EXECUTIVE SUMMARY

MOBILITY AND PERSISTENCE OF TURFGRASS PESTICIDES IN A USGA GREEN

George H. Snyder and John L. Cisar
University of Florida, IFAS

The use of reduced irrigation for one week following fenamiphos application was studied as a means of reducing fenamiphos/metabolite leaching in a USGA green in south Florida. Leaching was reduced during the period of limited irrigation, but total leaching was equivalent for low and high irrigation treatments over a longer period that included plentiful irrigation and rainfall. It appeared that the fenamiphos and its metabolites that were not leached when irrigation was restricted eventually leached when excessive irrigation and rainfall occurred.

The percolate collection system in the USGA green at the Ft. Lauderdale Research and Education Center was expanded to include twelve lysimeters. This will permit greater numbers of replications in studies involving two or more treatments, which is very important for pesticide studies. During excavation it was noted that 7 cm of topdressing had accumulated on the green since the lysimeters were first installed. This layer appeared to hold more water than the underlying media. It contained somewhat higher percentages of the finer sand sizes. It also had considerable more organic matter than either the original rooting mix or than the topdressing material. No movement of rootzone mix into the coarse sand layer, or of coarse sand into the underlying gravel was observed during excavation for the newly-added lysimeters.

Volatilization of the organophosphate pesticides isazofos, chlorpyrifos, and fenamiphos was measured in two studies using the Theoretical Profile Shape technique. Volatilization was greatest for chlorpyrifos, and least for fenamiphos. It was less for an application that was followed by rainfall than for one followed by dry weather. Isazofos volatilization amounted to 1 and 9% of that applied for the two rainfall situations, respectively.

Fenamiphos and fenamiphos metabolite adsorption by a stabilized organic polymer (SOP) was investigated in the laboratory. It was determined that when mixed with sand at the rate of 15% by volume, SOP could retain an amount of metabolite equivalent to the recommended rate of fenamiphos. Sufficient SOP of has been prepared for field studies on the USGA green.

The principal investigators each spent approximately 40% of their time on the project, and other University personnel contributed approximately 2.5 full-time equivalents. Grant funds were utilized as 73% for labor, 13% for supplies, and 14% for university-withheld overhead.

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Submitted to: Dr. Michael P. Kenna
United States Golf Association
Green Section Research
P. O. Box 2227
Stillwater, OK 74076

Submitted by: Dr. George H. Snyder
University of Florida, IFAS
Everglades Research and Education Center
P. O. Box 8003
Belle Glade, FL 33430

and

Dr. John L. Cisar
University of Florida, IFAS
Ft. Lauderdale Research and Education Center
3205 S. W. College Avenue
Ft. Lauderdale, FL 33314

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George H. Snyder and John L. Cisar
University of Florida, IFAS

ABSTRACT

Leaching of the pesticide fenamiphos, and especially of its metabolites, has become a concern because these compounds have been observed in groundwater and surface waters in and around golf courses. The use of reduced irrigation for one week following fenamiphos application was studied as a means of reducing fenamiphos/metabolite leaching in a USGA green in south Florida. Leaching was reduced during the period of limited irrigation, but total leaching was equivalent for low and high irrigation treatments over a longer period that included plentiful irrigation and rainfall. It appeared that the fenamiphos and its metabolites that were not leached when irrigation was restricted eventually leached when excessive irrigation and rainfall occurred.

The percolate collection system in the USGA green at the Ft. Lauderdale Research and Education Center was expanded to include twelve lysimeters. This will permit greater numbers of replications in studies involving two or more treatments, which is very important for pesticide studies. During excavation it was noted that 7 cm of topdressing had accumulated on the green since the lysimeters were first installed. This layer appeared to hold more water than the underlying media. It contained somewhat higher percentages of the finer sand sizes. It also had considerable more organic matter than either the original rooting mix or than the topdressing material. No movement of rootzone mix into the coarse sand layer, or of coarse sand into the underlying gravel was observed during excavation for the newly-added lysimeters.

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Fenamiphos and fenamiphos metabolite adsorption by a stabilized organic polymer (SOP) was investigated in the laboratory. It was determined that when mixed with sand at the rate of 15% by volume, SOP could retain an amount of metabolite equivalent to the recommended rate of fenamiphos. Sufficient SOP of various sand sizes has been prepared for field studies on the USGA green.

IRRIGATION MANAGEMENT FOR REDUCING FENAMIPHOS LEACHING

INTRODUCTION

Fenamiphos (Nemacur) is widely used for nematode control on greens and fairways in Florida. There are few labeled alternatives to this pesticide. Snyder and Cisar (1993) observed considerable leaching of fenamiphos metabolites (sulfoxides and sulfones) following fenamiphos application to a USGA green. Leaching of the metabolites, and to a lesser extent the parent compound, greatly exceeded that of all other organophosphates examined by the authors in a USGA-sponsored three-year program (Snyder and Cisar, 1995). Because fenamiphos has been observed in waters in or adjacent to golf courses (Swancar, 1996), and because of a highly-publicized fish kill in south Florida (Zaneski, 1994), the State of Florida Department of Environmental Protection has issued new regulations for limiting fenamiphos use on golf courses, and continues to review the situation. Since fenamiphos is important to the golf industry in Florida, and there is concern about leaching of fenamiphos and/or its metabolites, methods need to be identified to allow the use of fenamiphos in ways that do not lead to significant leaching. Irrigation management was investigated for this purpose.

METHODS AND MATERIALS

An irrigation management study was undertaken on a previously-described (Cisar and Snyder, 1993) USGA green fitted with six stainless-steel lysimeters for collecting percolate at the University of Florida Ft. Lauderdale Research and Education Center (FLREC) in south Florida to evaluate the hypothesis that reducing water percolation through prudent irrigation management following fenamiphos application could reduce pesticide leaching.

On June 7, 1995 fenamiphos was applied as a 10G product across the lysimeter area at the rate of 1.125 g A.I. m^{-2}. Fenamiphos had not been applied previously to the green since 27 January, 1992. One-m^{-2} areas centered over three lysimeters received irrigation by hand using a sprinkler can twice weekly at 12.5 mm per application (Low Irrigation), and three areas received the same amount of irrigation on a daily basis (High Irrigation). Thus the Low Irrigation plots were irrigated on 7, 10, and 13 June, and the High Irrigation plots were irrigated each day. For the first 6 days of the study, the plots were covered with plywood at night to prevent irrigation by the system used to irrigate the remainder of the green, and when rain appeared imminent. Thereafter, the differential irrigation treatments and rainfall protection were suspended, with all plots receiving irrigation from the commercial sprinkler system. Percolate was withdrawn from the lysimeters daily for the first week after fenamiphos application, and at 3 to 5 days intervals for the next two weeks. The water was analyzed for fenamiphos and its metabolites (sulfoxide+sulfone) in the manner previously described (Snyder and Cisar, 1993). Thatch and soil (0-5, 5-10, and 10-15 cm depths) were samples several times weekly, and analyzed for fenamiphos and metabolite as previously described (Snyder and Cisar, 1993).

The study was repeated beginning January 16, 1996. Fenamiphos was applied to the lysimeter area in the above-described manner, except that lysimeters that were used for the Low Irrigation plots in 1995 were used for the High Irrigation plots in 1996, and lysimeters used for the High Irrigation plots in 1995 were used for the Low Irrigation plots in 1996. The Low Irrigation plots were irrigated at 12.5 mm per application on January 19, 23, and 25, and the High Irrigation plots were irrigated at the same rate, daily. Following the January 25th irrigation, all plots received routine irrigation from the commercial sprinkler system, and 52 mm of rainfall+irrigation on January 29, 1996.

RESULTS AND DISCUSSION

Fenamiphos generally was higher in thatch for Low Irrigation in the 1995 and 1996 studies, although the differences between the two irrigation treatments were not great for the relatively immobile parent compound (Fig. 1). Metabolite also was greater in thatch for Low Irrigation in both years (Fig. 2). In the deeper portion of the soil profile (10 - 15 cm), when differences occurred the metabolite was greater for High Irrigation in both years (Fig. 3). Thus the distribution of the more mobile metabolite in the soil profile suggests that the Low Irrigation treatment reduced movement out of the thatch layer into the deeper portion of the soil profile. Figures depicting fenamiphos and metabolite concentrations in other soil layers are included in the Appendix.

Analysis of the percolate water provides more direct evidence of the effect of irrigation on pesticide movement than do the soil data. For the first two weeks of the first study, the Low Irrigation treatment clearly reduced fenamiphos leaching (Fig. 4a). However, following a 72 mm rainfall on 20 June, more fenamiphos was observed to leach from the Low Irrigation treatment than in the High Irrigation treatment (Fig. 4b).

