduct additional sampling.

C. Sample Collection

Several methods of sampling were used in determining dislodgeable residues: 1.) Damp cheesecloth wipe, 2.) Damp cotton cloth press, 3.) Damp leather press, 4.) Golf ball putt, 5.) Golf grip roll, 6.) Chip and wipe. Each method was replicated five times for a given sampling time. The areas sampled were marked with orange-spray paint to prevent overlapping of sampling areas. Samples were placed into glass jars following collection and immediately stored at -20 C until extraction.

1. Damp Cheesecloth Wipe

The damp cheesecloth wipe method was executed by firmly wiping a dampened piece of cheesecloth four times in four directions over an area of the plot demarcated by a template. This area was 625 cm² on 11-12 March 1997, and 603 cm² for wipes conducted on 3-4 June 1997, 29-30 October 1997, 29-30 January 1998, and 5-6 March 1998. The cheesecloth was held firmly in

place using an aluminum holder. A 10 x 10 cm piece of aluminum foil was placed between the cheesecloth and the holder reducing possible transfer of pesticide onto the holder which could lead to the contamination of subsequent cheesecloth samples. Both the cheesecloth and aluminum foil were placed in the glass sampling jar. The cheesecloth as well as the aluminum holder were 10 x 20 cm.

2. Damp Cotton Press

The damp cotton press method was executed by placing a 10 x 10 cm piece of damp cotton on the turf surface overlaid by a 10.5 kg weight for 30 sec.

3. Damp Leather Press

The damp leather press method was executed by placing 10 x 10 cm piece of damp leather on the turf surface overlaid by a 10.5 kg weight for 30 sec.

4. Golf Ball Putt

The golf ball putt method was executed by putting a golf ball 36 times over a .5 x 4 m area of the putting green. This method was only conducted on unoverseeded bermudagrass.

5. Golf Grip Roll

The golf grip roll method was executed by placing and rolling (three revolutions) a standard size golf grip on the turf surface. A metal rod (0.218 kg) was inserted into the grip to insure firm contact with the turf and to allow the grip to be rolled and transported without being touched.

6. Chip and Wipe I

The chip and wipe I method was executed by swinging the golf club in such a manner so that the club face made contact with the blades of turf without penetrating the soil surface. The club was swung five times over a new area of turf each time. After each swing, the club face and back was wiped with a single, damp piece of cheesecloth. No attempt was made to remove any blades of turf which may have become attached to the club face and back while swinging before wiping with cheesecloth. Five swings constituted one replication.

7. Chip and Wipe II

On 29-30 October 1997 a new version of the chip and wipe method was conducted in conjunction with the chip and wipe I method described above. In this new version, one swing constituted a replication rather than five.

D. Experiments

a. 11-12 March 1997

The study was conducted over two days beginning on the morning of 11 March 1997 and ending on the morning of 12 March 1997. Dislodgeability samples were taken from the 'Tifgreen' section of the USGA putting green. There were 10 1 x 12 m plots; five overseeded and five that were not overseeded. Plots were treated with 2,4 - D and dicamba at 9:25 a.m. (ambient temperature 24 C; calm conditions). Dislodgeability samples were taken from randomly selected, undisturbed locations on each plot. Irrigation (0.34 cm) was applied on the morning of 12 March 1997 prior to sampling. See table 1 for sampling schedule and methods.

b. 3-4 June 1997

Dislodgeability samples were taken over a two day period beginning on 3 June 1997 and ending on 4 June 1997. The samples were taken from the 'Tifgreen' section. There were five 1 x 12 m plots. Isazofos, chlorpyrifos, and fenamiphos were applied at 1:00 p.m. (ambient temperature 32 C; calm conditions). Following the first set of samplings, approximately 0.34 cm of irrigation was applied. Samples were taken from randomly selected, undisturbed locations on each plot. See table 2 for sampling schedule and methods.

c. 29-30 October 1997

On 29-30 October 1997, additional sampling was conducted to further determine dislodgeable residues of pesticides between zero and three hours after application. In addition, the chip and wipe II method was conducted to quantify the residues dislodged by one golf swing. Dislodgeability samples were taken from the 'Tifdwarf' section. The pesticides were applied at 10:55 a.m. (ambient temperature 21 C; calm conditions). A single 1 x 6 m experimental area was utilized. Samples were taken from randomly chosen, undisturbed locations within the treated area. Immediately following the first set of sampling, approximately 0.34 cm of irrigation was applied to the experimental site. See table 3 for sampling schedule and methods.

d. 29-30 January 1998

2,4-D and dicamba were applied to the 'Tifdwarf' section at the previously described rates. The application was made at 9:25 a.m. (ambient temperature 18 C; calm conditions). The sampling area was 1 x 7 m. Five replicate samples were taken from randomly chosen areas using the damp cheesecloth method. The sampling area was applied with 0.34 cm of irrigation the next day before sampling and sampled after the turfgrass was allowed to dry. See table 4 for sampling schedule and method.

e. 5-6 March 1998

2,4-D and dicamba were applied to the 'Tifgreen' section at the previously described

rates. A single 1 x 12 m area was used for sampling. At 12:00 p.m. (ambient temperature 24 C; wind 3 - 7 mph) the pesticides were applied. Five replicate samples were taken from randomly chosen areas on the plot. Approximately 0.34 cm of irrigation was applied the following day prior to sampling.

f. 7-8 April 1998

2,4-D and dicamba were applied to the 'Tifgreen' section at the previously described rates. The application was made at 8:50 a.m. (ambient temperature 23 C; 5-10 mph wind) to four 1 x 12 m plots. Fifteen randomly chosen areas, upon which the golf ball putting occurred, were marked prior to application. The areas remaining were used for random sampling via the other methods. Irrigation (0.34 cm) was applied on the morning of 8 April 1998 prior to sampling.

E. Analytical Method Development

1. Laboratory Recoveries of Pesticides

Cheesecloth (American Fiber & Finishing, Inc., Burlington, MA), cotton fabric, leather, grips, and golf balls were used to dislodge pesticide residues. In order to determine extraction efficiency, the materials were fortified with standards of each compound and extracted with the appropriate organic solvent. For purposes of quantification, untreated materials were extracted and analyzed. Co-extractants that interfered with pesticides of interest were removed via cleanup steps included in each extraction method.

a. 2,4-D and Dicamba

Hexane/Ether was used to extract 2,4 - D and dicamba from cheesecloth, cotton fabric, and golf balls. Each sample was shaken, in the same glass jar that it had been placed during sampling, with a solution of 90 mL of water and 10 mL of 1N NaOH for 30 min and then decanted into a 1000 mL flask. This procedure was repeated three times per sample. From this combined sample, 100 mL was decanted into a 200 mL screw cap bottle, and 35g NaCl were added. The aliquot was then extracted two times with hexane/ether solution to remove co-extractants. The hexane/ether phase was discarded. Following the removal of co-extractants, the sample was acidified using 5 mL of 2.88N H₂SO₄. The acidified sample was then extracted three times with 50 mL hexane/ether. The extract was then evaporated using a rotary evaporator. The pesticides in the concentrate were then derivatized into their methyl ester form using diazomethane in ether. Diazomethane was generated in the laboratory without distillation following a laboratory technique described by Aldrich (1998). The derivatized pesticide concentrate was increased to a final volume of 10 mL using hexane and decanted into a crimp top vial.

b. Isazofos/Chlorpyrifos/Fenamiphos

Methylene chloride was used to extract isazofos, chlorpyrifos, and fenamiphos from cheesecloth, cotton fabric, and golf balls. Each sample was shaken, in the same glass jar that it had been placed in during sampling, with 150 mL of methylene chloride for 15 min and then decanted into a 500 mL round-bottom evaporation flask. This procedure was repeated three times per sample. The solvent extracts were concentrated using a rotary-evaporator. The pesticide concentrate was increased to a final volume of 10 mL using methylene chloride and decanted into a crimp top vial.

