INSECTICIDES IN RUNOFF FROM BT COTTON IN MISSISSIPPI DELTA MANAGEMENT SYSTEMS EVALUATION AREA

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ABSTRACT

Runoff samples were collected and analyzed from Bt (Bacillus thuringiensis) cotton and non-Bt cotton fields for insecticides from 1996 through 1999 at the request of the Delta Council. The insecticide analyses included pyrethroid and organophosphate insecticides based on the popularity and use throughout the Mississippi Delta in cotton-producing areas. The purpose of this paper was to present and compare the insecticide concentration data for runoff samples from the Bt-cotton fields to that from non-Bt cotton fields within the Mississippi Delta Management Systems Evaluation project. The use of the genetically engineered Bt cotton plant to produce its own pesticide reduced the volume of pyrethroid insecticides sprayed into the environment at the Beasley Lake Watershed. The reduced application dates and pyrethroid types on the Bt cotton sites as compared to the multiple applications of mutiple pyrethroid insecticides on the non-Bt cotton sites to control the tobacco budworm and bollworm resulted in dramatic reduction of pesticides released into the environment. Even though the non-Bt cotton sites resulted in little to no detects of the pyrethroid insecticides, the Bt cotton site had even lower concentrations in the runoff. Insignificant detects were found with the organophosphate insecticides for boll weevil control from either Bt or non-Bt cotton sites. No detrimental environmental effect from the pyrethroid and organophosphate insecticides was found from water samples of runoff from all tested sites within the watersheds o this study. Other than economics or costs of the Bt cottonseed, reduced pyrethroid types, and reduced applications for budworm and bollworm control in heavily infected areas as compared to the costs of non-Bt cottonseed, the multiple pyrethroid types, and their multiple applications, there is little negative environment effect from either type of cottonseed.

INTRODUCTION

Much attention has been given in the last decade to nonpoint source contamination of our Nation's water resources. Potential nonpoint source contaminants include sediment, nutrients, and pesticides in watersheds that drain from agricultural enterprises. Although impacts due to sediment and nutrients will probably outweigh impacts from pesticides, pesticides currently have been highly publicized. The concerns with pesticides have been on the potential impact to human health as well as the impact on aquatic and wildlife habitat.

Agricultural biotechnology, with its promise of high crop yields and dramatic reduction in pesticide use, has been touted as the way to feed the worlds escalating population and reduce environmental damage from farming. Ever since the mid-1970s, when scientists found an easy way to copy genes and then transfer them to other species, the potential benefits to agriculture seemed extraordinary. It didn't take a visionary to see that corn engineered to produce more oil might have added value as animal feed or that soybeans packed with more protein might lead to a healthier human diet. Or that a cotton plant genetically engineered to produce its own pesticide could one day dramatically cut the volume of pesticides sprayed into the environment.

Patented by the U.S. company Monsanto, Bt *(Bacillus* thuringiensis) cotton is the first genetically modified plant for commercial release to resist tobacco budworms. Monsanto scientists discovered a way to insert an insecticidal protein derived from the bacterium Bacillus fhuringiensis. into a cotton strain. The cotton industry believes the plant will help reduce pesticide use. Timely applications of pyrethroid pesticides to control the tobacco budworm would be adverted and eliminated with the Bt cotton. While there is some concern that worms will become resistant to Bt cotton, Monsanto is working on additional genetic alterations that will delay worm resistance. Moreover, producers now have another family of chemical insecticides, e.g. Tracer, which will provide another layer of protection against the worms. If the Bt cotton resulted in Bt-resistant worms, the crop could be sprayed with only one application of Tracer that would take out all of the Bt- resistant worms.

Current use insecticides account for 20 to 30 percent of all pesticides used in cotton. Most of the current-use insecticides include organophosphates (such as malathion, parathion, dimethoate) or carbamates (such as aldicarb and carbofuran). The newest group of insecticides, the synthetic pyrethroid compounds, includes such products as esfenvalerate, cyfluthrin, and cyhalothrin. Synthetic pyrethroids are only slightly toxic to birds and mammals, but are highly toxic to fish and other aquatic animals. The Bt cotton would require **less** of these chemicals for budworm control. Detection of these chemicals in runoff from the Bt cotton sites should be less frequent resulting in enhanced water quality entering adjacent streams and lakes.