The same trend for irrigation occurred for metabolite leaching as for fenamiphos, but with much greater amounts being observed (Fig. 5a, 5b). Note that the units used in Fig. 4 are $\mu g\ M^{-2}$, whereas in Fig. 5 they are $mg\ M^{-2}$, with the latter being 1000 times the former. Metabolite leaching was much reduced for the Low Irrigation treatment two weeks after pesticide application (Fig. 5a). However, more leaching was observed from the Low Irrigation treatment following the rainfall event on 20

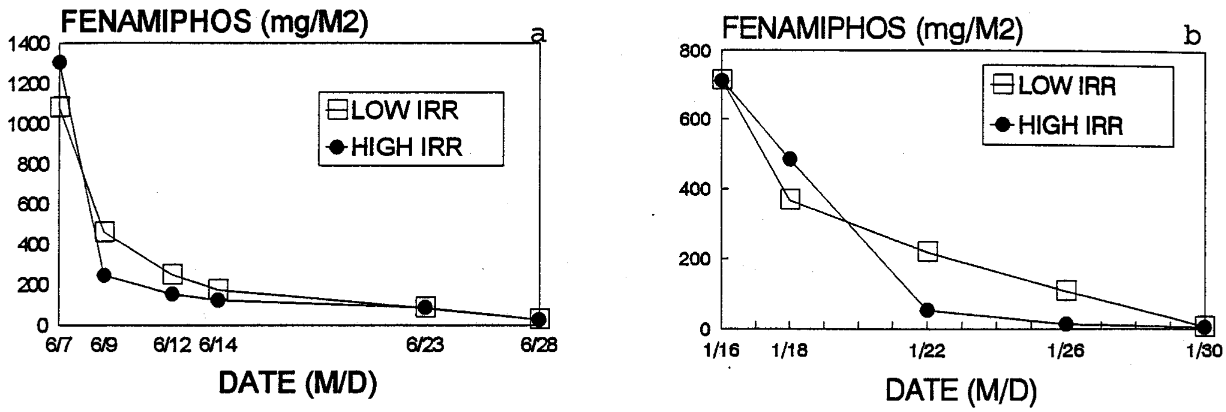

Fig. 1. Effect of irrigation on fenamiphos in thatch following application on a) 7 June 1995 and b) 16 January 1996.

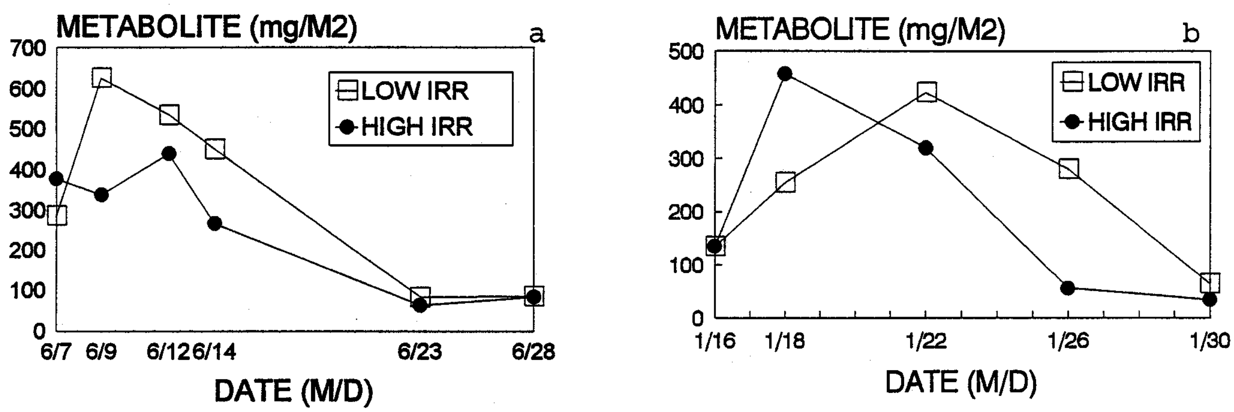

Fig. 2. Effect of irrigation on metabolite in thatch following application of fenamiphos on a) 7 June 1995 and b) 16 January 1996 (right).

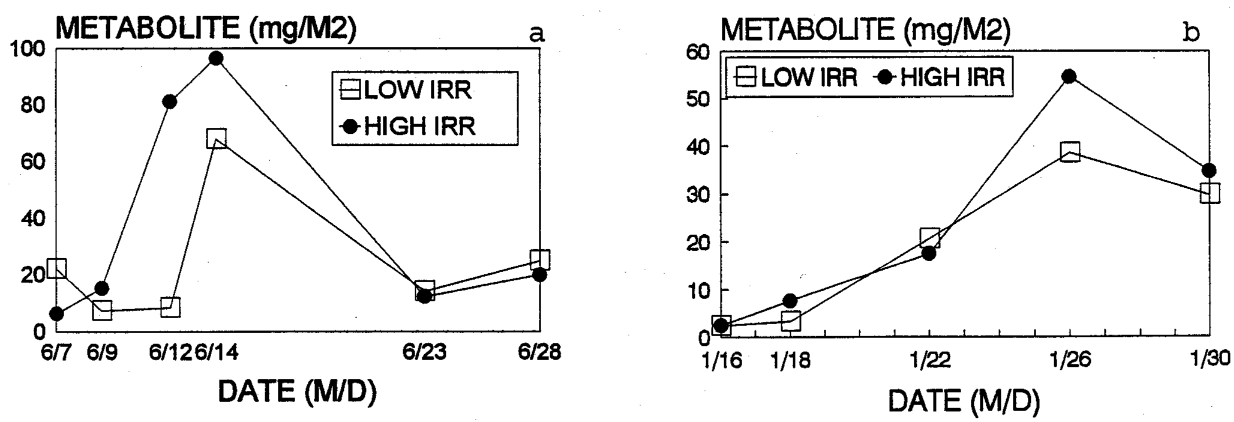

Fig. 3. Effect of irrigation on metabolite in the 10-15 cm layer following fenamiphos application on a) 7 June 1995 and b) 16 January 1996 (right).

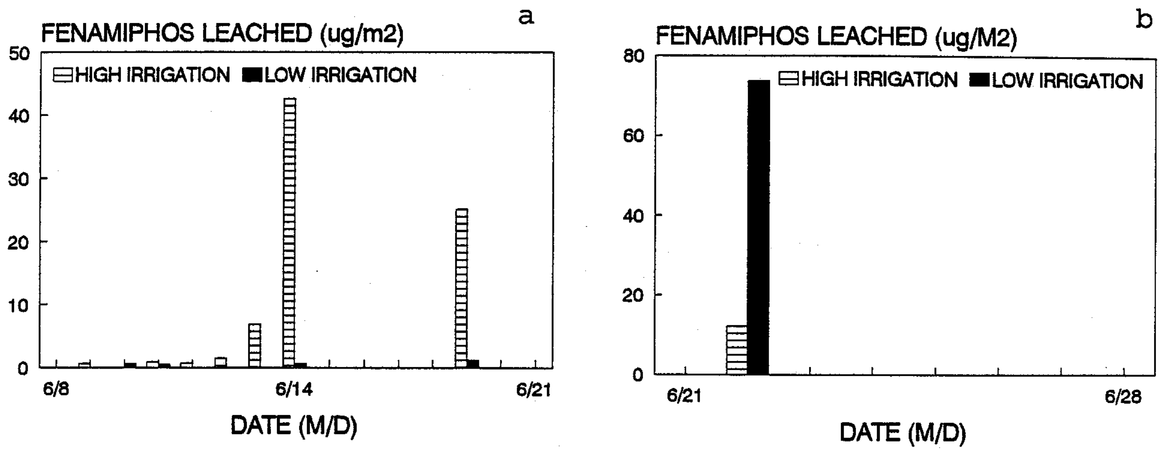

Fig. 4. Effect of irrigation on fenamiphos leaching following fenamiphos application on 7 June 1995 for a) the first two weeks after application, and b) following rainfall on 20 and 23 June.

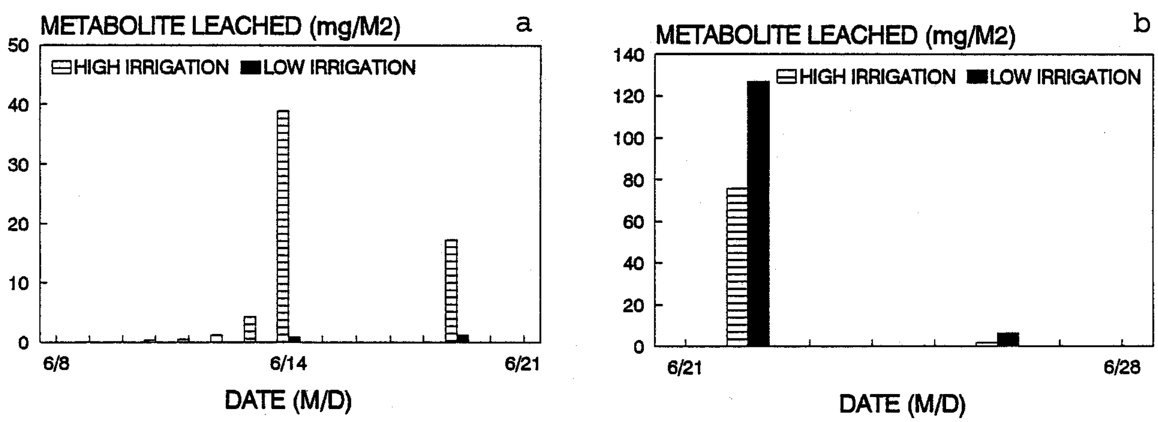

Fig. 5. Effect of irrigation on metabolite leaching following fenamiphos application on 7 June 1995 for a) the first two weeks after application, and b) following rainfall on 20 and 23 June.

June than was observed in the High Irrigation treatment (Fig. 5b). The same observation was made following a 46 mm rainfall on 23 June, i.e., more metabolite leaching occurred in the Low Irrigation treatment.

