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Degradation of Two Acetanilide Herbicides in a Tropical Soil

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The acetanilide herbicides alachlor and metolachlor are registered for control of most annual grasses and certain broadleaf weeds in many crops such as corn (*Zea mays* L.), soybean (*Glycine max* [L.] Merr.), rice (*Oryza sativa* L.), and peanut (*Arachis hypogaea* L.) (WSSA 1989). In Malaysia, these two herbicides are used for weed control in corn and peanut. While much is known about their activity and mode of action, little quantitative information is available concerning their mode of dissipation from soils under Malaysian conditions. The primary factors affecting soil degradation of acetanilide herbicides are adsorption and microbial decomposition, with 90% of the loss attributable to the latter (WSSA 1989). Adsorption and bioactivity of the acetanilide herbicides were correlated with organic matter, clay content and other soil parameters (Weber and Peter 1982). Organic matter was the primary adsorbing surface in the soil (Rahman et al. 1978; Weber and Peter 1982; Nishimoto and Rahman 1985). Propachlor and alachlor were found to be about 50 times more persistent in sterile soil than in non-sterile soil (Beestman and Deming 1974). Alachlor could be degraded by a common soil fungi *Chaetomium globosum* (Tiedje and Hagedorn 1975).

Because acetanilide herbicides are degraded quickly by soil microbes, their soil half-lives are relatively short. Beestman and Deming (1974) found half-lives of 4.0 and 7.3 days for alachlor and 1.9 and 4.4 days for propachlor in a silt and a silty-clay soil, respectively. The half-life of metolachlor has been estimated between 30 and 50 days in the northern areas and 15 to 25 days in the southern areas of the United States depending on soil type, moisture and temperature (WSSA 1989). No reports are known to exist on the persistence of these herbicides in tropical soils. Therefore, experiments were conducted to determine the degradation of alachlor and metolachlor in the soil at various moisture levels and in a field to be planted with corn and peanut.

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MATERIALS AND METHODS

Experiments were conducted in a greenhouse and at the Experimental area of the University. The soil used was a sandy loam with 45% sand, 35% silt, 20% clay, 0.38% organic C, and pH 5.9. The two acetanilide herbicides used in the study were alachlor (2-chloro-2',6'-diethyl-N-(methoxymethyl) acetanilide and metolachlor (2-chloro-N-(2-ethyl-6-methylphenyl)-N-(2-methoxy-1-methyl-ethyl) acetamide).

All samples were bioassayed in the greenhouse under 12 h of natural light/day. Temperature in the greenhouse averaged 32±2 C. The experimental design was a randomized complete block and data were subjected to an analysis of variance with mean separation by Duncan's multiple range test.

Four bioassay species, viz. cucumber (*Cucumis sativus* L.), corn, rape (*Brassica rapa* L.) and spinach (*Amaranthus viridis* L.) were tested to detect linearly the concentration range of the two herbicides in the soil used for field and greenhouse studies. The required volume of either herbicide was thoroughly mixed with air dry soil to obtain a concentration 20 ppm. Other required concentrations were prepared by diluting the treated soil with untreated soil. The concentrations used for both herbicides were 0, 0.5, 1.0, 2.0, 3.0, 4.0, 5.0, 10.0, 15.0 and 20.0 ppm. Treated-soil (1.0 kg) of each concentration for each herbicide was transferred into the pot separately. First-order linear-regression curves were obtained for each herbicide by plotting the average plant fresh weight of five replicates as a percent of the control vs. log herbicide concentration.

For each herbicide, nine 10-kg batches of air dry soil were treated to obtain a final concentration of 6.7 ppm for alachlor and 6.4 ppm for metolachlor. After mixing, five 1-kg portions of the treated soil were transferred into the pot. The pots were divided into three groups, each having soil moisture levels of either 20, 50 or 80% field capacity. Pots were kept in greenhouse and weighed weekly and the soil was stirred after water was added to maintain the required field capacity. Five pots containing soil treated with either herbicide at each moisture level were kept at 4 C on day 0, 7, 14, 21, 28 and 35 for incubation. After completion of all incubations, samples were thawed and air-dried overnight. Each 1-kg sample was then mixed and split into ten 500 g portions which were placed in styrofoam pots and 5 cucumber seeds were planted in each pot at a depth of 1 cm. After emergence, plants were thinned to two/pot. Eighteen days after planting, the plants were cut at soil level and fresh weights were recorded. The concentration of herbicide in the soil was determined by referring to dose-response curve that was run concurrently. Half-lives were calculated by assuming first-order kinetic behaviour.