One of the most intensive agricultural areas of the United States is the Mississippi River Alluvial Plain in northwestern Mississippi, a 18,130-square-km (7,000-square-mile) area. The hot, humid conditions during the long growing season in the Mississippi Delta increase the frequency and dependency of pesticide use, especially on cotton that is highly sensitive to intense insect and weed pressures. Concern exists for potential off-site movement of these compounds during runoff events, due to the amounts of pesticides used in the Mississippi Delta along with the fact that the region is characterized with high regional rainfall [about 1524 mm (60 inches) per year], low slopes, and slightly permeable soils.

The Delta Council, a regional economic development organization, in 1996 requested research of water quality from Bt cotton grown in the Mississippi Delta due to the Bt cotton initial commercial release. As part of an ongoing research and demonstration effort called the Mississippi Delta Management Systems Evaluation Areas (MDMSEA) begun in 1994 to address the concerns of agricultural nonpoint source pollution in the Delta (Rebich et *al.*, 1995), water quality from runoff from Bt-cotton sub-watersheds was analyzed and compared to other non-Bt cotton sub-watersheds in the area. Oxbow lakes within the MDMSEA accumulate all runoff from the surrounding agricultural sub-watersheds that provides an opportunity to understand the impacts of pesticides throughout the ecosystem of the whole oxbow lake watershed.

The U.S. Department of Agriculture (USDA), Agricultural Research Service (ARS). Water Quality and Ecological Processes Research Unit (WQEPRU) of the National Sedimentation Laboratory, in Oxford, MS began operating an automated acquisition system in June 1996 to sample and measure storm runoff from Bt cotton and non-Bt cotton watersheds. Also that year, the USGS began cooperating with the USDA-ARS Soil and Water Research Unit, in Baton Rouge, LA, to provide samples from their automated streamflow and water-quality sampling network (Rebich, 1997) for the purpose of insecticide analyses. In 1998, more emphasis was placed on low-level analyses of pyrethroid insecticides, and additional samplers were installed in cooperation with the pyrethroid manufacturing industry (Pyrethroid Working Group) to ensure that samples would be collected for as many runoff events as possible. The purpose of this paper is to present the insecticide concentration data for runoff samples from the Bt-cotton sub-watersheds and compare to concentration data from the non-Bt sites for the MDMSEA project from 1996 through 1999.

METHODS AND PROCEDURES

Study Sites: The study involved the fields in Beasley Lake watershed in Sunflower County, MS that were grown to Bt cotton and the fields in the Deep Hollow watershed in Leflore County, MS that were grown to non-Bt cotton. Runoff from these watersheds was gauged by USGS (Southwick *et al.*, 2000). Due to not knowing what each cotton grower would plant in this four-year period, additional sites located in the Beasley Lake watershed were gauged for runoff and water quality measurements.

In 1996, these additional two fields, 4 ha (10 acres) and 4.85 ha (12 acres) in size, were selected and planted to Bt cotton denoted as A1 and non-Bt cotton denoted as A2. respectively. Their respective owner managed each field. In each field. runoff was routed through a 61-cm (24-in) culvert. Attached to each culvert was a 0.6-m (2-ft) H flume. A bubbler flowmeter was attached to each flume for flow and flowrate determinations. A composite water sampler was wired into the flowmeter and activated based on flow proportion of every 0.25-mm (0.01-inch) of runoff.