The fenamiphos and metabolite leaching data from the 1996 study were similar to that collected in 1995. Fenamiphos leaching was reduced for Low Irrigation during the week after pesticide application when the differential irrigation treatments were used (Fig. 6a). But when appreciable irrigation and rainfall occurred on all plots, greater or nearly as much leaching was observed in the plots previously receiving low irrigation (Fig. 6b). Metabolite leaching in 1996 generally followed the same pattern observed in the previous year, with metabolite leaching usually being lower for the Low Irrigation treatment during the first week after pesticide application (Fig. 7a), but being greater for the Low Irrigation treatment following irrigation and precipitation on all plots (Fig. 7b).

In 1995, total fenamiphos leaching over the three-week period was 90 $\mu g\ m^{-2}$ for the High Irrigation treatment, as compared to 77 $\mu g\ m^{-2}$ for the Low Irrigation treatment. In 1996 the comparative values were 367 and 49 $\mu g\ m^{-2}$, respectively. There was no statistically-significant ($p < 0.10$) difference between the treatments in either year. For the metabolites, total leaching amounted to 141 and 135 mg m^{-2} for the High and Low irrigation treatments, respectively, in 1995, and 17 and 38 mg m^{-2}, respectively, in 1996, with no significant differences between treatments in either year.

It is interesting to note that in the first study, which was conducted on a portion of the green that had not been treated with fenamiphos for 3 1/2 years, metabolite leaching averaged 12.3% of the fenamiphos applied. In 1996, it averaged only 2.1% of the applied rate of fenamiphos. The observation of considerably less leaching of metabolite following a second, closely-spaced, fenamiphos application is consistent with the observation that fenamiphos and, presumably, fenamiphos-metabolite degrading microorganism populations increase following a fenamiphos application (Ou, 1991). The observation also is consistent with the authors' previously-published experience with fenamiphos (Snyder and Cisar, 1993), in which metabolite leaching following an initial application of fenamiphos amounted to 17.7% of the parent compound applied, whereas following the second application metabolite leaching amounted to only 1.1% of the applied rate of fenamiphos.

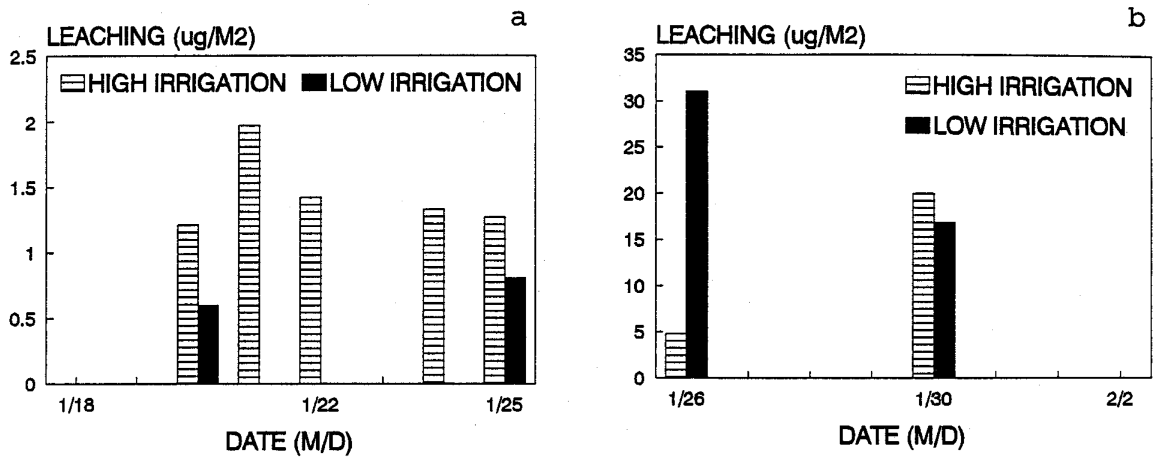

Fig. 6. Effect of irrigation on fenamiphos leaching following fenamiphos application on 16 January 1996 for a) the first week after application, and b) following exposure of all plots to routine irrigation and to rainfall.

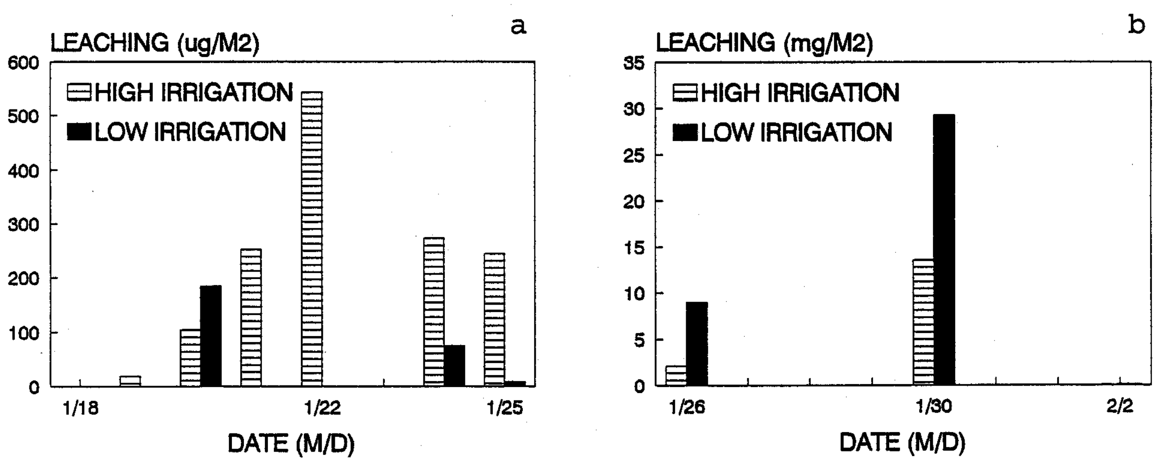

Fig. 7. Effect of irrigation on metabolite leaching following fenamiphos application on 16 January 1996 for a) the first week after application, and b) following exposure of all plots to routine irrigation and to rainfall.

CONCLUSION

Both studies suggest that fenamiphos, and its more mobile metabolites, remained in the soil under the Low Irrigation treatment, but were subject to leaching when major percolation events occurred, resulting in statistically similar total leaching for the two irrigation treatments over the full length of each study. Thus it is questionable whether irrigation control alone can provide assurance against leaching of fenamiphos/metabolites in south Florida where abundant rainfall can occur at any time of the year, or in similar climates. Irrigation management might be more effective for reducing leaching of both parent and metabolite compounds in arid climates, as is evidenced by the reduced leaching observed during the period when the Low Irrigation plots were not exposed to rainfall. This hypothesis awaits testing.

LYSIMETER SYSTEM REPAIR AND EXPANSION

During the spring and early summer of 1996, problems developed with the lysimeters on the USGA green at the FLREC such that percolate extraction from some lysimeters became irregular, and in some cases the water samples were clouded with soil and organic matter. A number of attempts were made to correct the problem in situ, without success, so the lysimeters had to be excavated to locate the problem. It was discovered that silver-soldered joints in certain extraction lines had developed leaks. The fittings were replaced with stainless-steel compression fittings. While the lysimeter system was under repair, an additional six lysimeters were installed. One lysimeter was added to the west side of each of the three existing east-west rows, and a new row of three lysimeters was added to the north side of the existing rows (Fig. 8). There now are twelve lysimeters in all, making it possible to conduct experiments with six replications of two treatments or four replications of three treatments, where before there could be only three replications of two treatments, which really are not enough for pesticide studies. Specially-modified switching valves were purchased so that the six stations for collecting percolate within the shed on the edge of the green could accommodate twelve lysimeters.

During the excavation process, it was noted that the soil surface was approximately 7 cm higher than at the time of the original lysimeter installation, presumably due to frequent topdressing of the green. The accumulated layer was noticeable because it was darker in color and appeared to contain more moisture than the underlying soil. The organic matter content and particle size distribution were determined for the accumulated layer and for the topdressing material that has been used consistently for the past several years, and compared with

LYSIMETER ARRANGEMENT

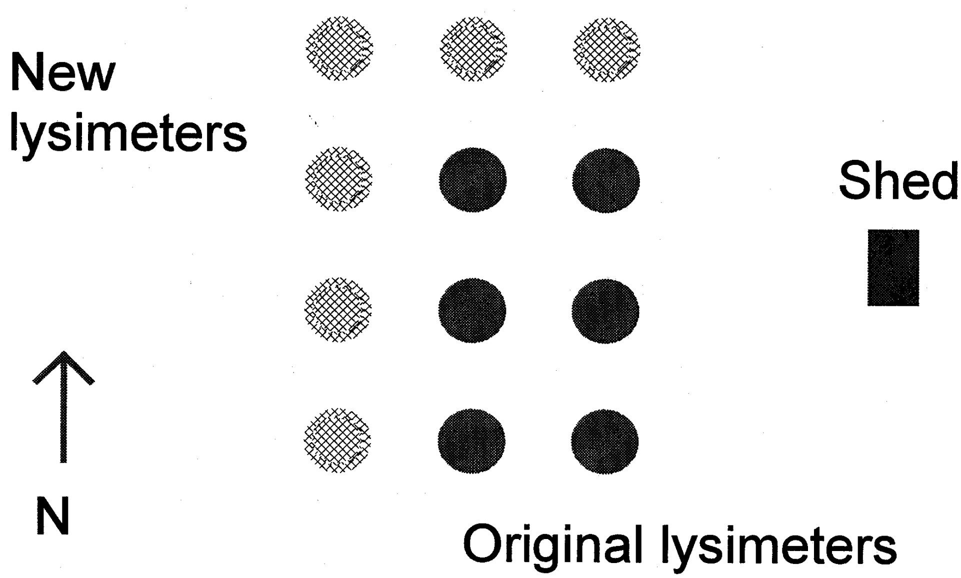

Fig. 8. Schematic of lysimeter arrangement showing the location of the new and previously existing lysimeters on the USGA green at the FLREC.

the original rootzone mix (Table 1). Although the total of the MS and CS fractions does not vary greatly among the three

Table 1. Organic matter content and particle size distribution of the FLREC USGA green original rooting media, top-dressing sand, and accumulated topdressing layer.