Due to the presence of co-extractants that result from the direct extraction of leather and grips with methylene chloride, a modification of the methylene chloride method described above was necessary for the extraction of isazofos, chlorpyrifos, and fenamiphos from leather and golf grips to avoid interference with pesticide resolution. An extracting solution comprised of methanol, water, and sulfuric acid was developed. The extracting solution (150 mL) was added to the jar containing the sample. The sample was shaken for 30 min and the extracting solution was decanted through a Buchner funnel into a 500 mL filter flask. This procedure was repeated three times. Solvent extracts were transferred to a 1 L separatory funnel. Deionized water (200 mL) and sodium chloride (60 g) were then added to the separatory funnel and shaken. Methylene chloride (100 mL) was then added to the separatory funnel and shaken for approximately 2 min. Following shaking, the separatory funnel was placed on a holder allowing the aqueous and organic phases to separate. Methylene chloride phase was drained into a 250 mL bottle. This extracting procedure was repeated three times. Prior to the transfer of the solvent extract from the 250 mL bottle to a round-bottom evaporation flask, sodium chloride (15 g) was added and stirred for approximately 3-5 min. Addition of sodium chloride helped to prevent the possible transfer of water to the round-bottom evaporation flask, thus significantly decreasing the time required to concentrate the extract solution. Solvent extracts were concentrated using a rotary-evaporator. Pesticide concentrate was increased to a final volume of 10 mL using methylene chloride and decanted into a crimp top vial.

G. Instrumentation

1. Isazofos/Chlorpyrifos/Fenamiphos

The extracted solvent was analyzed by HP 5890 - A series II gas chromatography with a 10 m x .53 mm, HP - 5 cross linked 5 % phenolmethyl silicon capillary column, and a flame photometric detector. The detection limit was 0.1 ug/sample for all pesticides.

2. 2,4-D/Dicamba

The extracted solvent was analyzed by HP 5890 series II gas chromatography with a 20 m x 0.53 mm id, HP - 5 cross linked 5% phenolmethyl silicon capillary column, and an electron capture detector. The detection limit of 2,4 - D and dicamba was 0.1 ug/sample.

Table 1. Sampling Schedule and Method for 2,4 - D/Dicamba study conducted on 11 - 12 March 1997

Day 1	Method
9:15 - 9:25 a.m.	Pesticide application
11:25	Damp cheesecloth wipe
11:35	Damp cotton cloth press
11:50	Golf ball putt
12:20 p.m.	Chip and Wipe I
1:25	Damp cheesecloth wipe
1:35	Damp cotton cloth press
1:55	Golf ball putt
2:25	Chip and wipe I
Day 2	
10:00 a.m.	Damp cheesecloth wipe
10:15	Damp cotton cloth press
10:55	Golf ball putt
11:10	Chip and Wipe I

Table 2. Sampling Schedule and Method for Organophosphate study conducted on 3 - 4 June 1997

Day 1	Method
1:00 p.m.	Pesticide application
1:15	Damp cheesecloth wipe
1:20	Damp cotton cloth press

1:35	Damp leather press
1:42	Golf ball putt
2:15	Golf grip roll
2:27	Chip and wipe I
3:45	Damp cheesecloth wipe
4:28	Damp cotton cloth press
4:40	Damp leather press
4:51	Golf ball putt
5:24	Golf grip roll
5:32	Chip and wipe I
Day 2	
8:30 a.m.	Damp cheesecloth wipe
8:38	Damp cotton cloth press
8:47	Damp leather press
8:55	Golf ball putt
9:15	Golf grip roll
9:20	Chip and wipe I

Table 3. Sampling schedule and method for Organophosphate study conducted on 29 - 30 October 1997

Day 1	Method
11:00 a.m.	Pesticide application
11:05	Damp cheesecloth wipe
11:15	Damp leather press
11:22	Chip and Wipe II

11:35	Chip and Wipe I
12:20	Damp cheesecloth wipe
1:20	Damp cheesecloth wipe
2:20	Damp cheesecloth wipe
2:30	Damp leather press
2:38	Chip and wipe II
2:51	Chip and wipe I
Day 2	
11:25 a.m.	Damp cheesecloth wipe
11:35	Damp leather press
11:45	Chip and wipe II
11:58	Chip and wipe I

Table 4. Sampling schedule and method for the 2,4 - D/Dicamba study conducted on 29 - 30 January 1998

Day 1	Method
9:25 a.m.	Pesticide application
9:30	Damp cheesecloth wipe
1:30	Damp cheesecloth wipe
5:30	Damp cheesecloth wipe
Day 2	Method
9:30 a.m.	Damp cheesecloth wipe
11:30	Damp cheesecloth wipe

Table 5. Sampling schedule and method for the 2,4 - D/Dicamba study conducted on 5 - 6 March 1998

Day 1	Method
12:00 p.m.	Pesticide application
12:13	Damp cheesecloth wipe
12:25	Damp cotton fabric press
12:35	Damp leather press
3:53	Damp cheesecloth wipe
4:00	Damp cotton fabric press
4:10	Damp leather press
Day 2	
2:30	Damp cheesecloth wipe
2:45	Damp cotton fabric press
2:52	Damp leather press

Table 6. Sampling schedule and method for the 2,4 - D/Dicamba study conducted on 7 - 8 April 1998

Day 1	Method
8:50 a.m.	Pesticide application
8:55	Golf grip roll
9:05	Golf ball putt
9:35	Chip and wipe I
12:55 p.m.	Golf grip roll
1:00	Golf ball putt
1:25	Chip and wipe I
Day 2	
9:05 a.m.	Golf grip roll
9:10	Golf ball putt
9:35	Chip and Wipe I

RESULTS

1. 2,4 - D

3-4 March 1997

No significant difference ($P < .05$) in the quantity of dislodgeable residues of 2,4-D was found between 'Tifgreen' bermudagrass and 'Tifgreen' bermudagrass overseeded with *poa trivialis*. Since no statistical difference was found, all dislodgeable residues of 2,4 - D were averaged across both grasses.

Residues dislodged by the damp cheesecloth wipe decreased appreciably from day 1 to day 2. At 2 h (hours) after application approximately 12.2% of the applied 2,4 - D was recovered as dislodgeable residues. Residues measured 4 h after application decreased 7%. Residues measured 24 h after application decreased 97% from residues dislodged 4 h after application.

Dislodgeable residues recovered by the damp cotton press decreased with time. Dislodgeable residues of 2,4-D were greatest 2 h after application; 13% of the applied 2,4-D was

recovered. Residues dissipated slightly 4 h after application by 13%. Residues 24 h after application were 40 ug m^{-2} .

