THE EFFECT OF BEST MANAGEMENT PRACTICES ON FLUOMETURON SORPTION

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INTRODUCTION

The EPA has stated that agricultural stresses, largely from excess nutrients, sediment, and pesticides, affect 58 % of impaired lake acres, 55 % of impaired stream miles, and 21 % of impaired estuarine systems (Wells 1992). Due to the humid sub-tropical climate in Mississippi, both weed and insect pressure have a high impact on farm production compared to other areas of the nation. Similarly, increased microbial activity promotes oxidation of organic matter, requiring synthetic fertilizer for nutrient replenishment. As a consequence, the intensity of agrichemical use in crop production is exceptionally high, particularly in cotton. Spring rainfall amount and intensity are also high and a primary object for crop producers is to expeditiously move water off the field through trenched water furrows. Since most agriculture contaminants move off-site with water, the potential for significant contaminate flux through the ecosystem exists.

Currently, the Department of Environmental Quality (DEQ) sets total maximum daily loads (TMDL) of nonpoint-source pollution for bodies of water, and each state is responsible for administrating pollution abatement programs to assure water quality improvement for impaired watersheds. However, if water quality does not improve, the EPA could intervene and dictate the control of runoff in the near future. Therefore, management systems evaluation areas (MSEA) projects provide an excellent opportunity to educate the public with scientific information concerning cropped water-sheds as a nonpoint contaminant source. MSEA projects are part of a program titled Agriculture Systems for Environmental Quality (ASEQ). They were included in the President's 1989 Initiative on Water Quality to investigate water quality contamination from pesticides and fertilizers used in field crop production. In 1994, the Mississippi Delta MSEA project was initiated to identify, implement, and evaluate BMPs for use in the Delta. A BMP is the physical application of plant, land, and water management knowledge, in order to protect soil and water resources (Parkman 1996). BMPs are designed to lower the kinetic energy of moving water and consequently reduce the transport of nonpoint-source contaminants such as pesticides, nutrients, and eroded sediment. Once effective BMPs have been adopted, states can incorporate them in nonpoint-source pollution abatement programs to achieve compliance.

MD-MSEA research is being conducted by several local, state and federal agencies at three watersheds located in Sunflower and Leflore counties in Mississippi. Each location has a watershed that drains into an oxbow lake. These lakes were once a part of natural meandering channels or floodplains of the Sunflower or Yazoo Rivers. However, a change in the course of river flow has left these lakes isolated from their adjacent river channels. The cropped area surrounding the oxbow lake creates a closed watershed system, hence an ideal environment to study the physicochemical processes in runoff influenced by various BMPs. Some BMPs for preserving water quality include: ultra low selective agrochemical applications, conservation tillage, grass filter strips, slotted board risers, and riparian forest management. This report will focus on the use of an established grass filter strip and a riparian forest as BMPs for surface water quality improvement.

Farmers generally cultivate land to the edge of ditches and roads, leaving no grass border. However, small-plot research at Mississippi State University has demonstrated that edge-of-field grass filter strips can reduce sediment and herbicides in runoff at least 50% (Rankins et al. 1997; Tingle et al. 1997; Webster and Shaw 1996). A grass filter strip is designed to remove sediment, organic matter, and other pollutants from runoff and waste water by filtration, deposition, infiltration, sorption, decomposition, and volatilization, thereby increasing water quality (SCS 1989). However, research has not been effectively evaluated on a watershed scale.

Historically, riparian forests and wetlands in the Mississippi Delta were viewed as undesirable swamps to be drained, and their benefits in water quality improvement went unnoticed. These forest areas are transitional between ecotones of land and water and they may serve as a BMP for water quality improvement in forestry practices (Hubbard and Lowrance 1994). In addition, riparian forests can remove sediment and other pollutants in runoff from adjacent croplands (Jordan et al. 1993). Studies have shown that a riparian zone can retain 70 to 90% of total nitrogen inputs and that most NO_3^- removed occurs within 20 m of the forest / field boundary (Jordan et al. 1993).