Particle size		Original	Topdressing	Accumulation
Designation	mm		%	
Gravel	>2.0	0	0.3	0
VCS	1.0-2.0	17.0	9.6	6.9
CS	0.5-1.0	59.3	48.0	44.6
MS	0.25-0.5	18.2	34.1	32.6
FS	0.10-0.25	4.6	7.9	14.9
VFS	0.05-0.10	0	0	0.6
Silt	<0.05	0	0	0.6
Total CS+MS		77.5	82.1	77.2
Organic matter		0.7	0.9	4.7

materials, the topdressing has roughly half the VCS, less CS, and approximately and twice the MS and FS as the original soil, making it finer textured and more conducive to water retention. The accumulated layer reflects this shift in particle size distribution which, along with the accumulated organic matter, may account for the darker color and apparent greater water-holding capacity of the accumulated layer. When the sod above the old and new lysimeters was removed, the accumulated layer was removed with the grass. The combination will be replaced, thereby maintaining the character of the entire green above the lysimeters.

During lysimeter excavation, it also was noted that there was no visible migration of rootzone mix into the coarse sand (choker) layer, or of coarse sand into the gravel layer. The boundaries were clean and sharp, indicating that the layers were properly sized and stable in this green.

PESTICIDE VOLATILIZATION

While the lysimeter system was being repaired, two studies of pesticide volatilization were conducted using the Theoretical Profile Shape technique described by Jenkins et al. (1993). Isazofos, chlorpyrifos, and fenamiphos were applied at 0.229, 0.229, and 1.125 g AI m^{-2}, respectively, to a bermudagrass green at the FLREC. Fenamiphos was applied as a granular material in the first study, and the other pesticides were applied as emulsifiable concentrates (EC). In the second study, EC materials were used for all three pesticides. Following Jenkins et al., pesticides were applied over a 20 m radius circle. Airborne residues were collected with a Staplex TF1A high volume air sampler containing Amberlite XAD-4 polymeric resin set in the center of the circle at a height of 73 cm. Wind speed was measured with a standard anemometer. In the first study, which was conducted on a cloudy, rainy day, the pesticide applications were completed by 10 AM on October 4, 1996. Resin was changed at 2 h intervals for the first six hours, and then at 18 and 24 hours. Irrigation following pesticide application totaled 0.6 cm, but 1.25 cm rainfall occurred several hours later, and another 2.69 cm fell during the evening and night of the same day. In the second study, which was conducted on a clear day, pesticides were applied by 10:30 AM on October 10, and resin was changed hourly for the first six hours, after one-half hour of exposure, and then left in place overnight for an additional 14 hours. Irrigation totaling 0.6 cm followed application of the pesticides, and there was no rainfall. Pesticides were extracted from the resin with methylene chloride and analyzed by GC.

RESULTS AND DISCUSSION

Volatilization of all three pesticides decreased rapidly with time after application, (Fig. 9 and 10). Total volatilization was considerably greater in the second study, which was conducted on a clear day, than on the first (Table 2).

Table 2. Volatilization of isazofos, chlorpyrifos, and fenamiphos following application to a bermudagrass green on two dates.

Pesticide	Application date: October 4[a]		October 10[b]	
	$mg\ m^{-2}$	% of applied	$mg\ m^{-2}$	% of applied
Isazofos	2.38	1.04	20.93	9.14
Chlorpyrifos	6.13	2.66	26.54	11.59
Fenamiphos	0.40	0.04	2.8	0.25

[a] Collected over a 48 hour period on a cloudy, rainy day.
[b] Collected over a 22 hour period on a clear day.

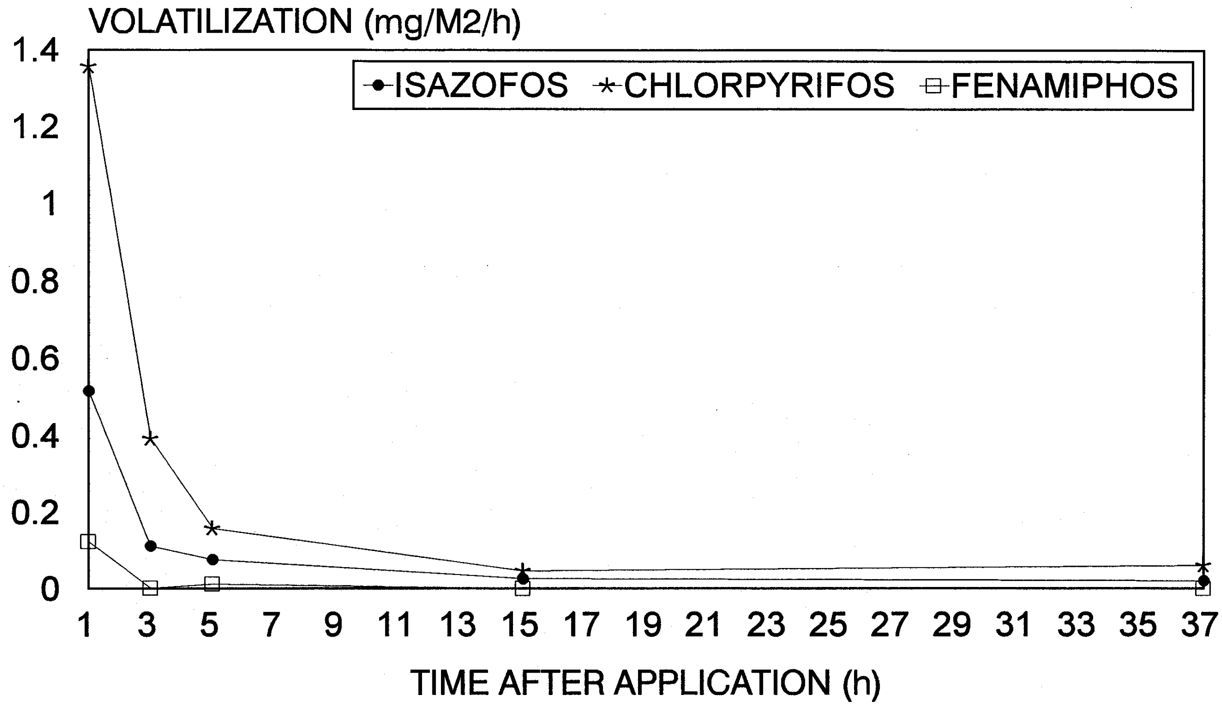

Fig. 9. Volatilization of isazofos, chlorpyrifos, and fenamiphos during a rainy, cloudy period.

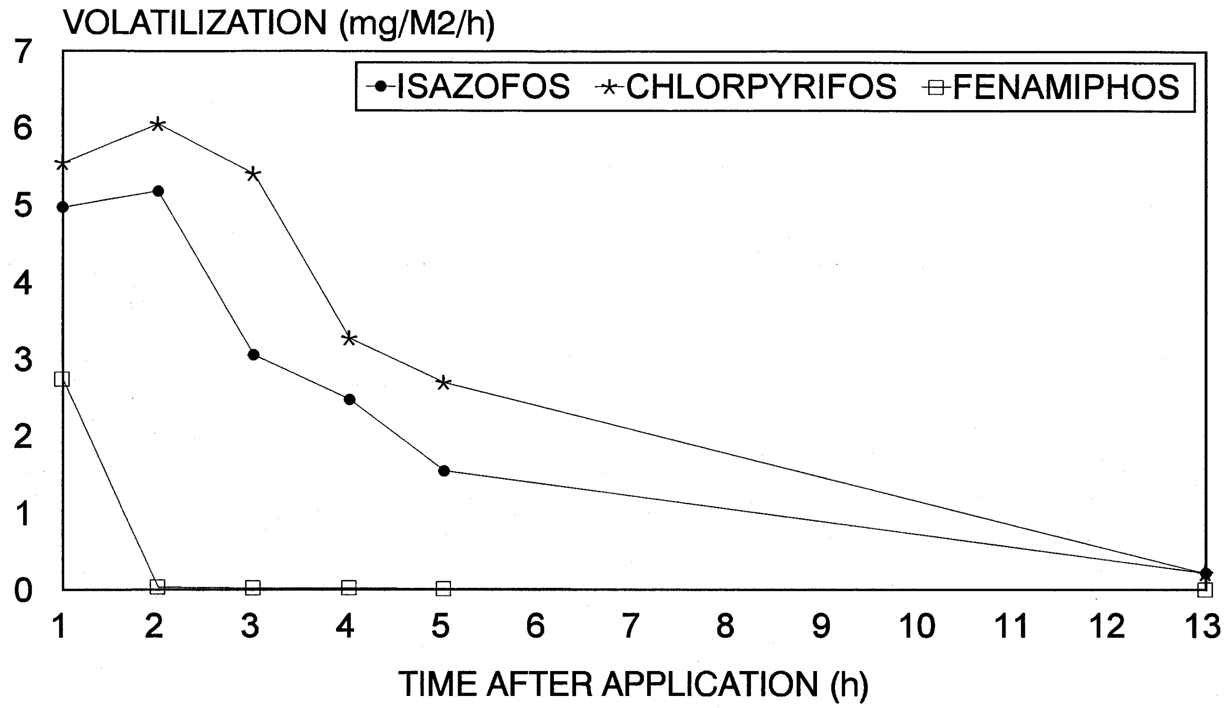

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Fig. 10. Volatilization of isazofos, chloropyrifos, and fenamiphos during a clear, dry period.