Dislodgeable residues measured by the golf ball putt method were variable over the course of the 25.5 h sampling period. Residues 2 h after application were $1.09 \text{ ug sample}^{-1}$. Residues measured 4.5 hrs after application decreased to less than 1 ug sample^{-1} . Residues measured 25.5 h after application ($0.77 \text{ ug sample}^{-1}$) were on average greater than residues at 4.5 h, however, a standard deviation of 1.03 should be noted.

The chip and wipe method I sampling was conducted 3, 5, and 25.5 h following application. Dislodgeable residues were greatest 5 h after application reducing to $0.32 \text{ ug sample}^{-1}$ 25.5 h after application.

There was no significant difference ($P < .05$) in dislodgeability of 2,4-D between the damp cheesecloth wipe and damp cotton press methods (equal area basis) from 'Tifgreen' bermudagrass and 'Tifgreen' bermudagrass overseeded with *poa trivialis*.

ii. 29-30 January 1998

Dislodgeable residues were the greatest 5 min. following application recovering 14.20 % of the applied pesticide. Residues decreased to 5271.64 ug^{-2} (9.10%) and 6534.33 (11.30%) at 4 h and 7 h after application. 2,4 - D residues measured 3517.91 ug^{-2} 24 h after application and dropping to 527.86 ug^{-2} 26 h after application due to a scheduled irrigation event.

iii. 5-6 March 1998

Dislodgeable residues of 2,4 - D using the damp cheesecloth wipe method were at a maximum 13 min. post - application and decreased with time. Residues measured at 4 and 26.5 h after application were 1193.37 ug^{-2} and 84.91 ug^{-2} .

Dislodgeable residues of 2,4 - D as determined by the damp cotton press were greatest 25 min. following application and diminished with time. Residues dissipated to 2410 ug^{-2} 4 h after application and 434 ug^{-2} 26.75 h after application.

iv. 7-8 April 1998

The golf ball putt residues of 2,4 - D recovered 5 min. after application averaged $4.89 \text{ ug sample}^{-1}$. Residues taken 4 h after application increased to $6.04 \text{ ug sample}^{-1}$. Residues 24 h following application decreased averaging $3.62 \text{ ug sample}^{-1}$.

Dislodgeable residues as determined by the chip and wipe method I procedure were greatest 35 min. after application and decreased with time. Residues 4.5 and 24.5 h after application were 39.35 and $15.02 \text{ ug sample}^{-1}$.

2. Dicamba

i. 3-4 March 1997

No significant difference ($P < .05$) in the amount of dislodgeable residues of dicamba was found between 'Tifgreen' bermudagrass and 'Tifgreen' bermudagrass overseeded with *poa trivialis*. Since no statistical difference was found all dislodgeable residues of dicamba were averaged across both grasses.

Dislodgeable residues of dicamba as determined by the damp cheesecloth wipe differed little 2 and 4 h after application decreasing appreciably 24.5 h after application. Maximum residue recovery occurred 4 h post - application (15.60 %).

The damp cotton press dislodged the greatest quantity of residues 2 h after application (891 ug^{-2}) with residues decreasing over time. Residues recovered 25 h after application were only 1.40% of applied.

Dicamba residues on golf balls decreased with time from 2.5, 4.5, and 25.5 h after application. Residues determined 2.5 h post - application averaged $2.42 \text{ ug sample}^{-1}$.

Dislodgeable residues of dicamba as determined by the chip and wipe method I deviated considerably. Residues recovered were the greatest 5 h after application.

A comparison of the damp cheesecloth wipe and the damp cotton press on an equal area basis revealed a significant method by time interaction. Dislodgeable residues of dicamba measured by the damp cheesecloth wipe were significantly greater than those of the damp cotton press only at 4 h after application.

ii. 29-30 January 1998

Dislodgeable residues of dicamba measured using the damp cheesecloth wipe were highest 5 min. after application (858.71 ug^{-2}) with residues decreasing thereafter. At 24 h after application dicamba residues dissipated to a low of 321.39 ug^{-2} . Following a scheduled irrigation event, dicamba residues increased 2.4% between 24 and 26 h after application.

iii. 5-6 March 1998

Dislodgeable Residues of dicamba decreased over time as determined by the damp cheesecloth wipe method. Residues were greatest 13 min. after application with 9.80% of the applied dicamba recovered. By 26.5 h after application less than 1 % was recovered.

The damp cotton press method conducted 25 min. after application dislodged 593 ug^{-2} . Residues decreased over time with 2.00% of the applied dicamba dislodged 26.75 h after application.

iv. 7-8 April 1998

Residues dislodged by the golf ball putt method decreased over time. Residues recovered 5 min. post - application averaged less than 1 ug sample⁻¹.

Residues recovered on the club face and back using the chip and wipe method I decreased over time. At 35 min. after application dicamba residues averaged 41.53 ug sample⁻¹. Dicamba residues dislodged 4.5 h after application were 91.4 % less than those recovered 35 min. after application. By 24.5 h after application, dicamba residues averaged less than 2 ug sample⁻¹.

3. Isazofos

i. 3-4 June 1997

Isazofos residues dislodged by damp cheesecloth 15 min. after application averaged 3216.25 ug⁻². Isazofos residues decreased 94% following a scheduled irrigation event and an additional 2.5 h of elapsed time. At 19.5 h after application residues averaged 51.58 ug⁻² or 0.02 % of the isazofos applied.

Isazofos residues dislodged by damp cotton decreased over time. At 20 min. after application less than 1% of the applied isazofos was recovered. An irrigation event occurred prior to sampling at 3.5 h after application decreasing residues dislodged at 20 min. by 94%. Recovery of isazofos residues 19.5 h after application was 0.03%.

Isazofos residues removed by damp leather decreased from 3.75 to 19.75 h following application. Residues dislodged at 35 min. after application are not available due to an error occurring during the extraction of the 35 min. samples.

Isazofos residues recovered from golf balls decreased after irrigation and over time. Isazofos residues dissipated 88% between times 42 min. and 4 h after application. By 20 h after application isazofos residues recovered were less than 0.5 ug sample⁻¹.

Isazofos residues as dislodged by golf grips were only recovered 1.24 h after application. At times 4.5 and 20.25 h after application no residues or an undetectable amount of residues were dislodged.

Isazofos residues dislodged by a golf club head varied little over time. Residues recovered were greatest and most variable 4.5 h after application (5.81 ug sample⁻¹). Residues were lowest 20.5 h after application (3.83 ug sample⁻¹).

There was no statistical difference (P<.05) in the quantity of isazofos dislodged between the damp cheesecloth wipe and the damp cotton press. Method was found to be significant (P<.05) when the damp cheesecloth wipe, damp cotton press, and damp leather press were compared on an equal area basis at 3.75 and 19.5 h after application. Damp leather dislodged

38% and 62% more chlorpyrifos than damp cheesecloth and damp cotton 3.75 h after application. In addition, damp leather significantly dislodged more chlorpyrifos than damp cheesecloth and damp cotton 19.5 h after application.

ii. 29-30 October 1997

Dislodgeable residues of isazofos reduced over time as determined by the chip and wipe method I procedure. Residues recovered 35 min. post - application dissipated by 65% and 88% at 4 and 25 h after application.

Isazofos residues also decreased over time using the chip and wipe method II procedure. At 22 min. post - application residues measured 33.33 ug sample⁻¹. A 90% reduction in residues was measured 3.5 h after application.