After application, the environmental fate of a herbicide depends on compound retention, transportation, transformation, and interactions of these processes

(Koskinen and Harper 1990). Some of the environmental sinks in the soil-plant-atmosphere continuum include: sorption and desorption to the soil colloidal fraction, runoff movement in the dissolved or sorbed state, plant uptake, volatility or photolysis, and hydrodynamic transport as soluble constituents of the aqueous phase (convection, transpiration, or evaporation) (Weber 1986). Herbicide retention primarily refers to adsorption, which is defined as the accumulation of a pesticide or other organic molecule at either the soil water or the soil-air interface resulting in molecular layers on the surface of soil particles (Koskinen and Harper 1990). Adsorption is an important reversible process that is generally measured by herbicide disappearance from solution. However, it can be extremely difficult to distinguish between true adsorption and general sorption. Sorption is a term that generally refers to chemical loss from solution that includes adsorption, absorption, and precipitation (Koskinen and Harper 1990). When a herbicide is absorbed, it can move into the interior matrix of the colloidal fraction (clay minerals and humus) or plant biomass and become tightly bound. If precipitation occurs, the herbicide molecule could form a separate solid phase or covalently bond to the colloidal surface (Harper 1994). The influence of BMPs may change immediate soil rhizosphere constituents, hence a change in the physicochemical dynamics of compound retention, transportation, and transformation. This rhizospheric change of succession may differ among different BMPs. The organic matter content, clay type, and microbial environment may be changed over time due to factors such as sediment and herbicide deposition. Therefore, watershed management that directs runoff water flow through an established filter strip or riparian forest could increase the quality of water in nearby lakes. To ascertain the influence of these BMPs on water quality improvement, an initial investigation was conducted to determine the potential for fluometuron and sediment retention throughout the BMP areas. In order to achieve this objective, research was conducted to determine soil properties and fluometuron sorption in soil from an established grass filter strip, riparian forest, and adjacent cropped watershed epipedon at Beasley Lake in Sunflower County, Mississippi.

MATERIALS AND METHODS

Field Sampling

The study was established in October 1996 with a Dundee silt loam (fine silty, mixed, thermic, Aeric Ochraqualf) collected from a cropped watershed and an adjacent established filter strip epipedon (0-2 cm depth); and a Dowling overwash phase (fine, montmorillonitic, thermic, Vertic, Epiaquept) from a riparian forest epipedion (0-2 cm). These BMPs surround Beasley Lake in Sunflower County, Mississippi, in the Mississippi River alluvial floodplain. Established filter strip sampling points were arranged in a 10 m x 1 m matrix design to include a mixing zone (1m prior to strip edge, but not in crop area), strip edge, 1 m, and 2 m (into filter strip). Each soil composition will consist of 4 subsamples taken at each matrix point from four vertical rows (4 replications).

Channeled runoff from an adjacent watershed moves through the riparian forest and is discharged into the oxbow lake. Riparian forest sampling points were: entrance, 10 m, 25 m, 50 m, 100 m, 200 m, 400 m, and 800 m. Sampling points were divided into three areas based on fine soil particle stratification. Area designation in the riparian forest include the following: area 1 (0 to 25 m), area 2 (50 to 200 m), and area 3 (400 to 800 m).

Sample Preparation and Treatment

Samples were air-dried, sieved (2 mm), and soil moisture was determined. Samples were characterized for organic matter (%), texture, pH, and cation exchange capacity. Soil (5 g) was transferred to 45 ml centrifuge tubes. Technical fluometuron was dissolved in 0.01 M $CaCl_2$ to achieve solution concentrations of 0.01, 1, 4, and 8 $\mu g\ ml^{-1}$. Fluometuron solutions contained 0.0045$\mu Ci\ ml^{-1}$ uniformly ring-labeled ^{14}C-fluometuron. Fluometuron solutions were added to soil (5g/10 ml), and samples were placed on a rotary shaker for 15 h to allow the soil-herbicide system to reach equilibrium. After equilibration, samples were centrifuged (4000 rpm; 20 min) and a 1 ml aliquot of supernatant was transferred to 15 ml of water-accepting cocktail. Liquid scintillation spectrometry was used to count ^{14}C radioactivity for each sample. Fluometuron sorption to soil was determined by a change in the amount of extractable herbicide compared to the initial herbicide concentration in solution. Sorption isotherm models were developed using Freundlich parameters (Kf and [1/n]) calculated via linear regression of log-transformed data.

