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ABSTRACT

As no-tillage and other conservation tillage practices continue to increase, it is important to have knowledge of herbicide adsorption on crop residue with regard to the potential for the herbicide to be removed from the residue and move with runoff water from the field into nearby surface waters. Previous research had compared herbicide adsorption to various residues, but it was difficult to make comparisons among these studies because the residues were from different crops or the amount of residue decomposition was different. The amount of "weathering" or "aging" of the residue at the time of herbicide treatment could alter the amount initially adsorbed and subsequent desorption by rainfall. The amount of herbicide adsorbed varied greatly among the herbicides evaluated. Of the triazine herbicides, AAtrex had the least amount adsorbed (5%) and Princep was adsorbed the most (32%) with Bladex (15%) having an intermediate amount of adsorption. The two acetochlor formulations had a similar amount of adsorption with Surpass being 57% adsorbed and Harness being 61% adsorbed. Dual (44%) and Frontier (38%) had lesser amounts adsorbed compared to Surpass and Harness. A calculated Herbicide Contamination Potential (HCP) more accurately reflected potential contamination of surface water than did herbicide adsorption.

Focus Categories: AG, SW, WQL

Key Words: Agriculture, Conservation, Herbicides, Runoff

Table of Contents

List of Tables

Chapter I - Introduction

Research Objectives.

1. Determine the capacity of corn and soybean residue to adsorb herbicides commonly used in Kentucky.

2. Summarize the data obtained under Objective 1 into a format useful for making site specific herbicide recommendations based on the type and amount of surface crop residue and the amount of herbicide applied.

Herbicides are used for weed control on practically all of the corn and soybeans grown in Kentucky, because they are essential for economical crop production. Of the six herbicides most commonly used in corn in Kentucky in 1992, 88% were applied to the soil (2). For soybeans, in over 70% of the treated acres [those that received at least one herbicide] the herbicides were applied to the foliage weeds and soybeans (2). Herbicides have been detected in various surface waters in Kentucky (7), but the mechanisms of how the herbicides move from the fields into surface waters has not been documented fully.

The factors that determine the potential for herbicide contamination of surface waters include the amount of herbicide applied, the persistence of the herbicide on crop residue or soil, the adsorptivity of the herbicide to soil constituents and plant residue on the soil surface, the timing and intensity of the first rainfall after application and the amount of herbicide that reaches the soil surface or crop residue. Additionally, the slope of the field will impact the surface movement of herbicides moving in surface water either in solution or adsorbed to soil particles. Conservation tillage (defined here as greater than 30% of ground covered by previous crop residue) of some type is practiced on over 62% of acres planted to corn and over 73% of acres planted to soybean in Kentucky (1). The widespread utilization of conservation tillage results in less soil erosion and increases soil water conservation. Both of these factors can impact surface water contamination from herbicides. As less soil is moved from the fields, less herbicide will be moving from the field.

It is important that information pertaining to herbicide adsorption and desorption of these herbicides from crop residues be determined. This is especially true in Kentucky because of the emphasis on conservation tillages. Also, the primary application methods of herbicides in corn and soybeans are very different. This project proposes to determine the herbicide adsorption to, and desorption from, crop residues. These data will be utilized to make site-specific herbicide recommendations in corn and soybean to further reduce herbicide contamination in surface waters.

Chapter II - Research Procedures

Soybean residue was collected in April 1995, from a field planted to soybeans the previous year. This resulted in soybean residue that had "aged" in the field for about 10 months. This would be the normal aging process that would occur under field conditions, since soybeans are planted from late May to mid-June and corn is planted from early to mid-April. After collection, the residue was cut into 10 cm segments and frozen at -10 C until used.

Herbicides evaluated (Table 1) are frequently used for weed control in corn planted without tillage into soybean residue. Atrazine, simazine and cyanazine formulations evaluated were applied as Dry Flowable formulations, because these are the formulations most widely used by growers. Metolachlor, acetochlor, and dimethenamid are formulated only as emulsifiable concentrates. Two formulations of acetochlor were evaluated, because they are both used by growers and are slightly different from each other. All formulations used in the study are those currently available to growers as commercial products.

Table 1. Herbicides evaluated for adsorption to soybean residue. DF = Dry Flowable; E = Emulsifiable Concentrate.