4. Chlorpyrifos

i. 3 - 4 June 1997

Residues of chlorpyrifos dislodged using damp cheesecloth decreased markedly over time. An irrigation event occurring between the 15 min. and 2.75 h sampling periods likely contributed to the dissipation of chlorpyrifos residues for a 95% reduction in residues occurred within this time frame. At 19.5 h after application 0.01 % of the applied chlorpyrifos was recovered.

Dislodgeable residues of chlorpyrifos decreased over time as measured using the damp cotton press procedure. Residues decreased by 94% between the 20 min. and 3.5 h sampling periods. Again, irrigation most likely helped to diminish chlorpyrifos residues. A 96% reduction in dislodgeable residues had occurred 19.5 h after application.

Residues dislodged by damp leather 35 min. after application were not determined due to a mistake occurring during the extraction of time 1 samples as previously noted. However, a decrease in residues was observed between 3.75 and 19.75 h after application.

Chlorpyrifos residues on golf balls decreased over time. An irrigation event occurring between the 42 min. and 4 h sampling period likely contributed to the reduction in residues. At 20 h after application only 8% of the residues measured 42 min. after application were recovered.

Chlorpyrifos residues on golf grips were only detected 1.25 h after application. An average of less than 1 ug sample⁻¹ was detected.

Dislodgeable residues recovered by the chip and wipe method I procedure fluctuated over time. Residues were greatest and most variable 4.5 h after application increasing 60% as compared to residues recovered 1.5 h after application. Chlorpyrifos residues dislodged 20.5 h after application decreased 13.4% from residues at 4.5 h after application.

A significant method by time interaction was found between the damp cheesecloth wipe and the damp cotton press. On an equal area basis, residues dislodged by the damp cheesecloth wipe were significantly greater ($P < .05$) than residues dislodged by the damp cotton press at 3.75 h after application.

A significant method by time interaction was found between the damp cheesecloth wipe, damp cotton press, and damp leather press when compared on an equal area basis at 3.75 and 19.50 h after application. The damp cheesecloth wipe dislodged 56% and 87% more chlorpyrifos than the damp cotton press and the damp leather press 3.57 h after application. There was no significance between the damp cheesecloth wipe and damp cotton press 19.50 h after application. The damp leather press 19.5 h after application dislodged significantly less chlorpyrifos than damp cheesecloth and damp cotton.

ii. 29-30 October 1997

Dislodgeable residues of chlorpyrifos recovered via the chip and wipe method I procedure decreased over time. Residues 35 min. after application averaged $41.67 \text{ ug sample}^{-1}$. A 72% decrease in residues occurred 4 h after application. By 25 h after application chlorpyrifos residues had reduced 80%.

Chlorpyrifos residues recovered by the chip and wipe method II procedure decreased overtime. Dislodgeable residues averaged $28.97 \text{ ug sample}^{-1}$ 22 min. after application. Residues decreased 94% and 95% by 3.5 and 25 h after application.

5. Fenamiphos

i. 3-4 June 1997

Fenamiphos residues dislodged by damp cheesecloth decreased appreciably between 15 min. and 2.75 h after application. The large decrease is likely due to an irrigation event occurring between sampling with time also as a contributing factor. Residues dislodged 19.5 h after application decreased almost 100% as compared to residues recovered 15 min. after application.

Fenamiphos residues recovered by the damp cotton press method decreased over time with irrigation a likely contributing to the dissipation in dislodgeable residues. Residues decreased 96% from 20 min. after application to 3.5 h after application. A decrease of 99% had occurred by 19.5 h after application.

Fenamiphos residues on damp leather decreased overtime. The damp leather press 3.75 h after application was only able to recover 0.03% of the fenamiphos applied. Residues dislodged 19.5 h after application reduced 87% from residues recovered 3.75 h after application.

Fenamiphos residues recovered from golf balls decreased overtime and in part due to

irrigation. Irrigation likely contributed to the dissipation of residues for a 99% reduction occurred between 42 min. and 4 h after application; the period during which the irrigation event occurred. By 20 hr. after application less than 0.1 ug sample⁻¹ was detected.

Fenamiphos residues on golf grips were only detectable 1.25 and 20.25 h after application. Residues recovered 20.25 h after application were 93% less than those residues recovered 1.25 h after application.

Dislodgeable residues of fenamiphos recovered from the chip and wipe method I procedure on average decreased over time. A 58% reduction in residues occurred between 1.5 and 20.5 h after application.

A significant ($P < .05$) method by time interaction was found between the damp cheesecloth wipe and the damp cotton press. At 0.30 min. and 3.75h after application the damp cheesecloth wipe significantly dislodged a greater quantity of fenamiphos residues than the damp cotton press. By 19.5 h after application no significance was found between the two methods.

A significant method by time interaction was found among damp cheesecloth, damp cotton, and damp leather when compared on an equal area basis 3.75 and 19.50 h after application. Damp cheesecloth significantly dislodged a greater quantity of fenamiphos than damp cotton and damp leather 3.75 h after application. There was no significance between the damp cotton press and the damp leather press 3.75 h after application. There was no significance between the three methods 19.5 h after application.

ii. 29-30 October 1997

Fenamiphos residues dislodged by the chip and wipe method I procedure decreased over time. Dislodgeable residues decreased appreciably (60%) between 35 min. and 4 h after application. After 25 h a 92% decrease in fenamiphos residues had occurred.

Residues dislodged by the chip and wipe method II procedure decreased over time. An 84% decrease in fenamiphos residues occurred between 22 min. and 3.5 h after application. By 25 h after application a 98% reduction occurred.

PESTICIDE DISLODGEABILITY SUMMARY AND DISCUSSION

The greatest amount of pesticide was dislodged from the turf surface by rubbing with damp cheesecloth. Interestingly, however, when calculated on an equal area basis, as much or almost as much pesticide was removed by simply pressing damp cheesecloth against the turf surface. Relatively little pesticide was dislodged by the rolling golf grip or by a golf ball putted over the turf. The chip and wipe method dislodged a significant amount of pesticide. For isazofos only, damp leather dislodged more pesticide than damp cheesecloth.

1. 2,4 - D / Dicamba

In this study where irrigation was withheld until just prior to sampling 24 h after application, dislodgeable residues of 2,4 - D and dicamba remained throughout the first day of sampling. In addition, upon further drying of the applied material, dislodgeable residues of 2,4 - D and dicamba may increase slightly during the day that the materials were initially applied. The appreciable reduction in dislodgeable residues of 2,4 - D and dicamba observed 24 h after application can most likely be attributed to wash-off by irrigation supplied the next day prior to sampling. Similar observations have been reported by Thompson et. al. (1984).

A maximum of only 14 and 15% of the 2,4 - D and dicamba applied were recovered suggesting that a large fraction of the applied pesticides are readily absorbed or adsorbed by the plant since losses of 2,4 - D and dicamba by photodegradation and volatilization are minimal (WSSA Herbicide Handbook, 1994). This observation may also help to explain their persistent nature.

Surprisingly, no significance was found between the damp cheesecloth wipe and the damp cotton press methods when compared on an equal area basis. A couple of factors may have contributed to this finding. A large standard deviation may have masked any differences between the two methods. The weight used in the damp cotton press method (10.5 kg) may have provided sufficient force to dislodge a large fraction of the pesticide applied.