RESULTS AND DISSCUSION

Chemical Properties of the Soil

In the established grass filter strip, percent organic matter, percent silt, percent clay, cation exchangeable capacity, and pH in surface soil were higher with increasing distance from strip mixing zone (just prior to strip edge), to 1 m down slope from strip edge: 0.4% to 2.1%, 35.5% to 46.0%, 18.0% to 21.6%, 12.2 to 18.2, and 5.9 to 6.33, respectively (Table 1). Percent sand decreased from 46.3% to 20.5%. The filter strip decreased the kinetic energy of runoff water causing coarse sediment, such as sand, to settle out of suspension before reaching the filter strip. Finer sediment, such as silt and clay, remained suspended longer before being substantially reduced at 1 m into the filter strip. In the crop area, percent silt was higher, and soil pH and percent clay were lower than all filter strip areas; percent sand was lower than strip mixing zone and strip edge; and CEC and percent organic matter were similar to strip mixing zone and strip edge. A similar trend was observed for sediment deposited in the riparian forest area. Percent organic matter, percent silt, percent clay, and cation exchange capacity in surface soil increased with increasing distance down slope from the forest entrance (0-25 m): 2.3% to 4.5%, 39.8% to 55.3%, 22.1% to 39.8%, 18.4 to 31.7, respectively (Table 2). Percent sand and pH decreased from 38.1% to 5% and 6.8 to 5.8, respectively. This suggests the coarser fine earth fractions are deposited near the forest entrance (0-25 m), and the more fine-textured particles travel further through the forest before settling out of suspension.

Fluometuron Sorption to Epipedons

In the established grass filter strip, predicted fluometuron sorption to soil from the 1 and 2 m areas was highest, followed by sorption to soil from the crop area. Sorption was lowest to soil from the strip edge and strip mixing zone areas (Table 3). Fluometruon deposition in the filter strip would decrease mobility in runoff based on sorption characteristics of the soil. In addition, other processes, such as sorption, volatilization, degradation, plant uptake, and environmental factors such as evapotransporation, precipitation, and temperature, could interact to effect herbicide mobility (Tindall and Vencill 1995). The potential for fluometuron to move off-site is greatest if fluometuron deposition occurs in the area between the crop and filter strip. With decreased sorption, fluometuron molecules (free or displaced by water exchange sites) could be dissolved in the soil solution and leach with the water through preferential pathways. Preferential pathways are areas of lower density in the pedon compared to the surrounding soil matrix (Tindall and Vencill 1995). These pathways may or may not contain macropores (i.e. cracks, biochannels), but can promote rapid movement of fluomeutron through the soil. In the riparian forest, fluometuron sorption to soil increased with increasing distance from the channel entrance. Sorption to soil in the filter strip (1 m) and riparian entrance was equivalent (Table 4). Overall, predicted fluometuron sorption to soil from the filter strip and riparian areas increased compared to the crop area (Figure 1). Sorption was highly correlated with organic matter, sum of exchangeable cations, and clay content (Table 5). Results from other research also emphasis a strong correlation of soil organic matter with fluomeutorn sorption (Kozak and Weber 1983; Carringer et al. 1975; Peeper and Weber 1974; LaFleur 1973). Therefore, fluometuron sorption to soil from epipedons influenced by BMPs may have a significant influence on the fate of herbicides moving off-site with run-off water.

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Table 1. Soil properties associated with sample points in an established grass filter strip epipedon at Beasley Lake in the Mississippi Delta, Sunflower County, Mississippi.

Epipedon	pH	Cation exchange capacity	Sand	Silt	Clay	Organic matter
		(meq/100g)		(%)		
Crop	4.73 c*	11.65 c	27.75	59.25	13.00	0.69 b
Est (mix zone)	5.90 b	12.19 bc	46.25	35.50	18.00	0.42 b
Est (edge)	6.00 ab	14.39 b	40.00	39.25	20.75	0.91 b
Est (1m)	6.33 a	18.22 a	20.50	57.75	21.58	2.13 a
Est (2m)	6.00 ab	18.13 a	31.25	46.00	22.75	2.37 a

* Means within a column followed by same letter do not differ significantly at the 5% level (*F* test).

Table 2. Soil properties associated with sample points in a riparian forest epipedon at Beasley Lake in the Mississippi Delta, Sunflower County, Mississippi.

Epipedon	pH	Cation exchange capacity	Sand	Silt	Clay	Organic matter
		(meq/100g)		(%)		
Crop	4.73 c*	11.65 d	27.75 b	59.25 a	13.00 c	0.69 d
Est (1m)	6.33 a	18.22 c	20.50 b	57.75 a	21.58 b	2.13 c
Rip (0-25 m)	6.77 a	18.43 c	38.08 a	39.83 b	22.08 b	2.25 c
Rip (50-200 m)	6.37 a	23.26 b	7.38 c	61.91 a	25.91 b	3.14 b
Rip (400-800 m)	5.77 b	31.71 a	5.00 c	55.25 a	39.75 a	4.54 a

* Means within a column followed by same letter do not differ significantly at the 5% level (*F* test).