Active Ingredient (AI)	Trade Name (Product)	Formulation	Amount of Product / Acre	Pounds of AI Per Acre
Atrazine	AAtrex	90 DF	1.67 lb	1.5
Simazine	Princep	90 DF	1.67 lb	1.5
Cyanazine	Bladex	90 DF	3.33 lb	3.0
Metolachlor	Dual	8 E	2.0 pt	2.0
Acetochlor	Harness	7 E	2.3 pt	2.0
Acetochlor	Surpass	6.4 E	2.5 pt	2.0
Dimethenamid	Frontier	7.5 E	1.6 pt	1.5

A procedure developed by Schmitz (11) was used to treat the soybean residue and recover the herbicides after application. In this procedure, 1.1 lb of quartz sand was placed into eight-inch diameter aluminum pie plates,and 1.0 oz of soybean residue was spread uniformly over the surface of the sand. A sand-only treatment was included for each herbicide treatment to compare the efficiency of herbicide removal from the sand. Each treatment was replicated three times.

All herbicide treatments were applied in a spray chamber with a flat fan nozzle tip. The herbicides were added to water and the resulting suspensions were sprayed at a volume equivalent to 25 gallons of spray mixture per acre at a pressure of 30 psi. This spray chamber allows for herbicide applications that have a spray droplet size and droplet distribution that is similar to that used under field conditions.

After the herbicides were applied, the residue was allowed to dry for 24 hours, and then 0.5 inch of simulated irrigation was applied over a 30-minute period. The residue and sand in each plate were allowed to drain for 15 min, after which the soybean residue was removed from the sand. The sand was washed two times with water and the water samples were frozen until extraction. Herbicides were extracted from the water with methylene chloride. The methylene chloride was reduced under vacuum and the herbicides dissolved in hexane. Herbicide analysis was determined with an HP 5890A Gas Chromatograph with a Nitrogen/Phosphorus detector. The oven, injector and detector temperatures were 100 degrees C, 250 degrees C, and 300 degrees C, respectively. Quantification of each herbicide was determined based on peak area of each sample compared to peak areas of known concentrations for each herbicide.

Chapter III - Data and Results

A preliminary experiment indicated there was no difference in adsorption of these herbicides to soybean residue at 7 days after treatment compared to 1 day after treatment; therefore, this study only evaluated the amount of adsorption one day after treatment.

The data obtained in this study indicated that considerable differences in adsorption to soybean residue exist among herbicides of similar chemistry (Table 2). The triazine herbicides AAtrex, Bladex, and Princep varied between 5 and 32 % and the acetamide herbicides Dual, Frontier, Harness and Surpass varied between 38 and 61 percent. The two acetochlor formulations, Harness and Surpass, had similar adsorption and both were in the Medium category. Those herbicides in the Very Low to Low category would be more prone to be removed from plant residue on the soil surface and move in runoff water from the field, while those in the Medium category would be less likely to be desorbed and move in the runoff water. Interestingly, none of the herbicides evaluated in this study were in the High category.

Table 2. Herbicide adsorption to soybean stubble. The amount of adsorption was grouped according to the following: Very Low = <25%; Low = 26-50%; Medium = 51-75%; High = > 75%. The percentage of the herbicide applied that was adsorbed onto the soybean stubble is given in parentheses.

Very Low	Low	Medium	High
AAtrex (5)	Princep (32)	Surpass (57)	
Bladex (15)	Frontier (38)	Harness (61)	
	Dual (44)		

Grouping of herbicides in these broad categories is useful for initial comparisons but does not take into account the pounds of herbicide applied on an area basis. In an attempt to standardize the potential for herbicide contamination of waters, based on herbicide adsorption to plant residue, a Herbicide Contamination Potential (HCP) was developed. The following equation was used:

$$HCP = R * A * F * 100$$

HCP = Herbicide Contamination Potential

R = Rate applied per acre, expressed as pounds active ingredient

A = Percent applied that was not adsorbed to residue

F = Fraction applied that reaches the soil surface

In the following discussion, F was assumed to be 0.5. This fraction was determined based on previous research of the Principal Investigator which shows that the amount of herbicide reaching the soil surface under no-tillage can vary between 30 and 75%, depending on the amount of crop residue on the soil surface at the time of application. The term "A" was expressed as the amount not adsorbed so that a herbicide that has little adsorption to crop residue will have a large HCP. For example, AAtrex would be calculated as HCP=1.5*0.95*0.5*100=71.25; Harness would be calculated as HCP=2.0*0.39*0.5*100=39.

The HCP of the herbicides evaluated are given in Table 3. When the amount of herbicide applied is coupled with the adsorption of the herbicide, it is evident that the potential contamination changes compared to using only the amount of adsorption. Based on adsorption, AAtrex would be more of a potential contaminant than Bladex, but when the HCP is calculated, Bladex becomes more of a potential contaminant. Similarly, Dual and Frontier have a different ordering because of the difference in amount used on an area basis.

Table 3. Herbicide Contamination Potentials calculated for several herbicides used in corn based on their adsorption to soybean residue. The larger the number, the greater the potential for contamination.