2. Isazofos / Chlorpyrifos / Fenamiphos

Dislodgeable Residues of all three organophosphate pesticides decreased rapidly. Several factors may have contributed to their rapid dissipation. Irrigation applied after application likely washed an appreciable portion of the applied pesticides from the turfgrass canopy into the soil and thatch. Over time the pesticides are adsorbed and or absorbed by the plant. Finally, all three pesticides have shown some appreciable degree of volatility (Exttoxnet, 1996).

The ability of each method to dislodge pesticide residues is particular to each pesticide. No significance was found between the damp cheesecloth wipe and the damp cotton press when compared on an equal area basis for isazofos with the exception of sampling at 3.75 h after application. This lack of significance can likely be attributed to a large standard deviation which masked any significance between the two methods. Significance was almost found between damp cheesecloth and damp cotton 0.30 h after application for chlorpyrifos. Again, a large standard deviation may have masked any significance. However, at 3.75 h after application the damp cheesecloth wipe significantly dislodged more chlorpyrifos than the damp cotton press indicating that wiping dislodges more chlorpyrifos residues than pressing because of its more vigorous nature. The same trend was also seen with fenamiphos where the damp cheesecloth wipe significantly dislodged a greater quantity of residues than the damp cotton press 0.30 and 3.75 h after application. The fact that there was no significance between the cheesecloth wipe and damp cotton press for all three pesticides 19.5 h after application is most likely due to the fact that only a very small quantity of dislodgeable residues still exists.

A comparison of the different methods including damp leather proved to be interesting. Damp leather significantly dislodged more isazofos at both 3.75 and 19.5 h after application than damp cheesecloth and damp cotton indicating that isazofos appears to have a greater degree of affinity for the damp leather material than it does damp cheesecloth and damp cotton. This preference for damp leather may be in part due to the lipophilic nature of the isazofos compound. This trend was not seen with chlorpyrifos or fenamiphos.

EXPOSURE AND RISK ASSESSMENT

1. Exposure Setting

A short, dense turfgrass surface serves as media upon which golfers compete. A variety of turfgrasses are used depending on the location of the golf course and the intended use of the turfgrass (tee, fairway, rough, and putting green). In Florida, a hybrid bermudagrass is most often the turfgrass of choice.

2. Identification of Exposure Pathways

Several pathways by which golfers may encounter pesticide residues exists. Direct and indirect contact may occur with the turfgrass surface. Direct dermal contact includes placement of the hand or fingers onto the turfgrass surface. This behavior is often exhibited by golfers during preparation for putting. Indirect dermal contact generally occurs when handling golf equipment such as golf balls, golf grips, and club faces that have direct contact with the turfgrass surface. Individually, these indirect pathways may not transfer a great deal of residues, however, the sum of the pathways can be appreciable especially if dermal contact leads to oral ingestion via hand-to-mouth contact.

3. Quantification of Exposure

Dislodgeable residues of two herbicides, two insecticides, and one nematicide were determined by various methods which attempt to simulate the previously noted exposure pathways. Damp cheesecloth wipe residues was used to provide the quantity of residues dislodged by human hand - turfgrass contact. Residues dislodged by the golf ball putt method served to provide the quantity of residues available for both dermal and oral exposure. The golf grip roll and chip and wipe methods provided the quantity of residues available for dermal contact.

For purposes of this study, a theoretical golfer was generated. This theoretical golfer was intended to serve as an extreme case of dermal and oral exposure. It is likely that most golfers will not exhibit the same behavior or receive as high a level of exposure as the theoretical golfer developed in this study.

i. Behavior Assumptions of the theoretical golfer

- 1.) One time placement of a single hand on the putting green surface.
- 2.) Handling of a golf grip following placement of the golf club on the putting green surface.
- 3.) Handling of a golf ball following two putts on the putting green surface.
- 4.) Handling of a golf club face and back following chipping (one chip per hole) onto the putting green surface.
- 5.) One placement of a the golf ball into the mouth following its use on the putting green surface.
- 6.) The golfer uses a bare hand to handle the golf grip and golf ball, remove debris from the club head, and touch the turfgrass surface of the putting green.

4. Risk Assessment

None of the pesticides used in this study have shown any carcinogenic effects. Therefore, assessing risk using the hazard index approach to assess potential non-cancer effects is appropriate and necessary. This approach compares the average daily intake (dermal and oral) of each pesticide to a published acceptable level of daily intake for chronic or subchronic exposure (RfD) (Borgert et. al., 1994). If the resulting hazard index is less than or equal to one, the chemicals are considered unlikely to represent a risk to human health. If the hazard index is greater than one, a potential risk to human health may exist (Davis and Klein, 1996).

Several exposure models have been used in determining risk (Ross, 1990, Zweigs et al, 1985, and USEPA, 1989). The Ross (1990) and Zweig et. al. (1985) models determined the transfer coefficients for their individual exposure environments. For example, in Ross's et. al. (1990) model subjects performed Jazzercise routines for 20 min. on carpet in pesticide-treated room. It is questionable as to whether a golfer's activity on a golf course is similar or can be related to a person performing a Jazzercise routine. In Zweig's et. al. (1985) model the dermal transfer coefficient was based on harvesters' dermal exposure upon reentering pesticide-treated crops. Again, exposure using this model would likely be exaggerated since golfers probably do not have the same or as frequent contact with vegetation as harvesters. Consequently, the use of such models could result in an overestimation of exposure and potentially cause unwarranted concern.

Several models, all of which are based on the USEPA (1989) model, were used in this study to determine if a significant toxicological risk is present. In these models, a transfer coefficient of 1.0 is assumed. For example, 100% of the pesticide dislodged by the golf ball is assumed to transfer from the golf ball to a persons hand. This is a conservative estimate. In reality 100% transfer is not likely. The exposure points used in the models were based on the theoretical golfer previously described in this chapter. The following equations which represent the dermal and oral doses are the basis upon which all of the equations used in the models are built.

Dermal Dose:

$$\frac{(QP_H + QP_B + QP_G + QP_{CF}) \times DP}{BW}$$

Oral Dose:

$$\frac{QP_B \times DP}{BW}$$

QP_H = Quantity of pesticide dislodged by a hand.

QP_B = Quantity of pesticide dislodged by a golf ball.

QP_G = Quantity of pesticide dislodged by a golf grip.

QP_{CF} = Quantity of pesticide dislodged by a golf club head

DP = Dermal permeability coefficient.

BW = Female body weight.

Total Dose: Dermal Dose + Oral Dose = Total Dose

Hazard Quotient: Total Dose / RfD Dose = Hazard Quotient

It is important to note that in the 2,4 - D and dicamba models, the QP_G is not include since a method for the extraction of 2,4 - D and dicamba from golf grips could not be developed during the course of this study.

5. An example of risk assessment calculations using chlorpyrifos.

The data collected in this study provide the basis for making risk assessments for a great variety of exposure scenarios. Several such examples will be presented in this report for chlorpyrifos. Calculations will be performed for additional scenarios and will be presented for chlorpyrifos and the other pesticides studied in the next annual report.

The adjusted damp cheesecloth wipe data which represents the quantity of pesticide dislodged by a hand, the golf ball data, and the golf grip data were taken from the study conducted on 3-4 June 1997. The chip and wipe II data were taken from the study conducted on 29-30 October 1997.

a. Model A

Exposure to chlorpyrifos occurs within 1 hr. after application. The exposure is assumed to occur on every putting green (18) every day for a lifetime.