After the first year, the owner of the non-Bt cotton field, site A2, converted to another cropping system other than cotton. Therefore, to compare the insecticides in runoff from the Bt cotton site to non-BT cotton sites, the insecticide data from the USGS water-quality sampling network (Southwick *et al.*, 2000) involving runoff from non-Bt cotton fields in the Deep Hollow Lake watershed labeled UL1 and UL2 were used. UL1 and UL2 were gauging sites located at edge of field. Meanwhile the cotton growers in the Beasley watershed were accepting Bt cotton and most of the cotton fields in that watershed were converted to Bt cotton in 1996. Therefore, the runoff from USGS sites labeled BL1, BL4a, and BL4b (Southwick *et al.*, 2000) were analyzed as Bt cotton fields throughout the study. BL1 was an edge-of-field site located in an open-channel ditch that was grassed and drained a large area of conventional-till cotton. BL4a and BL4b were located at the entrance of the riparian zone of Beasley Lake. Most of the eastern part of the watershed, which had mixed crops of conventional-till cotton, soybeans, rice, and corn, drained through BL4a and BL4b.

The pyrethroid insecticides lambda-cyhalothrin, cypermethrin, cyfluthrin, and deltamethrin and the organophosphate insecticides methyl parathion and azinphosmethyl were selected for this study due to their popularity and use among MDMSEA farmers.

Sample Collection and Analyses: The samples collected for this project were all flow-weighted composite samples from automated samplers installed at each site. Each of the samplers are stage-activated and deposit aliquots of water into sample containers each time a pre-determined amount of volume has passed the sampling point. Thus, each sample represents an average concentration of insecticides in the runoff water per storm. None of the samples are filtered prior to shipment. Quality assurance / quality control (QA/QC) measures were adopted to avoid possible contamination to the samples.

The USDA-ARS WQEPRU of the National Sedimentation Laboratory in Oxford, MS analyzed runoff samples for pesticides from the two runoff sites of A1 and A2 collected from 1996 through 1999 using methods described elsewhere (Smith, 2000; Smith *et al.*, 2000). The USDA-ARS Soil and Water Research Unit, in Baton Rouge, LA, analyzed stream samples for pesticides from USGS streamflow sites BL1, BL4a, BL4b, UL1, and UL2 from 1996 through 1997. As stated earlier, additional samplers were installed in 1998 to ensure that enough samples were collected for insecticide analyses, specifically pyrethroids. The ARS lab in Baton Rouge continued with analyses for the organophosphates; however, a contract lab, PTRL East, Inc., in Richmond, Kentucky, was used for pyrethroid analyses. The method for analyses of these pesticides by ARS in Baton Rouge, LA and the contract lab are given in Southwick *et al.* (2000).

RESULTS

Pyrethroids: Table 1 is a listing of the various dates of application of pyrethroids to cotton fields upstream of the various sampling sites in the Beasley and Deep Hollow watersheds. Even though deltamethrin was used in the non-Bt cotton fields at Deep Hollow watershed, it was not applied in the Beasley Lake watershed. Also, no pyrethroids were applied to the Bt cotton at site A1 in the first two years (1996 and 1997) of the study. The Bt cotton at the A1 site had only two application dates of one pyrethroid insecticide (one in 1998 and the other in 1999) as compared to a minimum of 2 and a maximum of 7 application dates of two pyrethroid insecticides in 1997 and 1998, respectively, during the four years on the other Bt cotton sites at Beasley Lake watershed. The non-Bt sites (UL1 and UL2) required a minimum of 4 and a maximum of 7 application dates of at least one up to four different pyrethroid insecticides during the study. All four pyrethroid insecticides were applied in 1999 at recommended levels to control the tobacco budworm and bollworm at the non-Bt cotton sites. From these application dates data, less pyrethroid insecticides was being used in the Bt cotton sites that would lead to less insecticides entering runoff and eventually into streams from areas having the Bt cotton.

Table 2 is a listing of the pyrethroid concentrations in the sample water that were collected from the A1 Bt cotton site, the three USGS Bt cotton streamflow sites, and the two USGS non-Bt cotton streamflow sites. In 1996 and 1997, no runoff samples were collected and analyzed in the five USGS sites. During 1996 and 1997 no pyrethroid insecticides were used in the Bt cotton at site A1 to control the tobacco budworm or the bollworm, and thus the six runoff events in 1996, the five runoff events in 1997, and the first six runoff events of 1998 had no pyrethroid insecticides.