The differences in rainfall and sunshine between the two studies easily account for the differences in volatilization that were observed. Using the same application rate and sampling technique, Cooper et al. (1955) reported isazofos volatile loss of 5.8% during the first day after application. Since their study was conducted in August and their irrigation was greater (1.25 cm) than ours in the second study, but less than the irrigation+rainfall that occurred in our first study, the values obtained for isazofos in our studies appear to agree well with that obtained by Cooper et al. Nevertheless, we feel that our application of the technique requires further verification, particularly in regards to concerns we have about possible incomplete trapping of the pesticides by the resin. Then, additional volatilization studies will be conducted.

PESTICIDE ADSORPTION WITH SOP

A stabilized organic polymer (SOP) was made from sugarcane filter-cake stabilized with a phenol-formaldehyde polymer. The resulting material was crushed and graded into particles corresponding to very coarse sand (1.0-2.0 mm), coarse sand (0.5-1.0 mm), and medium sand (0.25-0.50 mm).

Due to the unavailability of fenamiphos metabolite (sulfone), a protocol was developed for synthesizing sulfone in a pure crystalline form from fenamiphos. Fenamiphos was oxidized with aqueous potassium permanganate and the resultant sulfone was extracted into methylene chloride. After evaporation of the solvent, the crude sulfone was solubilized in ethanol:water (65:35). This solution was extracted with hexane:ether (50:50) to remove coextractants, the sulfone remaining in the ethanol:water phase. Pure (92%) sulfone crystals created by enrichment of the ethanol:water with water were isolated by filtration.

The adsorption capacity of various size grades of SOP for fenamiphos and fenamiphos metabolite was determined in 1.25 cm diameter glass columns containing 10-cm sections of 15% (v/v) SOP mixed in a USGA-sand. An excess of fenamiphos (11 mg) and metabolite (12 mg) was applied at the top of separate columns (4 replications for each organophosphate) and leached into the profile with small increments of water. Then the columns were flushed with two, 50 ml portions of water. Each resultant leachate was analyzed for fenamiphos or metabolite by placing 200 μl of leachate into 10 ml methylene chloride. After adding anhydrous sodium sulfate and shaking, the methylene chloride:organophosphate mixes were decanted into vials for analysis by gas chromatography. Adsorption was calculated as the difference between organophosphate applied minus that obtained in the total leachate. A similar adsorption capacity experiment was conducted for coarse-sand size activated charcoal and for the inorganic soil amendment "Profile".

The charcoal and inorganic amendment displayed little pesticide-retention capacity (Table 3). The finer sizes of SOP retained appreciable quantities of fenamiphos and sulfone. If a layer of 0.5 mm diameter SOP particles two particles deep were contained within the profile, the total volume of the SOP would be approximately 1 liter m^{-2}. Since the recommended rate of fenamiphos is 1125 mg m^{-2}, it appears that the 2-particle layer could absorb an entire application rate of fenamiphos or metabolite (Table 3). However, in previous studies, less than

Table 3. Adsorption capacity for fenamiphos and fenamiphos sulfone of various SOP grades, charcoal, and Profile.

Material*	Fenamiphos	Sulfone	Fenamiphos	Sulfone
	mg g^{-1}		mg L^{-1}	
SOP-VCS	2.39	0.69	1434	414
SOP-CS	2.30	1.97	1380	1182
SOP-MS	2.39	2.27	1434	1362
CS-Charcoal	0	0	0	0
Profile	0	0	0	0

* VCS = 1-2 mm, CS = 0.5-1.0 mm, and MS = 0.25-0.50 mm.

1% of the applied fenamiphos and no more than 18% of the metabolite leached (Snyder and Cisar, 1995), which indicates that even a small amount of SOP could absorb leachate from numerous applications of fenamiphos.

It is not proposed that SOP be placed in a single layer within the rootzone, but rather it be mixed into the lower portion of the rootzone mix, below the probable location of target organisms. It is statistically improbable that percolation water carrying pesticide would encounter two SOP granules when mixed at the rate of 1 liter m^{-2} (1% by volume in a 10 cm layer). A column study was conducted to determine the effect of SOP concentration in a 10 cm layer of USGA-sand on the adsorption of fenamiphos metabolite (sulfone). The study was conducted in a manner analogous to the study described above for determining the adsorption capacity of the SOP, except that an application rate of 1.125 g AI m^{-2} was used instead of an "excess". Based on this study, it appeared that SOP needs to be incorporated at a rate of 15% (v/v) to adsorb an amount of sulfone nearly equal to the normal application rate of fenamiphos (Fig. 11). The indication that this higher rate is required to

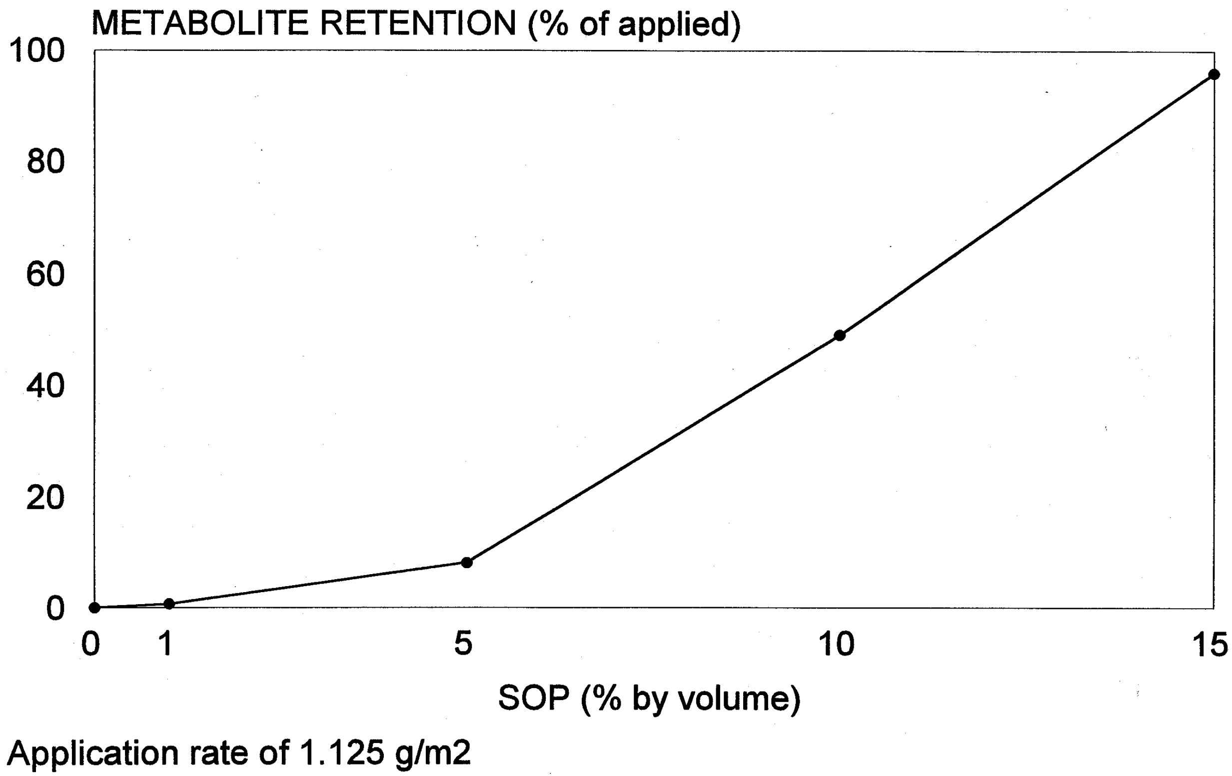

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Fig. 11. Effect of SOP on retention of fenamiphos metabolite applied at 1.125 g AI m^{-2}.

assure contact between the SOP and the percolate, and is not due to poor adsorption of the metabolite by the SOP, was confirmed when an amount of SOP equivalent to a 1% rate was placed directly on the top of a soil column and treated directly with a solution of metabolite at the 1.125 g AI m^{-2} rate. During subsequent percolation events, no metabolite was recovered in the percolate (data not presented).

Sufficient SOP has been produced for field studies that are planned for the lysimeter area of the FLREC USGA green. A local company having experience with and equipment for processing sugarcane filter-cake has expressed considerable interest in commercially manufacturing SOP.

PUBLICATIONS AND MANUSCRIPTS

During the past year, the following manuscripts were prepared for publication.

Cisar, J. L., and G. H. Snyder. 1996. Mobility and persistence of pesticides applied to a USGA green. III. Organophosphate recovery in clippings, thatch, soil, and percolate. Crop Science 36:(in press).

Snyder, G. H., and J. L. Cisar. 1996. Fate of pesticides applied to golf greens 6. 2,4-D and dicamba. Turfgrass Research in Florida. University of Florida, Gainesville. This paper also was presented at the University of Florida Turfgrass Field Day in Gainesville, March 1996.

Abstracts for the following two papers were accepted for presentation at the International Turfgrass Research Conference in Sydney Australia, in July, 1997. Full manuscripts have been prepared and submitted.