Alachlor at 1.12 kg/ha and metolachlor at 1.08 kg/ha were applied in August 1989 to 2m x 5m plots at the UKM experimental area not previously treated with these herbicides. Each herbicide was applied with a knapsack sprayer at 450 L/ha. Untreated plot was sprayed with water to serve as control. The experimental design was a randomized block with three replications. Composite samples of five 10cm-deep soil cores were taken randomly from each plot on days 0, 7, 14, 21, 24 and 35. Samples were placed in plastic-lined bags and frozen immediately. For the bioassay, soil samples were thawed, air-dried overnight, mixed thoroughly and 750 gm of soil from each composite sample was placed in a plastic pot in which five cucumber seeds were planted at 1 cm depth. After emergence, they were thinned to two seedlings per pot. Eight days after planting, the plants were harvested by cutting at soil level and fresh weight was recorded. All field samples were assayed together at the same time and compared to a dose-response curve.

RESULTS AND DISCUSSION

Cucumber was found to be the most sensitive of the four bioassay species tested. It was assumed that degradation of the two herbicides followed first-order kinetics and the data in Table 1 are presented as half-lives. R^2 values for alachlor and metolachlor were 0.96 and 0.86, respectively and second linear regression did not improve these values. Therefore, cucumber was used as a bioassay species for determination of the residues.

Results show that alachlor was degraded faster than metolachlor in the sandy loam soil (Table 1). For each herbicide, degradation rate increased with increasing moisture level. The half-life of alachlor was significantly different between three soil moisture levels. At 80% field capacity half-life of alachlor was 8 days while it was 12 days for metolachlor. Degradation rates of metolachlor at 50 and 80% field capacity were not significantly different but the rate was slower at 20% field capacity. In previous work Zimdahl and Clark (1982) showed that half-lives of propachlor, alachlor and metolachlor at 20 C and 80% of field capacity were 3.3, 18.8 and 33.4 days respectively in a sandy loam soil and 4.1, 11.1 and 15.8 days, respectively in a clay loam soil. These half-lives are of a similar magnitude and in a similar relative order as those Table 1.

Under field conditions, dissipation rate of alachlor was faster than metolachlor (Table 2). The concentration of both herbicides in the soil was similar on the day of treatment. But on day 21, alachlor residue in the soil was 0.07 ppm, while that of metolachlor was 0.32 ppm, four times higher than alachlor. The degradation rate of metolachlor was higher 7 days after treatment but it did not increase after 14 days. The half-lives of alachlor and metolachlor were 5 and 7 days, respectively, suggesting that the degradation rate of both herbicides was faster under field conditions than under a controlled environment.

Table 1. Half-lives (days) for alachlor and metolachlor in a sandy loam soil at different moisture levels. The standard bioassay was performed at ambient temperature (32 C).

Field capacity (%)	Half-lives (days)	
	Alachlor	Metolachlor
20	20a	22a
50	10b	16b
80	8c	12b

Means within a column followed by the same letter are not significantly different at 0.05 probability level.

The results reported here are in agreement with those of Zimdahl and Clark (1982) who found that alachlor is degraded faster in a clay loam soil compared to that of metolachlor. The correspondence between half-lives determined under field conditions and those from the laboratory study is fairly good. Others (eg. Zimdahl and Gwynn 1977; Zimdahl and Clark 1982) have reported a similar agreement between field and laboratory determinations of half-lives. It should be noted that the experimental plots were maintained vegetation-free by occasional hand-weeding which may have enhanced the dissipation by physical processes.

An increase in degradation at higher soil moisture levels is expected due to weaker adsorption of herbicide molecules by the soil particles making them available to soil microbes. As mentioned earlier microbial decomposition is the major avenue for dissipition of acetanilides herbicides from the soil (WSSA 1989) and chemical degradation accounts for less than 2% of the observed field losses under field conditions (Beestman and Deming 1974). Leaching was not found to make a significant contribution to dissipation of these herbicides from the soil (Beestman and Deming 1974) although it may not be true under tropical conditions.

Half-lives of the two acetanilide herbicides were found to be shorter under tropical conditions in our experiment than those reported from temperate regions. Beestman and Demings (1974) reported that the acetanilide herbicides have sufficiently short soil half-lives under warm (22 C), moist field conditions to preclude their build-up in the soil. Temperature and relative humidity had marked effect on the loss of alachlor from the soil surface (Hargrove and Merkle 1971). Therefore, under tropical conditions, acetanilides are not expected to accumulate in agricultural soil ecosystem and this agrees well with the results reported by Zimdahl and Clark (1982).

Results from the experiments presented here show marked differences in the soil persistence of the two acetanilides. Their relative persistence can be established by measuring rates of loss under standard laboratory conditions, and if rates of

Table 2. Herbicide residues (ppm) in the soil under field conditions at a moisture level of 60%.

Days after treatment	Residues (ppm) Alachlor	Metolachlor
0	5.31a	5.57a
7	1.68b	3.37b
14	1.08b	0.65c
21	0.07c	0.32c
28	0.07c	0.32c
35	0.07c	0.26d

Means within a coloum followed by the same letter are not significantly different at 0.05 probability level.

loss are measured for a range of temperatures and soil moisture contents, the data can be used in conjuction with weather records to predict persistence under field conditions.

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