The Bt cotton field at A1 had 30 runoff events from 1996 through 1999. In this four year period, only two applications of a pyrethroid insecticide were applied to help in control of the bollworm, the first application being cyfluthrin on July 10, 1998 during the third season of Bt cotton and the second application being cypermethrin on May 3, 1999 during the fourth growing season. Cyfluthrin was found in one runoff event at 25 ppt four days after application in 1998. The three other runoff events of 1998 and the nine runoff events of 1999 resulted in non-detectable amounts of cyfluthrin. No detectable amounts of cypermethrin were found in the seven runoff events of the 1999 season.

At the other Bt cotton sites (BL sites) in 1998, 8 samples were collected from April 28 to December 11 ranging from 110 to 343 days after application. No 1998 runoff sample contained pyrethroids above the detection limit. Runoff that occurs within one month of application has the best opportunity to contain measurable pyrethroid content due to the half-life of these pyrethroids being 30 days. During this season, no runoff events occurred less than one month after application at these sites.

In 1999, 16 samples were collected from the BL sites with Bt cotton from January 8 to May 31 and ranged from 5 to 313 days after application. There were a total of 4 detects of pyrethroids within the 1999 sampling period. On May 4, five days after application, the concentration of cypermethrin was 100 ppt at BL4a, which is the entrance of a large riparian area. For that same runoff event, no cypermethrin was detected at the other side of the riparian zone above the entrance to Beasley Lake. A lambda cyhalothrin concentration of 30 ppt was observed at the entrance (BL4A), and a concentration of 20 ppt was observed at the exit for the May 4-5 event as well. According to farm records, however, lambda cyhalothrin had not been applied at these sites since the previous growing season. Possible explanations for these two lambda cyhalothrin detections include: (1) false positive analyses, (2) a non-recorded application within one month of the runoff event, or (3) a misapplication of the chemical. On May 31, 13 days after a known application, lambda cyhalothrin was detected again at BL4a at a concentration of 20 ppt. In all cases of detection, the concentrations were lower than toxic levels for aquatic species such as bluegill where the lethal concentration (LC_{50}) is 210 ppt (EXTOXNET, 1999).

The fact that detections occurred at some sites and not others for runoff events shortly after application could verify the theory that sediment was elevated at some locations but not others. For instance, the detections that occurred in 1999 were at the BL4a site in the Beasley watershed that was located at the entrance of a riparian zone but drained a very large area of conventional-till row crops. This condition could result in high sediment-laden water entering the riparian area. Several other runoff events occurred in 1999 within one month of application that did not have detectable concentrations of pyrethroids. This supports the findings of others regarding the insecticide mitigating properties of riparian areas (Smith *et al.*, 2000). These non-detects occurred at locations such as the riparian exit in the Beasley watershed. Fairly low sediment loads could characterize the quality of the runoff water.

The non-Bt cotton sites also produced no detectable concentrations of pyrethroids even though more pyrethroid insecticides were applied as compared to the Bt-cotton sites. In 1997, the only runoff sample taken 3 days after application of cyfluthrin from the non-Bt cotton field at site UL1 had concentration less than the detection limit. In 1998, 20 samples were collected at the five USGS gauging sites previously described from April 27 to December 11 ranging from 8 to 343 days after application. No 1998 runoff sample from these USGS sites contained pyrethroids above the detection limit from either the Bt cotton nor the non-Bt cotton fields. Runoff that occurs within 1 month of application has the best opportunity to contain measurable pyrethroid content. During the 1998 season, there were only two runoff events that occurred less than one month after application. Both of these events were at the UL1 site, which has conservation tillage non-Bt cotton. The runoff event that occurred on May 28 was eight days after application of lambda cyhalothrin and 20 days after cypermethrin application. The June 15 runoff event occurred 26 days after application of lambda cyhalothrin and only 3 days after the second application of cypermethrin. Since pyrethroids exhibit low water solubilities [less than 0.01 mg L^{-1} (10 ppb)] and adhere to the soil particles, these compounds were expected to travel in runoff absorbed to suspended-sediment. The failure to detect the applied compounds within the first month, especially within the first 2 weeks of application, can imply that low levels of sediment characterized these runoff events. Other explanations for the lack of detection of these chemicals include higher than expected degradation rates and low application rates of approximately 42 gms per hectare (.037 lbs per acre) of each active ingredient.

