MECHANISMS AND CONTROL OF HERBICIDE LOSS IN AGRICULTURAL RUNOFF OF THE MISSISSIPPI DELTA

David R. Shaw, Eric P. Webster, Glen P. Murphy,
William L. Kingery, and Michele Boyette
Plant and Soil Sciences Department
Mississippi State University

Richard H. Coupe
U. S. Geological Survey
Pearl, Misisissippi

INTRODUCTION

As with other intensively farmed regions of the U.S., nonpoint-source contamination of surface water is a primary concern for the region of Mississippi commonly known as the Delta. This alluvial plain is one of the largest contiguous agricultural areas in the U.S. Nearly 800,000 ha of cotton and soybean are farmed on soils that are susceptible to leaching, sediment erosion, and runoff loss of agrichemicals to surface waters. The Delta is drained primarily by the Yazoo River, a major tributary of the lower Mississippi River, and its basin tributaries.

A number of tillage and crop production programs have been suggested to reduce sediment and pesticide losses in runoff. No-till programs can reduce sediment loss by as much as 91% (Hairston et al. 1984). However, producers throughout the region, and particularly in the flat, poorly drained soils of the Delta, have been reluctant to adopt strict no-till systems because of difficulties in planting, stand establishment, weed control, and crop management. A primary objective of Delta producers is to facilitate movement of water away from land by means of raised beds, water furrows, and drainage systems, since poor internal drainage and water-logged soils severely limit yield potential. Thus, reducing sediment and/or pesticide movement in surface runoff is not conducive to normal crop productions practices in the Delta. In addition, changing tillage or cropping practices to control sediment movement in runoff can have variable effects on herbicide losses. Some research has shown that herbicides in runoff decrease with a shift to no-till systems (Baker et al. 1978), while others have shown increases (Shaw et al. 1992). Similarly, use of a cover crop can decrease (Peterson et al. 1988) or increase (Banks and Robison 1986) herbicide concentrations and/or seasonal losses in runoff. Thus, in many instances shifting to a system that reduces sediment load in runoff may actually increase herbicide movement and vice versa.

Another system that has been evaluated from a sediment control standpoint is vegetative filter strips. These can be planted at intervals in the field or as buffers on turn rows at field edges. These strips are typically 5-10 m wide and composed of perennial, non-invasive grasses such as tall fescue. Filter strips can reduce sediment load by as much as 75% (Webster and Shaw 1996) and nitrates by 73% (Dillaha et al. 1989a, b). Vegetative filter strips have also been effectively used to trap sediments, nutrients, and microbial contaminants from feedlot runoff (Young et al. 1980). Filter or buffer strips have been quite attractive to some Delta crop producers in that conventional tillage can still be conducted, thus allowing improved crop and water management in the field, while at the same time filters trap suspended solids, thus improving the overall quality of water leaving the field.

To fully develop recommendations on controlling herbicide movement in runoff from Delta crop production systems, a complete assessment of current water quality from a herbicide standpoint is needed. Some studies have been done in Arkansas (Lavy et al. 1992) on lakes and waterways, and others have conducted assessments on the Mississippi River and its tributaries (Goolsby et al. 1993; Pereira and Hostettler 1993). Similar, but more detailed, assessments are needed in Mississippi to establish a baseline of residues currently present in surface waters of the Delta.

MATERIALS AND METHODS

Surface-Water Reconnaissance

In August of 1995 a surface-water reconnaissance was conducted to assess cyanazine concentrations throughout the Delta region of Mississippi. This sampling period was chosen to coincide with lay-by applications of cyanazine in cotton. Sampling sites were located at stream gaging stations operated and maintained by the U.S. Geological Survey and the U.S. Army Corps of Engineers, as well as several oxbow lakes in the Delta. For comparison purposes, eight locations were also sampled in the uplands area adjacent to but outside the Delta. Samples were collected in glass bottles, filtered through 0.45-micron filters, and stored on ice until analysis. Samples were analyzed for cyanazine concentration using an enzyme-linked immunosorbent assay, with a lower detection limit of 0.14 ppb.

Separate samples were also collected in May of 1995 to determine fluometuron concentration immediately following the peak use period after cotton planting. Immunoassay techniques were used for these samples as described above. A number of relatively high concentrations were detected by this procedure, some in excess of 100 ppb. However, confirmation efforts with GC-MS indicated that a number of false positives and artificially high levels were reported by immunoassay. The immunoassay used apparently reacted with other components in the water that were structurally similar to fluometuron. This is a major concern with detection techniques such as this when confirmation is not done.