Snyder, G. H., and J. L. Cisar. Mobility and persistence of pesticides applied to a USGA green. IV. Dicamba and 2,4-D.

Cisar, J. L., and G. H. Snyder. Mobility and persistence of pesticides applied to a USGA green. V. Effect of irrigation management on fenamiphos and fenamiphos metabolite.

LITERATURE CITED

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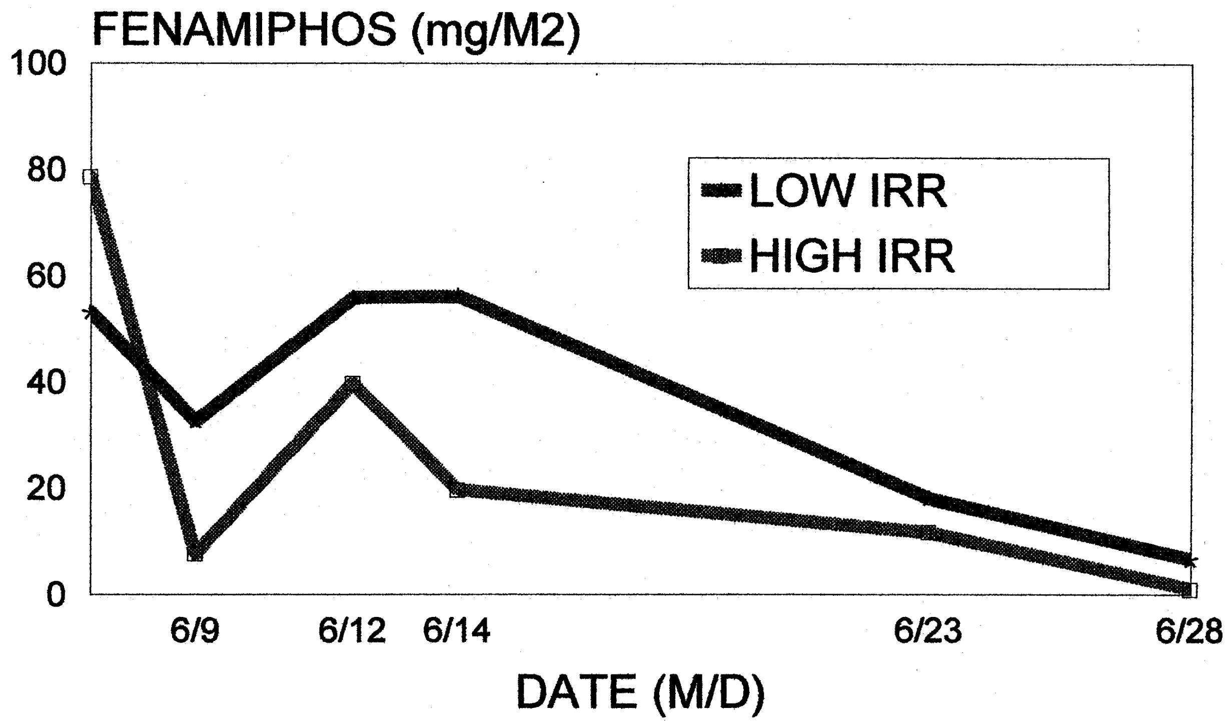
APPENDIX

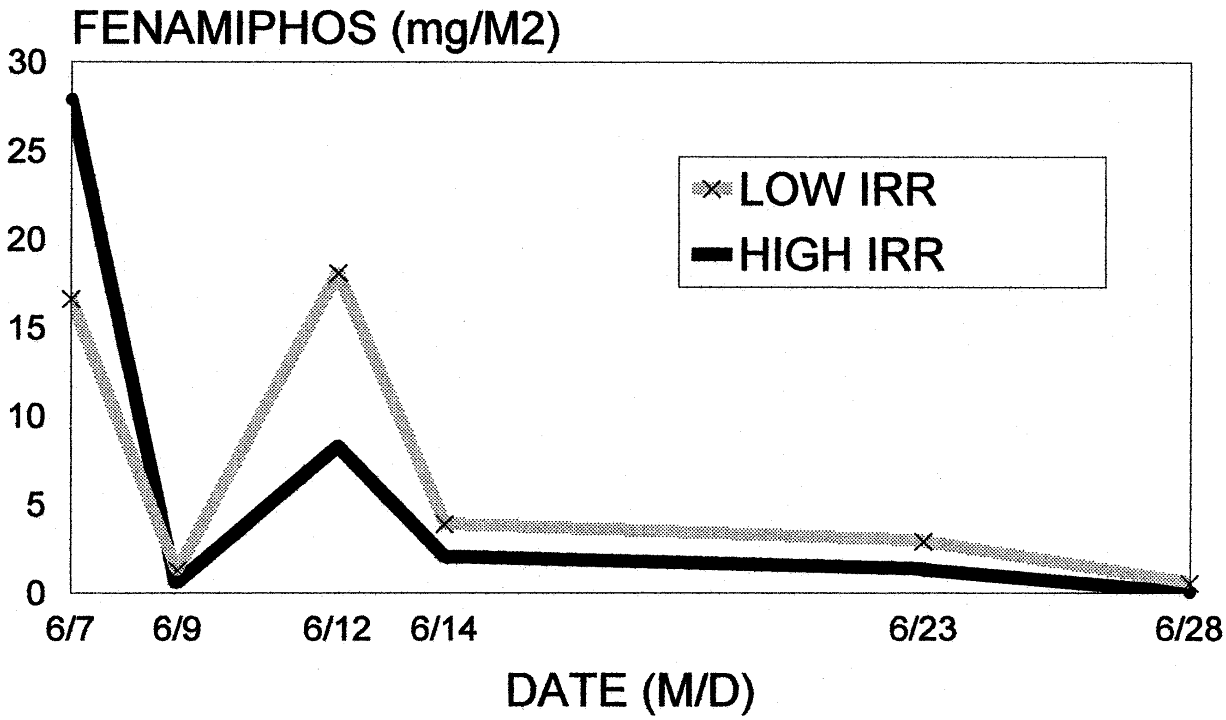
EFFECT OF IRRIGATION ON FENAMIPHOS IN 0-5 cm SOIL



1995

00131

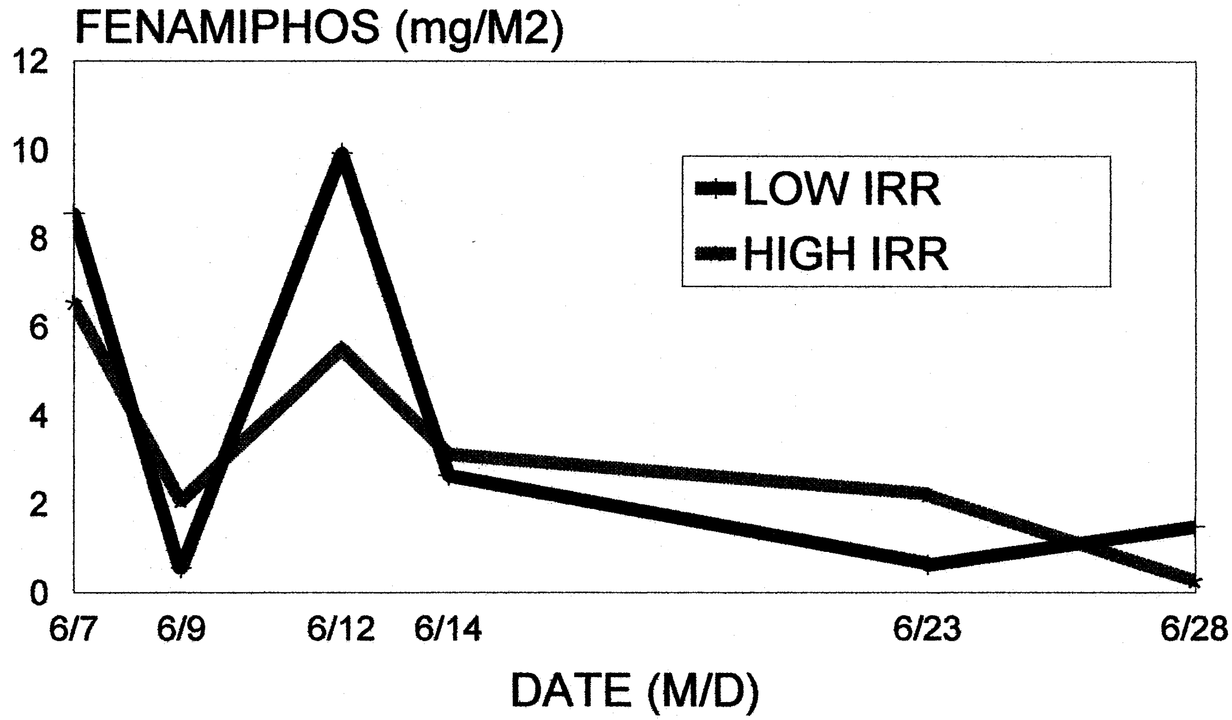
EFFECT OF IRRIGATION ON FENAMIPHOS IN 5-10 cm SOIL