Organophosphates: Table 1 is also a listing of the application dates of methyl parathion and azinphosmethyl in the Beasley and Deep Hollow watersheds for 1996 through 1999. Methyl parathion is used in both the Bt and non-Bt cotton fields to control the boll weevil, since the Bt cotton does not control the boll weevil. By eradicating the weevil from the area, no methyl parathion would be required. This would eliminate many application dates of this insecticide as seen in Table 1.

Table 3 is a listing of the concentrations of these two organophosphate insecticides in runoff samples collected during the study. Both application and runoff data were not available for the non-Bt cotton sites in 1999. Ten runoff events occurred after application of methyl parathion in 1996 ranging from 11 to 108 days after application. Six runoff events ranging from 3 to 275 days, 21 runoff events from 1 to 238 days, and nine runoff events ranging from 6 to 323 days after application of methyl parathion occurred during 1997, 1998, and 1999, respectively. In all cases except one, methyl parathion was insignificantly detected in extremely low amounts (<0.2 ppb). The one exception produced a detection of 2.671 ppb after 323 days of application. Possible explanations for this methyl parathion detection were false positive analyses, a non-recorded application within five days of the runoff event, or a misapplication of the chemical. The likely reason for no detection of methyl parathion in all runoff samples was probably due to the chemical's short soil half-life of 5 days and an even shorter half-life on cotton leaves of 0.1 day (Southwick *et al.*, 2000), thus degrading rapidly before being mobilized during a runoff event.

Five runoff events occurred after application of azinphosmethyl in 1998 ranging from 109 to 136 days after application and two runoff events ranging from 15 to 147 days application in 1999. There were no detections of azinphosmethyl in these samples from either Bt or non-Bt cotton sites. The soil half-life of azinphosmethyl is reported to be 10 days (Southwick *et al.*, 2000). Therefore, it is likely that azinphosmethyl degraded prior to these runoff events.

SUMMARY AND CONCLUSIONS

The U.S.D.A. Agricultural Research Service, Water Quality Ecology Research Unit of the National Sedimentation Laboratory, in Oxford, MS, at the request of the Delta Council in 1996 began operating an automated acquisition system to sample and measure insecticides in storm runoff from Bt (*Bacillus thuringiensis*) cotton and non-Bt cotton fields. Also in 1996, the USGS began cooperating with the USDA-ARS Soil and Water Research Unit, in Baton Rouge, LA, to provide samples from their automated streamflow and water-quality sampling network for the purpose of insecticide analyses. The insecticide analyses included pyrethroid and organophosphate insecticides based on the popularity and use of both throughout the Mississippi Delta in cotton-producing areas. In 1998, more emphasis was placed on low-level analyses of pyrethroid insecticides, and additional samplers were installed in cooperation with industry (Pyrethroid Working Group) to ensure that samples would be collected for as many runoff events as possible. The purpose of this paper was to present the insecticide concentration data for runoff samples from the Bt-cotton fields and compare to concentration data from non-Bt cotton sites within the Mississippi Delta Management Systems Evaluation project from 1996 through 1999.

