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Residues of Alachlor in Soil after Application of Controlled Release and Conventional Formulations

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The extensive use of herbicides for weed control in the U.S. has resulted in the detection of residues of several herbicides in ground water in most states in the U.S. (Patrick et al. 1987). Elimination of use of herbicides can, however, jeopardize high quality food supplies and efficient crop production. A search for herbicides, or techniques of applying them, that may reduce or prevent chemical contamination of ground water may provide some solutions to the problem.

From the environmental viewpoint an ideal preemergence herbicide should persist in the shallow zone of weed seed germination to control weeds during the critical stages of crop growth and then degrade so that residues do not carry over to the next season.

Controlled release formulations of herbicides offer the potential of controlling weeds for longer periods with less herbicide (Schreiber et al, 1987). Improved weed control with starch impregnated and microencapsulated controlled release formulation of alachlor has been reported (Wilson et al. 1988; Smith and Verma 1977; Petersen et al. 1988). Petersen et al. also reported microencapsulated alachlor to be more persistent than conventional emulsifiable alachlor. Chemical persistence and leaching of controlled release vs conventional alachlor are, however, not well documented. The objective of this study is to compare residues of alachlor {2-chloro-2',6'-diethyl-N-(methoxymethyl)-acetanilide} in soils after application of the alachlor in the field with controlled release and with conventional formulations.

MATERIALS AND METHODS

Microencapsulated and conventional emulsifiable concentrate formulations of alachlor were applied at varying rates to two field sites on May 12, 1988, and June 1, 1989, respectively.

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The sites were on Merrimac sandy loam soil with about 3% organic matter and a pH of 6.0. The soil was plowed and harrowed before herbicide application. The herbicides were applied with a hand-held four-nozzle boom calibrated to deliver 30 gal/A. Treatments were replicated four times in a randomized complete block design. Plot sizes were 6 by 10 ft, separated by 3 to 4 ft. alleys on all sides to reduce cross contamination from adjacent plots.

The test areas received about 0.5 in of water by irrigation 24 h after the 1988 application and 0.25 in of rainfall 2 h after the 1989 application. Irrigation was applied thereafter during dry periods. In 1988, rainfall was well below normal each month from May to October, except for July, which was about 2.5 times above normal. In 1989, however, rainfall was normal (3.66 in) only in July and well above normal in June, August and September.

In the 1988 experiment no crop was grown in the sections of the plots sampled for residues, but weeds were allowed to grow and were periodically killed with the contact herbicide paraquat (1,1'-dimethyl-4,4'-bipyridinium ion). In the 1989 experiment the herbicide atrazine (2-chloro-4-(ethylamino)-6-(isopropylamino)-s-triazine) was added to all of the alachlor treatments at 1 lb/A to control broadleaf weeds. The weeds in all plots were killed in July with glyphosate (N-(phosphonomethyl) glycine).

At approximately 4 months and 12 months following the 1988 herbicide application, and at 4 months following the 1989 application eight 0.75 in diameter soil cores were taken from the 0 to 4 in and 4 to 8 in depths from each of the plots. The samples were air dried in a greenhouse for 1 to 3 days, sieved through a 2 mm mesh screen to remove stones and foreign materials and then frozen at -18^{o} C until analysis.

Alachlor was extracted from the soil sample by an optimized method (Huang and Pignatello 1990), and analyzed by a GC/MS method (Huang 1989). Briefly, approximately 10 g of soil was weighed and combined with 35 ml methanol-water (80+20) in a sealed vial. The sample was then incubated on an orbital shaker in a thermostated oven (75^{o} C) for 16 hours. The supernatant liquid was removed for GC/MS analysis. A known amount of ^{15}N,^{13}C-alachlor was spiked into the extract as an internal standard. The herbicides were phase-transferred to 10 ml dichloromethane, which was subsequently concentrated to about 0.5 ml for splitless injection into a Hewlett-Packard 5970 GC/MS. Quantitation of alachlor was based on the response of isotope-labelled standards, which ensured good accuracy and precision.

RESULTS AND DISCUSSION

In the first experiment conducted in May 1988, emulsifiable and microencapsulated alachlor (controlled release) were applied at the rate of 3 and 6 lb/A. Soil residues of alachlor at 4 and 12 months after application are shown in Table 1. At 4 months only those plots treated with the 6 lb/A rate were sampled and analyzed for residues.

Replicate results for the same rate and the same formulation vary considerably, e.g., from 0.7 to 11.8 ppb for 3 lb/A for the conventional formulation. This variation is normal under field conditions. Herbicide depletion in the field by biodegradation, volatilization, surface movement or leaching is very dependent on variable field conditions such as intensity of rainfall, organic matter, soil moisture content, or other soil properties.

Despite the variation among replicates, the alachlor residues found at the 0 to 4 inch soil depth were consistently higher at 4 months or 12 months with the microencapsulated formulation than with the emulsifiable concentrate (about five-fold higher at 3 lb/A). As expected, residues found at 12 months also were directly related to the rate of herbicide application.

Unlike the residues in the surface soil, however, the residues at the 4 to 8 in depth did not appear to be affected by rate of application or type of formulation. Residues at the 4 to 8 in depth were much lower than at the 0 to 4 in depth and were about the same regardless of rate or formulation. No residues of alachlor were detected at the 4 to 8 in depth 12 months after treatment, regardless of the application rate or formulation.