Table 3. Fluometuron sorption to soil from an established grass filter strip epipedon at Beasley Lake in the Mississippi Delta, Sunflower County, Mississippi.

Epipedon	Adsorption (μg/g)
Crop	48.89 b*
Est (mix zone)	27.86 c
Est (edge)	19.38 d
Est (1m)	68.06 a
Est (2 m)	69.81 a

* Means within a column followed by same letter do not differ significantly at the 5% level (*F* test).

Table 4. Predicted fluometuron sorption to soil from an established grass filter strip epipedon at Beasley Lake in the Mississippi Delta, Sunflower County, Mississippi.

Epipedon	Adsorption (μg/g)
Crop	48.89 d*
Est (1m)	68.06 c
Rip (0-25 m)	84.88 c
Rip (50-200 m)	110.16 b
Rip (400-800 m)	146.74 a

* Means within a column followed by same letter do not differ significantly at the 5% level (*F* test).

Table 5. Correlation analysis of soil properties with fluometuron sorption for soil samples from established grass filter strip, riparian forest, and crop epipedons established at Beasley Lake in the Mississippi Delta, Sunflower County, Mississippi.

Independent Variables	Across Sorption Isotherms
Organic matter	0.97
pH	0.30
Sand	-0.72
Silt	-0.001
Clay	0.97
CEC	0.98

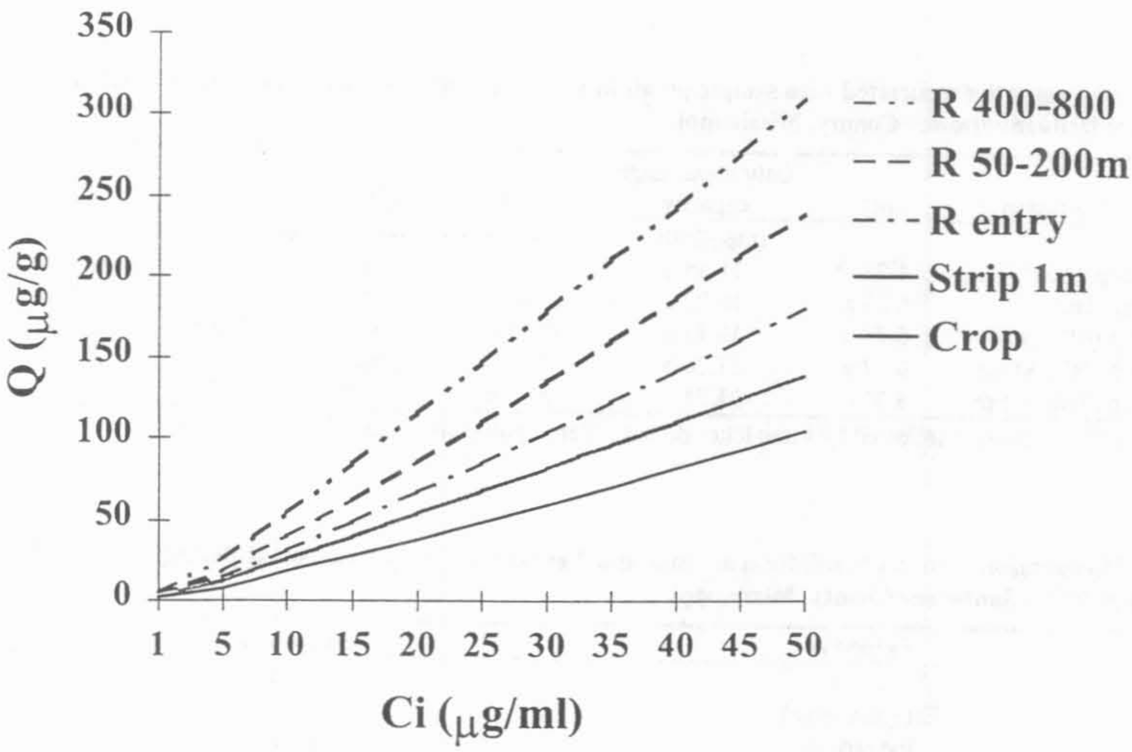

Figure 1. Predicted fluometuron sorption to soil form epipedons influenced by the following best management practices (BMPs) located at Beasley Lake in Sunflower Co, MS. BMPs include an established filter strip (1 m from edge of strip); and Riparian forest entrance, 50- 200 m, and 400-800 m.