Agricultural biotechnology, with its promise of high crop yields and dramatic reduction in pesticide use, has been touted as the way to feed the world's escalating population and reduce environmental damage from farming. The use of a cotton plant genetically engineered, called Bt cotton, to produce its own insecticide reduced the volume of pyrethroid insecticides sprayed into the environment at the Beasley Lake Watershed. The reduced application dates and pyrethroid types on the Bt cotton sites as compared to the multiple applications of mutiple pyrethroid insecticides on the non-Bt cotton sites to control the tobacco budworm and bollworm resulted in dramatic reduction of pesticides released into the environment. Even though the non-Bt cotton sites resulted in little to no detects of the pyrethroid pesticides, the Bt cotton site had even lower concentrations in the runoff. Also, insignificant detects were found with the organophosphate insecticides from either Bt or non-Bt cotton sites. No detrimental environmental effect from the applied pyrethroid and organophosphate insecticides was found from water samples of runoff from all tested sites within the Beasley Lake and Deep Hollow watersheds during this four year study. Other than economics or costs of the Bt cottonseed and reduced applications of insecticide for budworm and bollworm control in heavily infected areas as compared to the costs of non-Bt cottonseed, the insecticides used for budworm and bollworm protection, and their multiple applications, there is little negative environment effect from either type of cottonseed.

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Table 1. Applications of pyrethroid in 1996-1999 and organophosphate in 1996-1998 at Beasley sites.
[------, no insecticides applied; *****, runoff samplers not installed]

	Pyrethroid				Organophosphate	
Site	**λ-Cyhalothrin**	**Cypermethrin**	**Cyfluthrin**	**Deltamethrin**	**Methyl Parathion**	**Azinphosmethyl**
			1996			
A1		------	------	------	Jun 3; Jul 25; Aug 3	------
BL1	Jun 12; Jul 11, 17, 25; Aug 17	------	------	------	Jun 5, 12; Jul 7, 11, 20; Aug 31	------
BL4a	*****	*****	*****	*****	*****	*****
BL4b	*****	*****	*****	*****	*****	*****
UL1	May 24; Jul 15	May 3	Jun 1	------	Jun 8; Jul 10, 15, 22	------
UL2	May 24; Jul 15	May 3	Jun 1	------	Jun 8; Jul 10, 15, 22	------
			1997			
A1	------	------	------	------	Jun 28; Jul 7, 10, 16, 22	------
BL1	Aug 21; Sep 1	------	Jun 17, 21, 24; Jul 2	------	Jun 4, 10; Jul 2, 15, 21; Aug 6; Sept 3, 12	------
BL4a	Jul 19	------	Jun 20	------	Jun 14, 16, 28; Jul 7, 10 16, 22	------
BL4b	------	------	------	------	------	------
UL1	Aug 3,16	Jul 20	Jul 10	------	Jun 3, 11, 24	------
UL2	Aug 3,16	Jul 20	Jul 10	------	Jun 3, 11, 24	------
			1998			
A1	------	------	Jul 10	------	Jun 1, 3, 9, 12, 17, 26; Jul 30; Aug 3, 11	Jul 28
BL1	------	------	------	------	------	------
BL4a	Jun 17, 26	------	Jun 1; Jul 10, 15, 22, 27	------	Jun 1, 3, 9, 17, 26; Jul 30; Aug 3, 4, 10, 11	Jul 28
BL4b	------	------	------	------	------	------
UL1	May 20; Jul 1, 7	May 8; Jun 3; Aug 1	------	Aug 11	Sept 3	------
UL2	May 20; Jul 1, 7	May 8; Jun 8; Aug 1	------	Aug 11	Sept 3	------
			1999			
A1	------	May 3	------	------	Jul 5, 30	July 11, 26
BL1	Jul 8; Aug 13	May 9	------	------		
BL4a	May 18	Apr 29	------	------		
BL4b	May 13, 21; Jul 12	------	------	------		
UL1	May 30; Jun 15; Jul 31; Aug 14	May 11; Aug 14	Jun 9; Jul 17; Aug 14	Jul 24		
UL2	Jun 15; Jul 31; Aug 14	May 9; Aug 14	Jun 9; Jul 17; Aug 14	Jul 24		

The data for all BL and UL sites were taken from Southwick *et al.*, 2000.