Alachlor residue found 4 months after the 1989 application are given in Table 2. The results show the same trends as in 1988. Residues at the 0 to 4 in depth generally increased with rate of application and were again about five-fold higher with the microencapsulated formulation than with the conventional emulsifiable concentrate. Residues of alachlor at the 4 to 8 in soil depth were lower than at the 0 to 4 in depth, and were not related to rate of application or formulation. These effects are illustrated in Figure 1 in which the mean values of the residues are plotted against the amounts of alachlor applied.

Statistical analysis (Analysis of Variance) was used to compare the results from two formulations at rates of 1, 2, and 3 lb/A. The conclusions are that, regardless of formulation, the alachlor

Table 1. Residues of alachlor detected in soils collected 4 and 12 months following application in May 1988 by conventional and controlled release formulations.

Formulation	Rate lb/A ai[1]	Soil depth inches	4 months (ppb)		12 months (ppb)	
			mean	range	mean	range
conventional	3	0-4	-	-	6.8	0.7-11.8
		4-8	-	-	ND[2]	ND
	6	0-4	54.03	28.4-73.1	25.7	9.6-35.0
		4-8	5.15	3.7-7.8	ND	ND
controlled release	3	0-4	-	-	34.1	24.1-52.1
		4-8	-	-	ND	ND
	6	0-4	207.2	124.6-349.0	57.3	36.5-72.2
		4-8	8.15	7.6-9.3	ND	ND
untreated		0-4	ND	-	0.33	ND-1.3
		4-8	ND	-	ND	ND

[1] ai active ingredient

[2] ND non-detectable, less than 0.5 ppb

concentrations are significantly higher at the 0-4 in than at the 4-8 in depth, and that the concentrations of alachlor with controlled release are significantly higher than with conventional formulation at 0-4 in but not at 4-8 in at the 95% probability level.

In a review article of controlled release herbicides, Schreiber et al.(1987) predicted theoretical curves in which conventional application of herbicide should reach a much higher level in the field and drop quickly in short time, while controlled release should release a constant herbicide level within the effective range for a long time. Our experimental results in the field agree with the prediction in that controlled release formulation of alachlor is much more persistent than the conventional formulation.

In data not presented here the controlled release formulation of alachlor controlled weeds longer than the conventional formulation, which also suggests greater persistence in the surface soil. Thus, our results show that the microencapsulated controlled release formulation of alachlor has the increased persistence desirable to control weeds, but leaching potential, at least to the 4-8 in depth, is not increased. This suggests that if rates of application can be reduced by using the controlled release formulation of alachlor, the potential for leaching to ground water can be reduced.

Table 2. Residues of alachlor detected in soils collected 4 months after application in June 1989 by conventional and controlled release formulations.

CONVENTIONAL EMULSIFIABLE CONCENTRATE

RATE (lb/A)	SOIL DEPTH inch	ALACHLOR DETECTED (ppb) R1	R2	R3	R4	TOTAL	MEAN
1	0-4"	15.2	20.4	9.7	13.5	58.8	14.7
1	4-8"	9.9	12.0	4.6	18.7	45.2	11.3
2	0-4"	17.7	26.2	20.6	50.2	114.7	28.7
2	4-8"	9.3	12.4	14.1	20.6	56.4	14.1
3	0-4"	22.7	37.7	14.1	40.9	115.4	28.9
3	4-8"	13.3	13.9	12.4	21.4	61.0	15.3
4	0-4"	30.1	49.3	79.3	50.4	209.1	52.3
4	4-8"	14.1	15.2	11.1	14.1	54.5	13.6
CONTROLLED RELEASE (MICROENCAPSULATED) FORMULATION							
1	0-4"	17.1	83.9	69.0	114.6	284.6	71.2
1	4-8"	11.6	10.5	49.1	16.2	87.4	21.9
2	0-4"	118.9	221.3	79.3	205.3	624.8	156.2
2	4-8"	8.9	17.5	6.7	22.7	55.8	14.0
3	0-4"	61.1	95.3	64.9	326.8	548.1	137.0
3	4-8"	10.7	16.4	10.1	14.3	51.5	12.9

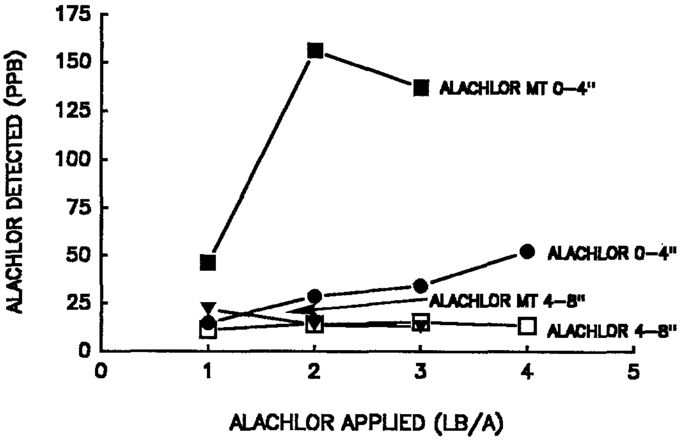

Figure 1. Alachlor Residues In Soil 4 Months After Application Of Controlled Release (Alachlor MT) And Conventional (Alachlor) Formulations.

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