Dermal Dose:

$$\frac{[(71.83\text{ug} \times 18) + 5.80\text{ug} + 7.02\text{ug} + (28.97\text{ug} \times 18)] \times 0.025}{56\text{kg}}$$

$$= 0.000816 \text{ mg kg}^{-1}$$

Oral Dose:

$$\frac{5.80\text{ug} \times 100\%}{56\text{kg}}$$

$$= 0.000104 \text{ mg kg}^{-1}$$

Total Dose:

$$0.000816 \text{ mg kg}^{-1} + 0.000104 \text{ mg kg}^{-1}$$

$$= 0.00092 \text{ mg kg}^{-1}$$

Hazard Quotient:

$$\frac{0.00092\text{mg / kg / day}}{0.003\text{mg / kg / day}} = 0.31$$

b. Model B

Exposure immediately after application occurs on at one putting green. Exposure at the 17 other putting greens occurs following irrigation. This exposure occurs over a lifetime.

Dermal Dose:

$$\frac{[71.83\text{ug} + (3.84\text{ug} \times 17) + 0.32\text{ug} + 0.71\text{ug} + 0.39\text{ug} + 28.97\text{ug} + (1.74\text{ug} \times 17)] \times 0.025}{56\text{kg}}$$

$$= 0.000088 \text{ mg kg}^{-1}$$

Oral Dose:

$$\frac{(0.32\text{ug} + 0.71\text{ug}) \times 100\%}{56\text{kg}}$$
$$= 0.000018 \text{ mg kg}^{-1}$$

Total Dose:

$$0.000088 \text{ mg kg}^{-1} + 0.000018 \text{ mg kg}^{-1}$$
$$= 0.00011 \text{ mg kg}^{-1}$$

Hazard Quotient:

$$\frac{0.00011 \text{ mg / kg / day}}{0.003 \text{ mg / kg / day}}$$
$$= 0.04$$

c. Model C

Exposure to chlorpyrifos following irrigation. The exposure occurs on every putting green (18) every day for a lifetime.

Dermal Dose:

$$\frac{[(3.84\text{ug} \times 18) + 0.75\text{ug} + 0.00\text{ug} + (1.74 \times 18)] \times 0.025}{56\text{kg}}$$
$$= 0.000045 \text{ mg kg}^{-1}$$

Oral Dose:

$$\frac{0.75\text{ug} \times 100\%}{56\text{kg}}$$
$$= 0.000013 \text{ mg kg}^{-1}$$

Total Dose:

$$0.000045 \text{ mg kg}^{-1} + 0.000013 \text{ mg kg}^{-1}$$
$$= 0.00006 \text{ mg kg}^{-1}$$

Hazard Quotient:

$$\frac{0.00006 \text{ mg / kg / day}}{0.003 \text{ mg / kg / day}}$$
$$= 0.02$$

d. Model D

Exposure to chlorpyrifos occurs the following day (19 - 20 h). The exposure takes place on all 18 putting greens every day for a lifetime.

Dermal Dose:

$$\frac{[(0.88 \text{ ug} \times 18) + 0.49 \text{ ug} + 0.00 \text{ ug} + (1.53 \times 18)] \times 0.025}{56 \text{ kg}}$$
$$= 0.00002 \text{ mg kg}^{-1}$$

Oral Dose:

$$\frac{0.49 \text{ ug} \times 100\%}{56 \text{ kg}}$$
$$= 0.000009 \text{ mg kg}^{-1}$$

Total Dose:

$$0.00002 \text{ mg kg}^{-1} + 0.000009 \text{ mg kg}^{-1}$$
$$= 0.000029 \text{ mg kg}^{-1}$$

Hazard Quotient:

$$\frac{0.000029 \text{ mg / kg / day}}{0.003 \text{ mg / kg / day}}$$
$$= 0.01$$

Clearly, the calculated risks for exposure to chlorpyrifos are not great for the golfing scenarios posed in this study. This is due, in part, to the high Reference Dose that has been established for this pesticide, and should not be taken to imply that exposure to all pesticides imposes a similar risk. Nevertheless, the dislodgeability data suggest that following irrigation the exposure, and therefore the risk, will be greatly reduced.

DEVELOPMENT OF A STABILIZED ORGANIC POLYMER (SOP) FOR REDUCING PESTICIDE LEACHING IN GOLF GREENS

Work on the development of a stabilized organic polymer (SOP) for reducing pesticide leaching in golf greens was reported to the USGA in annual reports and the final report of the project titled Mobility and Persistence of Turfgrass Pesticides Following Application to a USGA Green. The field evaluations of this material that were conducted after the final report was submitted for this project are reported herein.

INSTALLATION OF SOP IN LYSIMETERS

In October, 1997, silica sand was coated with a Stabilized Organic Polymer (SOP) at the rate of 10% by weight. The prepared material had a particle size range well within United States Golf Association (USGA) specifications (Table 7). USGA specification sand must be at least 60% medium+coarse, and less than 20% fine+very fine sand. On November 7, 1997, the twelve lysimeters in the USGA green at the Ft. Lauderdale Research and Education Center were excavated to the gravel layer. Five cm of coarse sand, corresponding in size to that used in the original greens construction (Cisar and Snyder, 1993), was placed over the gravel layer. The SOP-sand was mixed at a rate of 20% by volume with freshly-obtained USGA rooting mix sand that corresponded in particle size to that used in the original greens construction (Cisar and Snyder, 1993) to provide a 10 cm deep layer over the coarse sand in six of the twelve lysimeters. Additional freshly-obtained rooting mix sand was used to completely refill the excavated hole, and this sand also was used over the coarse sand layer in the six lysimeters that did not receive the SOP-sand treatment. SOP-sand treated and untreated lysimeters were arranged in blocked pairs. The cv. Tifdwarf bermudagrass sod cut from over the lysimeter was trimmed to a soil depth of approximately 4 cm and replaced over the lysimeter. The green was maintained using standard practices thereafter.

Table 7. Particle size range (mm) of SOP coated silica sand.

	Very coarse	Coarse	Medium	Fine	Very fine	Silt+Clay
> 2.00	2.00 - 1.00	1.00 - 0.05	0.05 - 0.25	0.25 - 0.10	0.10 - 0.05	< 0.05
----- % -----						
	0.1	1.2	28.5	56.2	12.9	0.8
						0.2

STUDY 1

METHODS AND MATERIALS. On November 12, 1997, the water collected in all lysimeters was evacuated and discarded. At approximately 1:00 PM, fenamiphos, as Namacure3E, was sprayed over the lysimeter area at the rate of 1.125 g A.I. m⁻², which is the label rate. Immediately after application, 1.7 cm of irrigation was applied to the area. Thereafter, irrigation

was applied as needed to maintain the turfgrass. The first rainfall was recorded at 7:00 AM on November 17th (3.00 cm). Being a Monday, the rainfall may have occurred anytime between 7:00 AM on the 14th and 7:00 AM on the 17th. Rainfall recorded on the 21st and 24th was 0.08 and 1.65 cm, respectively.

Lysimeter water was evacuated on November 14, 17, and 20. Pesticide in the lysimeter water was extracted with methyl chloride and analyzed by gas chromatography (Snyder and Cisar, 1993). A determination of both fenamiphos, and fenamiphos metabolite was performed.