Table 2. Concentration of pyrethroids in runoff from Beasley watersheds, 1996-1999.
[ppt, parts per trillion; DAA, days after application; [a], USDA data; [b], PTRL East, Inc., data]

Site	Runoff event date	λ-Cyhalothrin ppt (DAA)	Cypermethrin ppt (DAA)	Cyfluthrin ppt (DAA)	Deltamethrin ppt (DAA)
		1996 [a]			
UL1	Aug 2		< 400 (91)	< 600 (30)	
UL2	Oct 25		< 400 (175)	< 600 (114)	
UL2	Nov 1		< 400 (182)	< 600 (121)	
UL2	Nov 7		< 400 (188)	< 600 (127)	
		1997 [a]			
UL1	Jul 13			< 600 (3)	
		1998 [b]			
A1	Jul 14			25 (4)	
A1	Jul 23			<10 (13)	
A1	Dec 18			<10 (161)	
A1	Dec 30			<10 (173)	
BL1	Apr 28	< 50 (240)		< 125 (300)	
BL4a	May 28	< 50 (313)		< 125 (342)	
BL4a	Nov 14	< 50 (141)		< 125 (110)	
BL4a	Nov 20	< 50 (147)		< 125 (116)	
BL4a	Dec 10	< 50 (167)		< 125 (136)	
BL4a	Dec 11	< 50 (168)		< 125 (137)	
UL1	Apr 27	< 50 (254	< 125 (281)	< 125 (291)	
UL1	May 28	< 50 (8)	< 125 (20)	< 125 (322)	
UL1	Jun 15	< 50 (26)	< 125 (12)	< 125 (340)	
UL1	Nov 14	< 50 (130)	< 125 (105)		< 125 (95)
UL1	Nov 20	< 50 (136)	< 125 (111)		< 125 (101)
UL1	Dec 7	< 50 (153)	< 125 (128)		< 125 (118)
UL1	Dec 10	< 50 (156)	< 125 (131)		< 125 (121)
UL1	Dec 11	< 50 (157)	< 125 (132)		< 125 (122)
UL2	Apr 28	< 50 (255)	< 125 (282)	< 125 (292)	
UL2	Apr 30	< 50 (257)	< 125 (284)	< 125 (294)	
UL2	Nov 14	< 50 (130)	< 125 (105)		< 125 (95)
UL2	Dec 7	< 50 (153)	< 125 (128)		< 125 (118)
UL2	Dec 11	< 50 (157)	< 125 (132)		< 125 (122)
		1999 [b]			
A1	May 11		< 10 (8)		
A1	June 1		< 10 (21)		
A1	June 16		< 10 (36)		
A1	June 30		< 10 (50)		
A1	Jul 12		< 10 (62)		
A1	Aug 10		< 10 (99)		
A1	Dec 20		< 10 (231)		
BL1	May 31		< 10 (22)		
BL1	Jun 2		< 10 (24)		
BL4a	Jan 8	< 50 (196)		< 125 (165)	
BL4a	Mar 2	< 10 (249)		< 10 (218)	
BL4a	Mar 13	< 10 (260)		< 10 (229)	
BL4a	Apr 3	< 10 (281)		< 10 (250)	

Table 2. Concentration of pyrethroids in runoff from Beasley watersheds, 1996-1999.
continued
[ppt, parts per trillion; DAA, days after application; [a], USDA data; [b], PTRL East, Inc., data]