1995

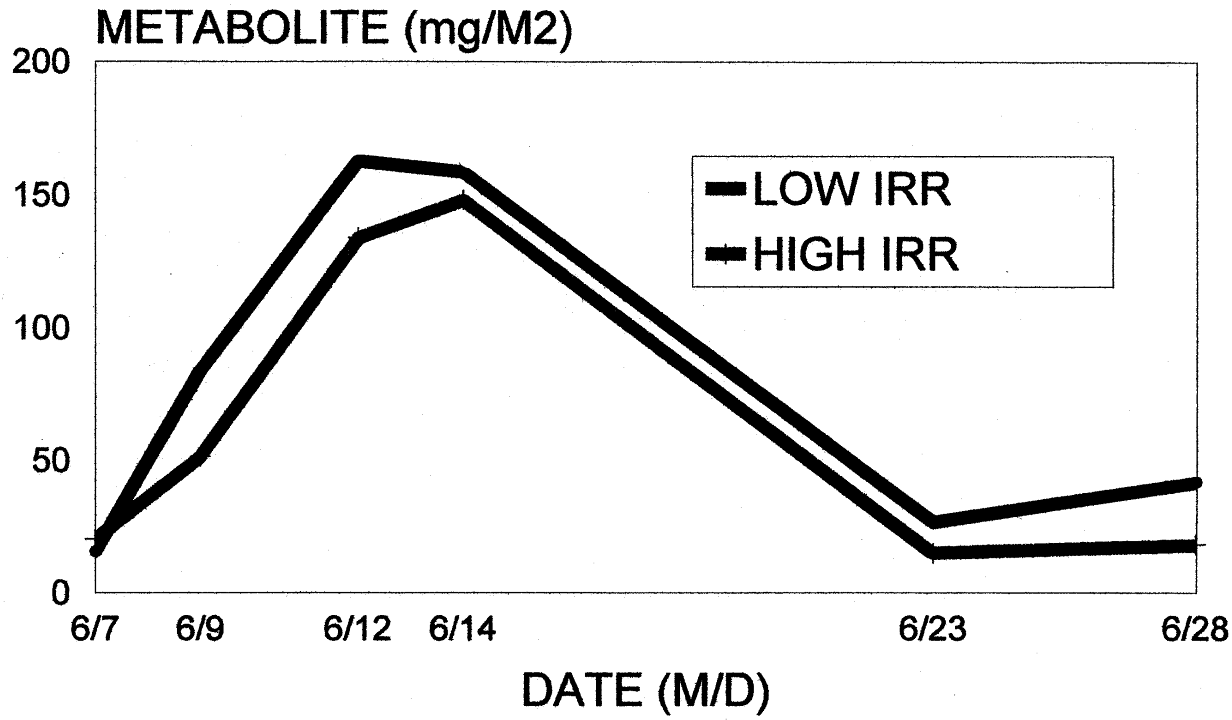
00132

EFFECT OF IRRIGATION ON FENAMIPHOS IN 10-15 cm SOIL



1995

EFFECT OF IRRIGATION ON METABOLITE IN 0-5 cm SOIL



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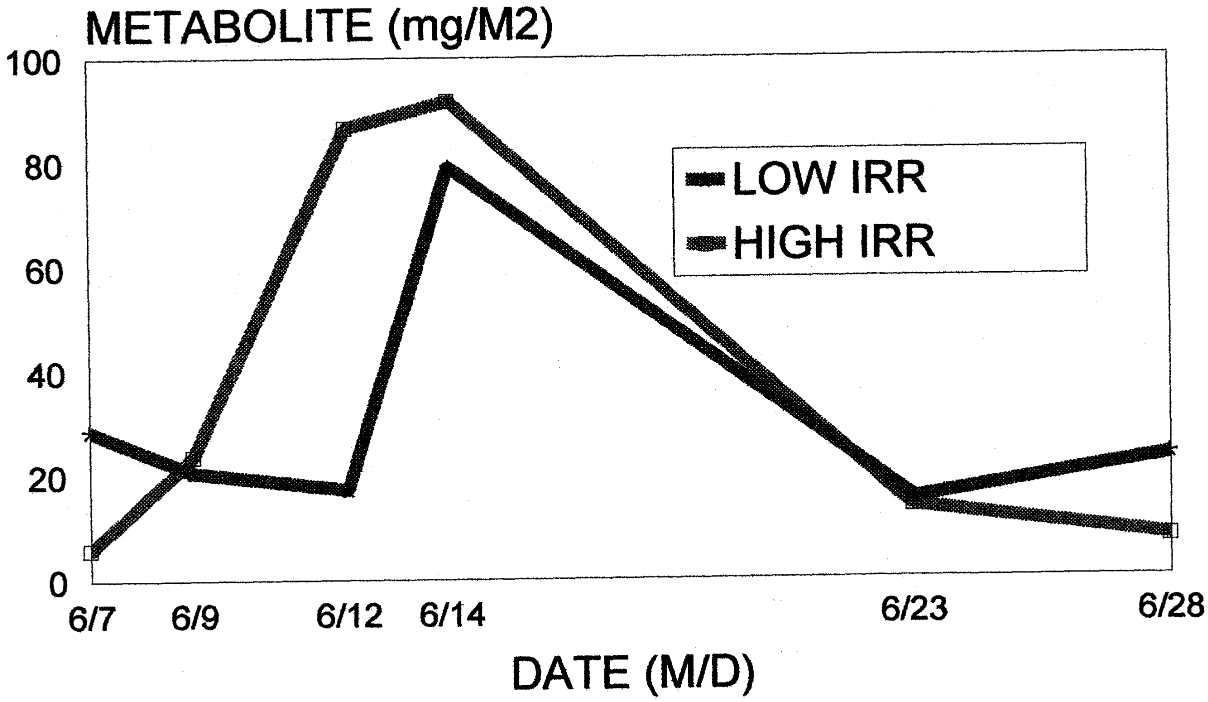
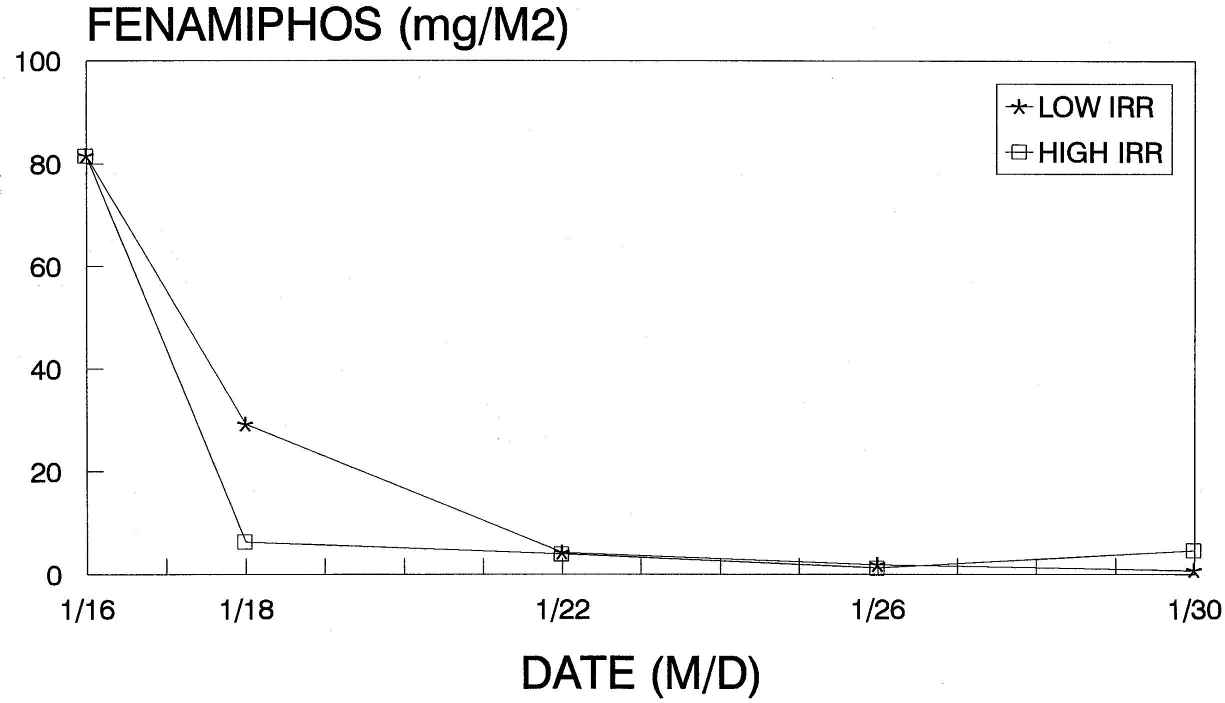
EFFECT OF IRRIGATION ON METABOLITE IN 5-10 cm SOIL