Mechanisms to Control Herbicides in Runoff

Studies were conducted over the last 5 years at the Black Belt Branch Experiment Station, Brooksville, Mississippi, to evaluate various methods of controlling runoff, erosion, and herbicide loss from standard USLE runoff plots planted to soybean or cotton. In both crops, tillage levels (no-till, reduced-tillage stale seedbed, and conventional tillage), cover crop (wheat present or absent), and tall fescue vegetative filter strips of 0.5 to 2.0 m in width at the base of the plot were evaluated. In cotton, the herbicides fluometuron and norflurazon were evaluated, while metolachlor and metribuzin were evaluated in soybean. A Brooksville silty clay soil (fine, montmorrillonitic, thermic Aquic Chromudert) was used in all studies. This soil has a high shrink-swell capacity and has many characteristics similar to the clay soils in the Delta.

A rainfall simulator was used in all studies to supplement natural rainfall/runoff events. The first runoff event was initiated within 3 days of planting and herbicide application each year. After each event, effluent was agitated and a 1-L sample was collected from each runoff plot and stored in glass containers at 5 C until analysis. GC or HPLC methodologies were used for all herbicides, with lower detection limits of 0.25, 0.10, 14, and 13 ppb, respectively, for metolachlor, metribuzin, fluometuron, and norflurazon.

Concentration values were combined with total runoff to determine total loss of each herbicide per runoff event on a per ha basis, and subsequently total loss due to off-site movement in runoff through the season. Concentration data were subjected to regression analysis to describe concentration of each herbicide in runoff and to determine the impact of filter strips or tillage systems on herbicide concentrations or loss patterns.

RESULTS AND DISCUSSION

Surface-Water Reconnaissance

During the summer of 1995, most of the Mississippi Delta experienced near-drought conditions with moderate rainfall occurring immediately following the normal time-frame for layby applications of cyanazine. Stream flow was relatively low during the sampling period which, coupled with sufficient rainfall to move cyanazine into surface water bodies, created a situation in which higher concentrations of cyanazine were expected (sufficient runoff to move herbicides into streams, but not sufficient to substantially increase stream flow).

With only one exception, all samples contained cyanazine at concentrations above the lower detection limit of 0.14 ppb. Concentrations ranged from 0.16 to 6.4 ppb. All concentrations were well below the health advisory level of 10 ppb. At all eight sampling sites outside the Delta, concentrations never exceeded 0.50 ppb. These results provide positive evidence that intensive agricultural activities in the Delta have a minimal impact on surface water quality from the standpoint of nonpoint-source pollution by herbicides.

Correlations between cyanazine concentration and various factors were attempted. No apparent trends with respect to measured cyanazine concentration and levels of usage by county were observed. High and low concentrations were measured in counties from all usage classes. Cyanazine concentration was also evaluated in relation to distribution of the major soil series in the Mississippi Delta. Clear trends were again not evident. Concentrations of 3 ppb and higher were measured at locations situated on Alligator-Sharkey, Commerce, and Dundee soil series. Alligator and Sharkey soils are cracking-clay soils with very low permeability, while Commerce and Dundee soils have upper horizons which are fine sandy loam to silty clay loam.

The clearest connection that could be drawn from the reconnaissance sampling was that time between herbicide application and rainfall/runoff is a critical factor. In instances where concentrations of 3 ppb or more occurred, rainfall had occurred quite recently and stream flow hydrographs were rising.

Mechanisms to Control Herbicides in Runoff

A great deal of variability has been noted in herbicide loss from different tillage systems. In some years, going to a reduced or no-till program reduced herbicide loss in runoff, while in other years and other environmental conditions, conventional tillage reduced herbicide movement. Similarly, presence of a cover crop reduced herbicide concentrations by as much as 50% in one year, while increasing losses by similar amounts in another year. Most theories on the reasons why this variability occurs has centered around amount, intensity, and timing of rainfall in relation to application, soil conditions (moisture, roughness, texture) in relation to planting and application, and changes in soil characteristics such as macropore development with changes in tillage and cover. Conclusions from the research indicate that no single tillage or cover crop program can consistently improve or adversely affect runoff water quality with respect to these herbicides.

Vegetative filter strips have, however, consistently reduced herbicide loss in runoff with all four compounds studied in Mississippi. Reductions have typically ranged from 50 to 85%, depending on overall runoff patterns and soil conditions. Filter strips have reduced concentrations of herbicides in runoff, indicating a true filtering effect, and also serve as a natural dam, which allows water to infiltrate into soil and keep the herbicides on-site.

The 0.5 and 1 m tall fescue filter strips reduced total sediment loss from conventionally tilled cotton by an average of 32%, and no difference between widths was noted. Across years, fluometuron and norflurazon losses from the unfiltered treatment averaged 10 and 9% of the total amount applied, respectively. When compared to the unfiltered treatment, the 0.5 and 1 m filter strips reduced fluometuron and norflurazon yearly loss by an average of 48 and 50%, respectively. Increasing filter strip width reduced concentrations of both herbicides in runoff.

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