Site	Runoff event date	λ-Cyhalothrin ppt (DAA)	Cypermethrin ppt (DAA)	Cyfluthrin ppt (DAA)	Deltamethrin ppt (DAA)
BL4a	Apr 5	< 10 (283)		< 10 (252)	
BL4a	Apr 14	< 10 (292)		< 10 (261)	
BL4a	May 4	30 (312)	100 (5)	< 10 (281)	
BL4a	May 31	20 (13)	< 10 (32)		
UL1	Jan 8	< 50 (185)	< 125 (160)		< 125 (150)
UL1	Mar 2	< 10 (238)	< 10 (213)		< 10 (203)
UL1	Mar 13	< 10 (249)	< 10 (224)		< 10 (214)
UL1	Apr 3	< 10 (270)	< 10 (245)		< 10 (235)
UL1	Apr 14	< 10 (281)	< 10 (256)		< 10 (246)
UL1	Jul 14	< 10 (29)	< 10 (65)	< 10 (26)	
UL1	Jul 21	< 10 (36)	< 10 (71)	< 10 (4)	
UL1	Aug 7	< 10 (7)	< 10 (88)	< 10 (21)	< 10 (14)
UL2	Jan 8	< 50 (185)	< 125 (160)		< 125 (150)
UL2	Mar 12	< 10 (248)	< 10 (223)		< 10 (213)
UL2	Apr 3	< 10 (270)	< 10 (245)		< 10 (235)
UL2	Apr 14	< 10 (281)	< 10 (256)		< 10 (246)
UL2	Jul 15	< 10 (30)	< 10 (66)	< 10 (27)	
UL2	Aug 7	< 10 (7)	< 10 (90)	< 10 (21)	< 10 (14)

The data for all BL and UL sites were taken from Southwick *et al.*, 2000.

Table 3. Concentration of organophosphate insecticides in runoff from Beasley watershed, 1996-99
[ppb, parts per billion; DAA, days after application]

Site	Runoff event date	Methyl Parathion ppb (DAA)	Azinphosmethyl ppb (DAA)
		1996	
A1	15-Jul	<0.025 (42)	
A1	19-Jul	<0.025 (46)	
A1	17-Sep	<0.025 (45)	
A1	30-Sep	<0.025 (58)	
A1	24-Oct	<0.025 (81)	
A1	29-Oct	<0.025 (86)	
UL1	02-Aug	< 0.2 (11)	
UL2	25-Oct5	< 0.2 (95)	
UL2	01-Nov	< 0.2 (102)	
UL2	07-Nov	< 0.2 (108)	
		1997	
A1	23-Jan	<0.025 (173)	
A1	19-Mar	<0.025 (228)	
A1	05-May	<0.025 (275)	
A1	11-Aug	<0.025 (20)	
A1	17-Oct	<0.025 (87)	
BL1	09-Aug	< 0.2 (3)	

Table 3. Concentration of organophosphate insecticides in runoff from Beasley watershed, 1996-99.
continued
[ppb, parts per billion; DAA, days after application]

Site	Runoff event date	Methyl Parathion ppb (DAA)	Azinphosmethyl ppb (DAA)
		1998	
A1	27-Feb	<0.025 (220)	
A1	10-Mar	<0.025 (231)	
A1	18-Mar	<0.025 (238)	
A1	02-Jun	<0.025 (1)	
A1	22-Jun	<0.025 (5)	
A1	06-Jul	0.083 (14)	
A1	14-Jul	0.029 (4)	
A1	23-Jul	0.074 (13)	
A1	18-Dec	<0.025 (129)	
A1	30-Dec	<0.025 (143)	
BL4a	14-Nov	< 0.2 (95)	< 0.5 (109)
BL4a	10-Dec	< 0.2 (121)	< 0.5 (135)
BL4a	11-Dec	< 0.2 (122)	< 0.5 (136)
UL1	14-Nov	< 0.2 (72)	
UL1	20-Nov	< 0.2 (78)	
UL1	07-Dec	< 0.2 (95)	
UL1	10-Dec	< 0.2 (98)	
UL1	11-Dec	< 0.2 (99)	
UL2	14-Nov	< 0.2 (72)	
UL2	07-Dec	< 0.2 (95)	
UL2	11-Dec	< 0.2 (99)	
		1999	
A1	6-Apr	<0.025 (238)	
A1	20-Apr	<0.025 (252)	
A1	11-May	<0.025 (273)	
A1	1-Jun	<0.025 (294)	
A1	16-Jun	<0.025 (309)	
A1	30-Jun	2.671 (323)	
A1	12-Jul	<0.025 (6)	
A1	10-Aug	<0.025 (11)	
A1	20-Dec	<0.025 (143)	

The data for all BL and UL sites were taken from Southwick *et al.*, 2000.