RESULTS AND DISCUSSION. Considerably more water was collected in the lysimeters than could be accounted for on the basis of rainfall, probable irrigation, and expected evapotranspiration. While the reason for this finding was not determined, it is possible that soil in the recently reconstructed lysimeter profile may have had a much greater hydraulic conductivity than that of the long-established surrounding green, and the surface of the soil over the lysimeters may have been somewhat lower than in the surrounding area. Both of these factors could have resulted in movement of surface water, possibly containing pesticide, from areas surrounding the lysimeters to the lysimeters, with subsequent percolation through the lysimeters.

For lysimeter water collected over the period from November 14 to 20, there was a 72% reduction in fenamiphos leached in the SOP-sand lysimeters as compared to the unamended lysimeters (Fig. 1). For the more water soluble metabolite, the reduction in leaching was 54% (Fig. 2).

STUDY 2

METHODS AND MATERIALS. The area containing the lysimeters was maintained as a golf green since the previous study. Periodically, lysimeter water was evacuated and discarded. On the morning of July 28, 1998, the green was hollow-core aerified and topdressed, which are standard greens maintenance practices used to improve soil aeration and water penetration. In the afternoon, fenamiphos (Nemacure 3E) was mixed with 3 to 4 liters of water and applied with a sprinkling can over 1 m² areas centered over the lysimeters to provide an application rate of 1.125 g A.I. m⁻². The plot area was irrigated to provide 0.8 cm water, and maintained as a golf green thereafter. Lysimeter water sampling began on July 31 and continued weekly or more often through September 14. The samples were analyzed for fenamiphos and metabolite.

RESULTS AND DISCUSSION. There was no significant ($P < 0.05$) effect of SOP-sand on percolation, which averaged 57.7 cm during the seven weeks following fenamiphos application. Virtually no fenamiphos was leached in lysimeters containing SOP-sand (Fig. 3). Two weeks after application, total metabolite leaching was reduced 90% by SOP-sand (Fig. 4). The comparative reduction declined with time. Seven weeks after application total metabolite leaching was reduced 76% (Fig. 5). This apparently occurred because after the initial great adsorption of metabolite by SOP sand, there was a slow desorption of the material, as evidenced by a gradual increase in accumulative metabolite leaching in the SOP-sand lysimeters over time (Fig. 6). Nevertheless, the initial high concentration of metabolite in percolate was prevented by the SOP-

sand. The desorption characteristic of the SOP-sand might make it suitable as a "slow-release" carrier for pesticides.

CURRENT PROJECT STATUS AND FUTURE PLANS

A number of field studies on pesticide dislodgeability have been concluded. Risk assessment calculations on several golfing scenarios resulting from these studies have been completed for chlorpyrifos. A risk assessment for various golfing scenarios will be completed in the next year for the other pesticides studied. The graduate student working on this project, Mr. Raymond Snyder, will complete his M.S. thesis in the coming year. Measurement of pesticide volatilization will be made in the coming year, and the data will be subjected to risk assessment analysis.

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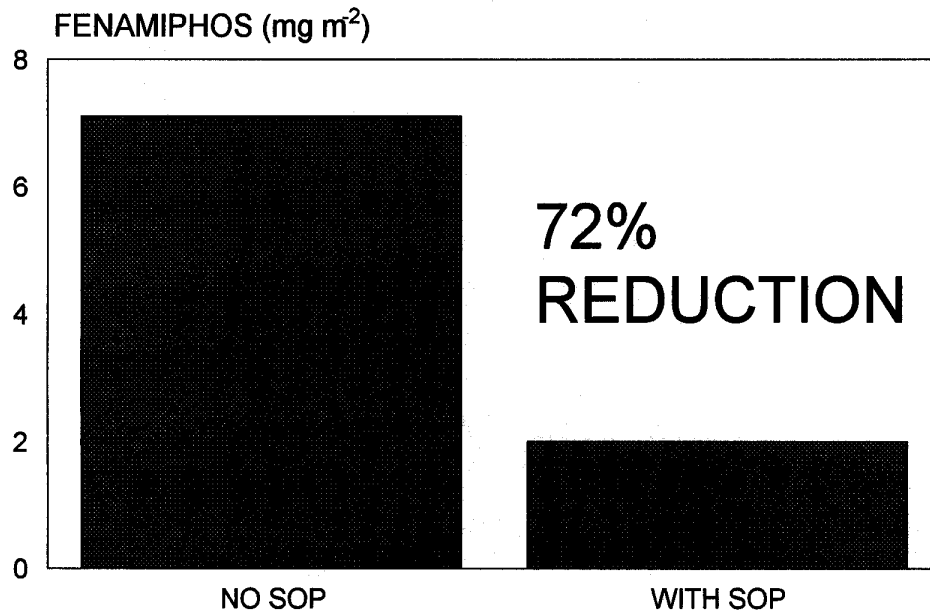


Fig. 1. Effect of SOP on fenamiphos leaching in the November, 1997 study.

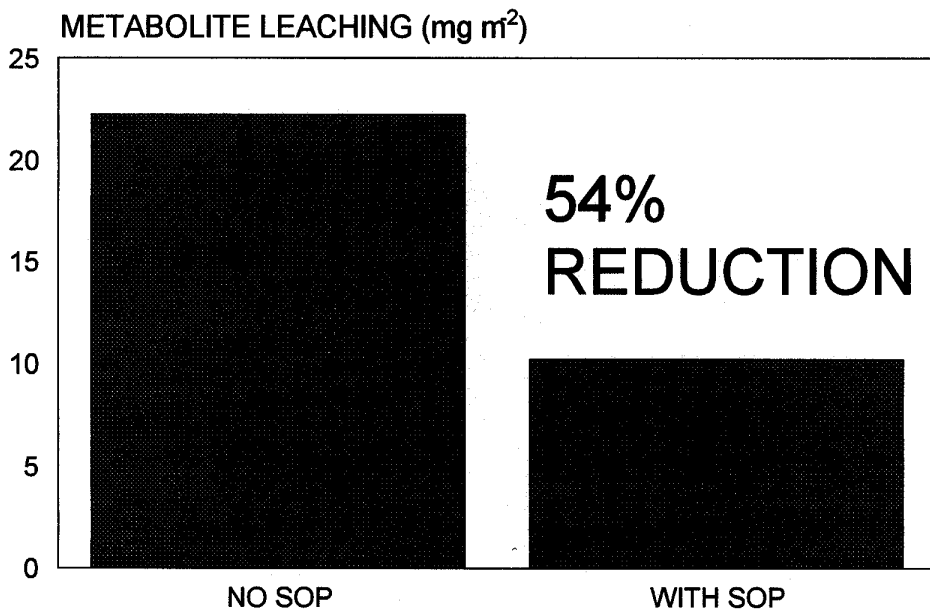


Fig. 2. Effect of SOP on metabolite leaching in the November, 1997 study.