Herbicide	HCP	% Adsorbed
Bladex 90 DF	127.50	15
AAtrex 90 DF	72.25	5
Dual 8 E	56.00	44
Princep 90 DF	51.00	32
Frontier 7.5 E	46.50	38
Surpass 6.4 E	43.00	57
Harness 7.5 E	39.00	61

Calculating an HCP will be useful for making direct comparisons of herbicides when adsorption is compared on the same plant residue. For example, Schmitz (11) compared the relative adsorption of three herbicides on wheat straw (Table 4). Herbicides such as imazaquin and chlorimuron can be applied to soil and crop residue or applied to weed foliage after soybeans and weeds have emerged. A lower HCP is obtained when applied to the weed foliage because the amount of herbicide used is smaller compared to applications to plant residue and soil. In the case of imazaquin, the difference in rate is 0.125 lb imazaquin per acre to soil and plant residue compared to 0.063 lb imazaquin per acre applied to weed foliage. In the case of chlorimuron, the rate is 0.04 lb chlorimuron per acre for soil and plant residue compared to 0.008 lb chlorimuron per acre applied to weed foliage.

Table 4. Calculation of Herbicide Contamination Potential (HCP) for herbicides applied to wheat straw.

Herbicide	Site of application	HCP
Imazethapyr	Weed foliage	0.35
Imazaquin	Soil	0.68
Imazaquin	Weed foliage	0.34
Chlorimuron	Soil	0.38
Chlorimuron	Weed foliage	0.08

The utility of using an HCP approach for ranking herbicides can be demonstrated by a comparison of two commonly used herbicides. The herbicides metolachlor, sold as Dual, and alachlor, sold as Partner or MicroTech, are used in corn and soybeans and the amount applied per acre is also the same in both crops. Further, both can be used in tilled and no-tilled situations. The amount of residue remaining on the soil surface at the time of planting corn or soybean differs depending on the previous crop and the amount of degradation of the residue that has occurred in the time between harvest of the preceding crop and the planting of the current crop. For example, soybean residue will usually cover about 30% of the soil surface at the time of corn planting. Corn stalks will cover about 90% of the soil surface and wheat straw will cover about 75% of the soil surface. These percentages are crucial to the calculation of the HCP because the R term in the HCP equation is the amount of herbicide not intercepted by plant residue. Therefore, a field covered with corn stalks will intercept about three times as much herbicide as would a field covered with soybean residue. This obviously would result in very different HCPs being calculated. Using data obtained in this project for soybean and data collected by Rodrigue for corn and wheat, comparisons of HCPs were calculated (Table 5). The amount of adsorption for metolachlor were 44, 39, and 31% for soybean, corn and wheat, respectively, while the adsorption for alachlor was 38 % for corn and 39% for wheat.

Alachlor was not included in the soybean adsorption study.

Table 5. A comparison of alachlor and metolachlor HCP on soybean, corn , and wheat residue. Soybean adsorption data was collected in this project. The corn and wheat straw data was obtained by Rodrigue (10). It was assumed that 30, 90, and 75% of the applied herbicides would be intercepted by soybean, corn, and wheat, respectively.

Herbicide	Soybean	Corn	Wheat
Metolachlor	78.4	12.2	34.5
Alachlor	--	12.4	30.5

Remembering that the larger the HCP, the greater the potential for movement in runoff water, it is evident that crop residues that cover a large percentage of the soil surface would be more effective in preventing herbicide movement.

Chapter IV - Summary and Conclusions

Information obtained in this project clearly show a major difference in the relative adsorption of commonly used herbicides to soybean residue. These differences were large enough that the amount of adsorption should be considered when making herbicide recommendations on highly erodible fields.

The calculation of Herbicide Contamination Potentials (HCP) for herbicides should be a more effective mechanism because it combines the amount of herbicide adsorption to crop residue, the amount of herbicide applied to an area, and the amount of herbicide that would be intercepted by residue on the soil surface. A single HCP for a herbicide across the state or region is not feasible to calculate because of the differences in plant residue on the soil surface; however, a specific HCP can be calculated on a field basis. Herbicide recommendations for weed control are based on individual fields, so professional crop consultants are familiar with field based, site specific recommendations. Calculating the HCP on a specific site should not pose a problem for crop consultants, but should increase their ability to make recommendations based on potential contamination. This should improve the ability for growers and consultants to further reduce surface water contamination from herbicides.

Using the HCP approach should be particularly important for areas with erodible fields, such as Kentucky. Over 60% of Kentucky's corn and soybean acreage utilizes some type of conservation tillage. This means that some kind of crop residue is on the soil surface at the time of crop planting. This is further evidence for the need for site specific herbicide recommendations. Such site specific herbicide selection could be incorporated into the GPS technology that is starting to be used on crop production fields.

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