1995

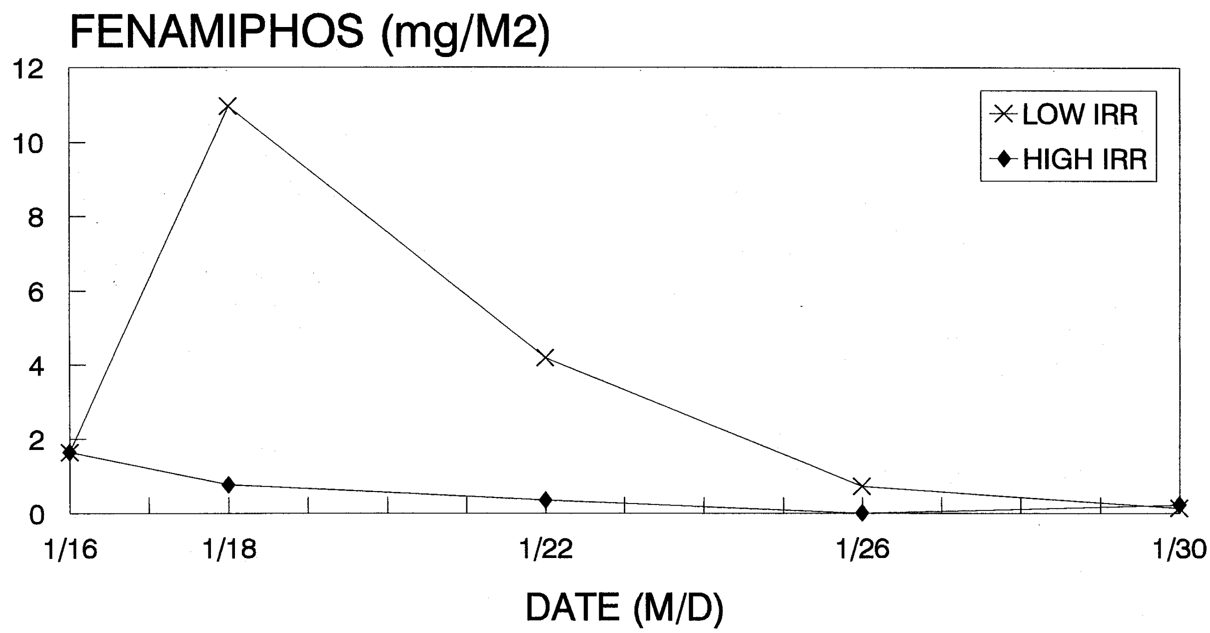
EFFECT OF IRRIGATION ON FENAMIPHOS IN 0-5cm SOIL



1996

00136

EFFECT OF IRRIGATION ON FENAMIPHOS IN 5-10cm SOIL



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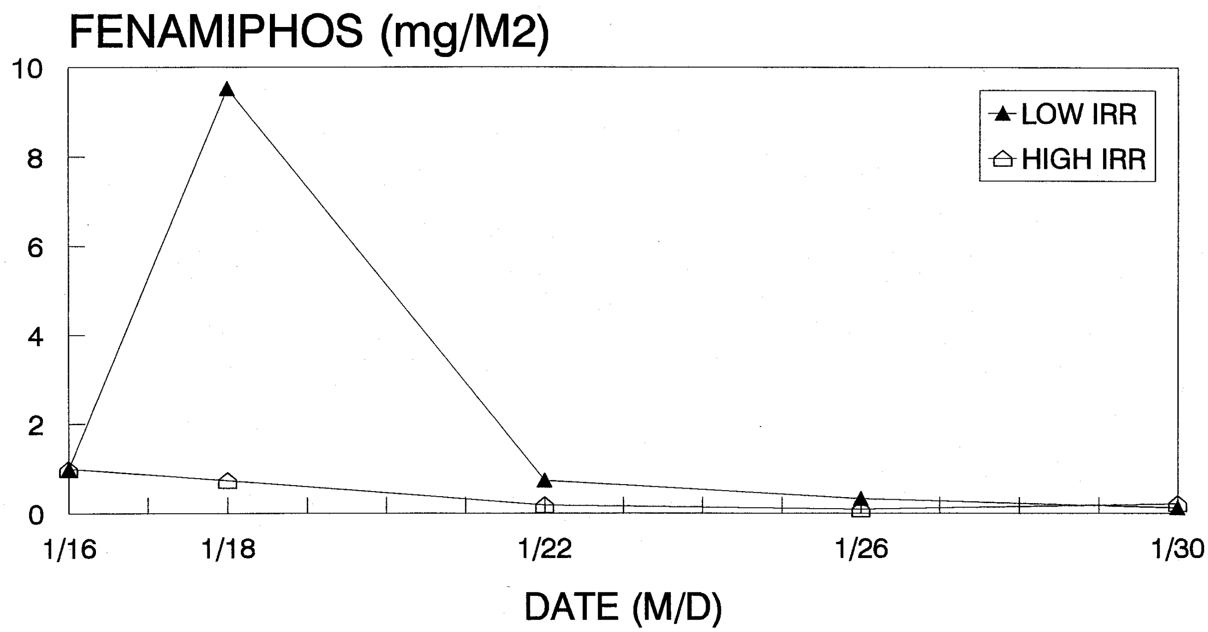
EFFECT OF IRRIGATION ON FENAMIPHOS IN 10-15cm SOIL



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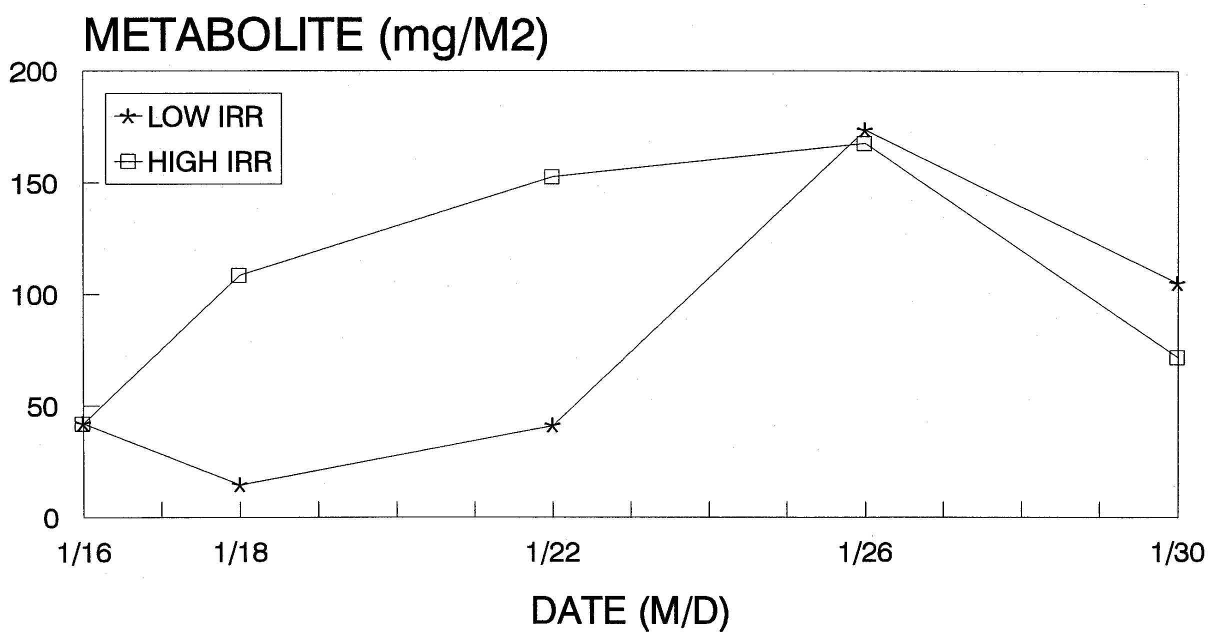
EFFECT OF IRRIGATION ON METABOLITE IN 0-5cm SOIL



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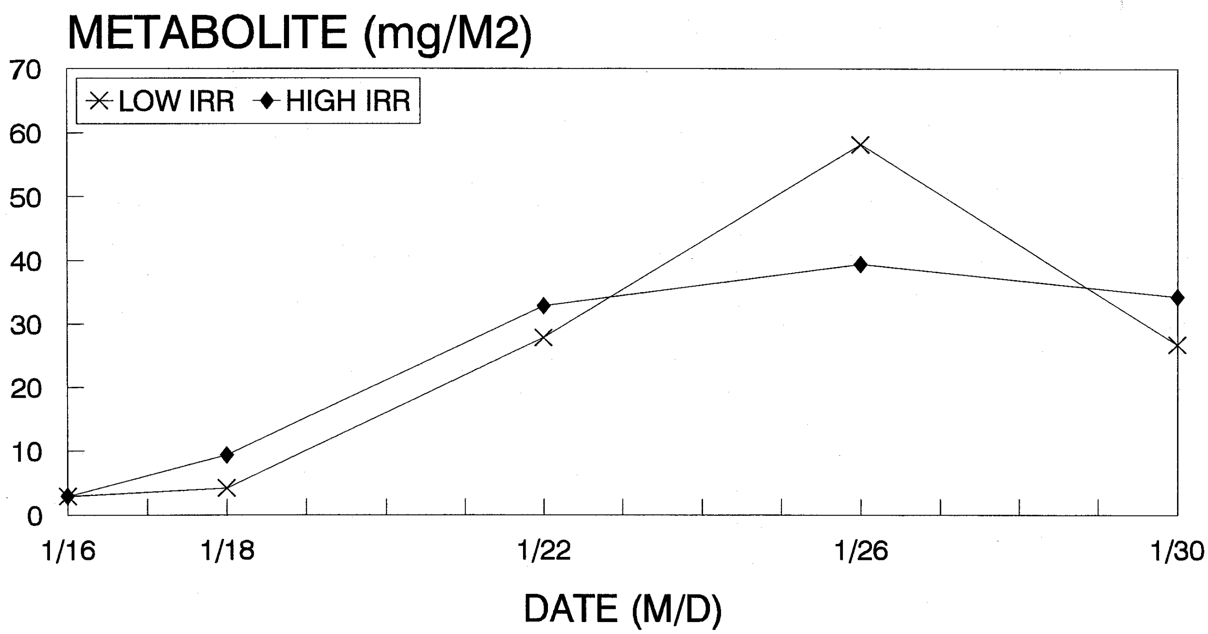
EFFECT OF IRRIGATION ON METABOLITE IN 5-10cm SOIL



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