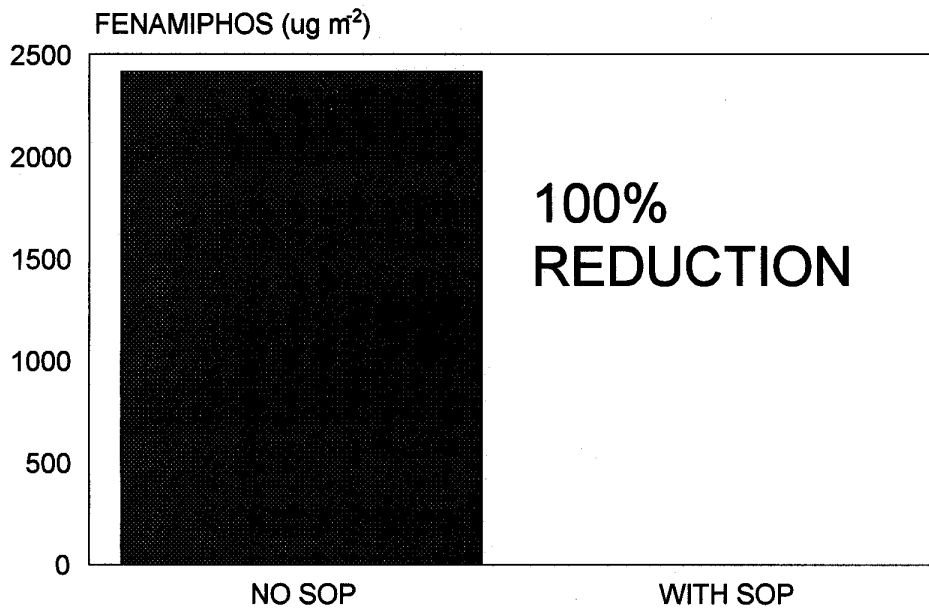


Fig. 3. Effect of SOP on fenamiphos leaching seven weeks after pesticide application in the August-September, 1998 study.

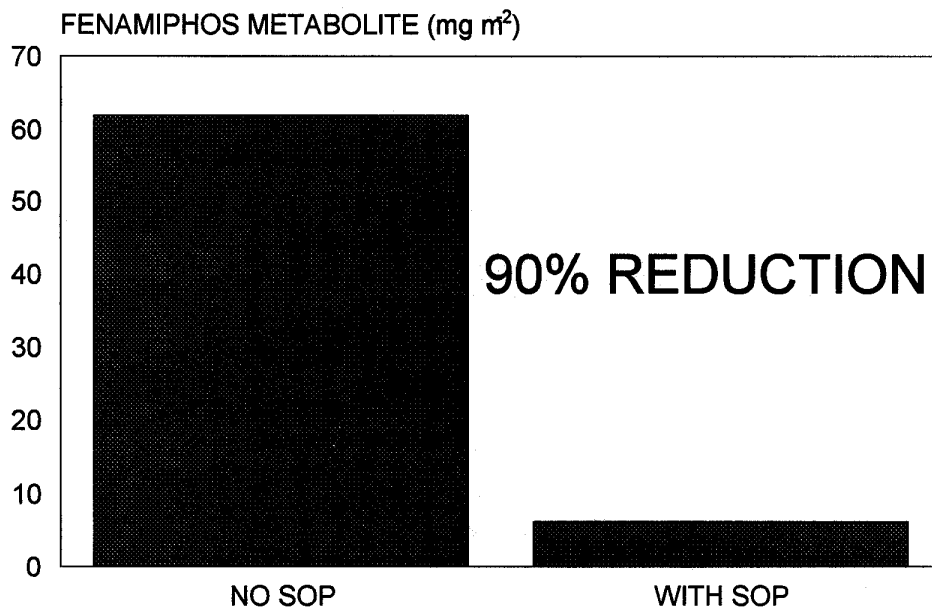


Fig. 4. Effect of SOP on fenamiphos metabolite leaching two weeks after pesticide application in the August-September, 1998 study.

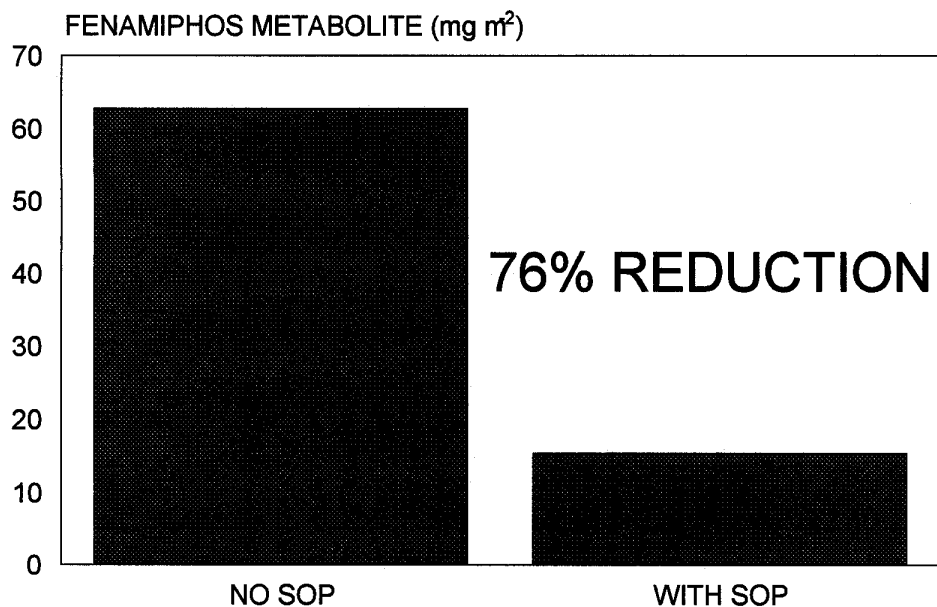


Fig. 5. Effect of SOP on fenamiphos metabolite leaching seven weeks after pesticide application in the August-September, 1998 study.

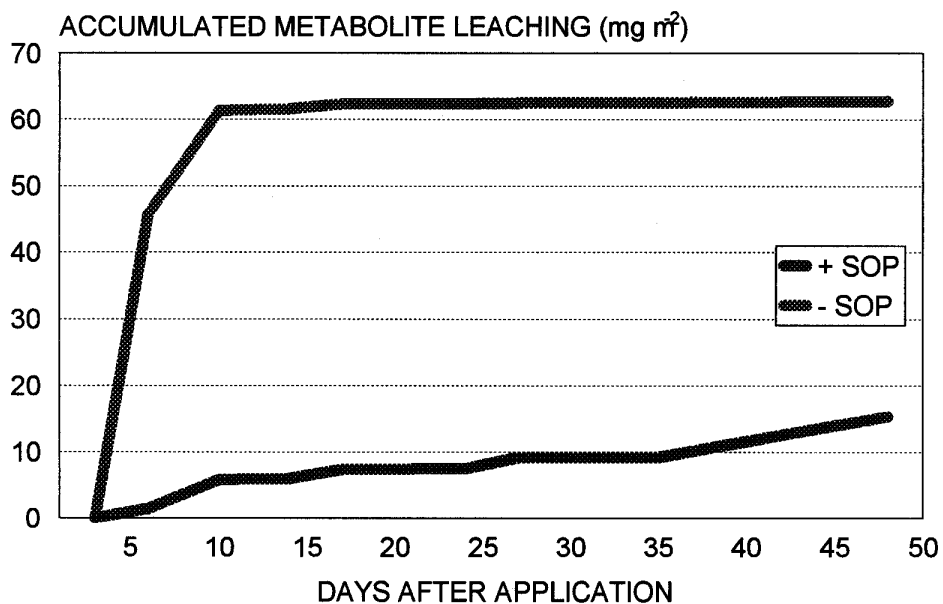


Fig. 6. Effect of time on accumulated fenamiphos metabolite leaching in the August-September, 1998 study.