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Microbial Degradation of Some Soil-Applied Insecticides, Herbicides, and Insecticide-Herbicide Combinations

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Ideally, agricultural pesticides once applied exert their toxic effects upon the target pests and are subsequently removed from the environment through mechanisms of degradation. However, certain insecticides and herbicides may be degraded so rapidly that efficacy declines or is even eliminated. Felsot et al. (1982) concluded that carbofuran, a carbamate soil insecticide, exhibited drastically shortened persistence in soils with histories of carbofuran use. In New Zealand, Rahman et al. (1978) observed that grass control declined when EPTC, a thiocarbamate herbicide, was applied continuously on the same soil. This phenomenon of a rapid decline in efficacy of some pesticides is known to be caused by accelerated microbial degradation (Kaufman and Edwards, 1982).

Pesticides such as carbamate insecticides and thiocarbamate herbicides are soil-applied and are often used simultaneously. The purpose of this research was to determine if soil microorganism populations adapted for the accelerated degradation of one pesticide (e.g., carbamate, thiocarbamate) also reduce the efficacy of another chemically-similar pesticide.

METHODS AND MATERIALS

Field studies were conducted at two sites (Andrew and Buchanan counties, MO) in 1984 and 1985. Site 1 (Andrew County) was in a field planted to continuous corn (_Zea mays_) and treated at planting time with carbofuran during 1981-83. This field exhibited a corn rootworm control problem in 1982 and 1983, although carbofuran was applied each year. Site 2 (Buchanan County) was in continuous corn during 1980-85. EPTC failed to control grass weeds at Site 2 in 1981, after which the grower discontinued use of this herbicide.

Four insecticides, three herbicides and control were replicated three times according to a split block design in plots consisting

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of four rows (15.2 m long with 76-cm row widths). The herbicides alachlor [3.4 kg active ingredient (a.i.)/ha], butylate (7.5 kg a.i./ha) and EPTC (7.5 kg a.i./ha) were applied at recommended rates. Granular insecticides, carbofuran, cloethocarb, isophenfos and terbufos, were applied at planting (May 17, 1984 and May 15, 1985) in an 18 cm band over the row at a rate of 0.75 g/m (1.12 kg a.i./ha). Plots were planted to corn in rows perpendicular to the direction of the previously applied herbicides.

Soil samples were collected at weekly intervals for seven weeks from the date of pesticide application. The soil samples, consisting of cores (8.9 cm diam.) obtained from the upper 10 cm of the profile within the two center rows of each plot, were placed in sterile plastic bags and transported to the laboratory. The samples were ground fine enough to pass a 2-mm screen and stored at $0^{o}C$ until assayed within 14 days.

Half of each soil sample taken from the plots treated with insecticides and herbicides and insecticide-herbicide combinations were used for insect bioassay (Burkhardt and Fairchild, 1967b) to assess residual insecticidal activity. Ten-day old house crickets, Acheta domesticus (L.), were placed on treated soil in one pint (473.6 ml) plastic containers and mortality read after 24 hours.

Viable microorganisms were isolated from duplicate samples of each treatment serial dilution. The samples were diluted serially (10-fold steps) in distilled water and transferred aseptically into duplicate petri plates. Appropriate agar medium (12 to 15 ml) at $40^{o}C$ was added to each plate. Bacteria and actinomycetes were isolated on egg albumin agar, pH 6.8, and fungi on rose bengal plus streptomycin agar, pH 6.5 (Wollum 1982). All plates were incubated at $25^{o}C$ for 10 to 14 days before enumeration and examination. Representative fungi developing on the plates were subcultured on Czapek-Dox agar, pH 7.2. Bacteria and actinomycetes were subcultured on nutrient agar, pH 6.8 (Wollum 1982).

On 8 August 1984, four corn plants were dug at random for root evaluation from each plot at Site 1. Roots were washed and rated on site for corn rootworm damage on a scale of 1-6 (Musick and Fairchild 1968). A rating of 1 indicates no feeding damage, and a rating of 6 indicates three or more root nodes destroyed per plant. Average damage was computed for each treatment. Root damage was not evaluated at Site 2 in 1984, but in 1985, roots were evaluated for damage at both sites from July 21-22.

Soil microorganism populations and residual cricket bioassay counts were analyzed over a seven week period for significant correlations. The objective of the analysis was to determine if soil microorganism population was significantly associated with the loss of pesticide activity when pesticides were applied alone or in combination. Significant correlation indicated that soil microorganisms were possibly influencing pesticide degradation.

RESULTS AND DISCUSSION

No significant differences in root damage among treatments were observed at Site 1 in 1984 (Table 1). The average root rating values for the carbofuran treated plots was 3.02, the remaining treatments including the untreated control did not exceed the acceptable economic threshold of 3.0.

In 1985, insecticide treatments cloethocarb and terbufos at Site 1 and carbofuran, cloethocarb, and terbufos at Site 2 significantly reduced corn root damage compared to the no insecticide treatment (Table 1).

Lack of rootworm control by isophenfos in 1984 and 1985 at Site 2 was similar to that described for northern Illinois, southern Wisconsin, and eastern Iowa in 1982 and 1983 when isophenfos failed to control corn rootworms following two consecutive years on the same field (Cohick and Murphy, 1985). These failures were hypothesized to be caused by accelerated microbial degradation.

Table 1. Means of corn root damage ratings for four insecticides applied for corn rootworm control at two sites in 1984 and 1985.[1]

Insecticide	1984 Site 1	1985 Site 1	1985 Site 2
Carbofuran	3.02	3.43	3.24*
Cloethocarb	2.89	3.00*	2.08*
Isophenfos	2.72	3.62	4.14
Terbufos	2.45	2.89*	2.52*
No Insecticide	2.72	3.79	4.08
LSD[2]	0.39	0.39	0.45

[1] General root damage ratings (Musick and Fairchild, 1968) used to assign injury levels are as follows: (1) no feeding damage, (2) light feeding damage, (3) occasional pruning; less than one node of roots eaten, (4) moderate feeding damage; one node of roots pruned, (5) severe pruning; two nodes pruned, (6) extensively pruned; three nodes pruned.
[2] LSD, least significant difference at P<0.05.
* Different from control.

Terbufos provided satisfactory control during 1985 at both sites. The performance of carbofuran and isophenfos at both sites in 1985 are patterns similar to those observed by Tollefson (1986).

Correlations of residual bioassays and microbial analyses for soil-applied insecticides, herbicides, and insecticide-herbicide combinations that were greater than r=0.75 (p=0.05) demonstrate accelerated degradation by soil microorganism class might be

Table 2. Simple correlation coefficients for the relationships between microbial numbers and % cricket mortality for each pesticide treatment and treatment combinations at sites 1 and 2 in 1984 and 1985.

	BUTYLATE			ALACHLOR			EPTC			CONTROL		
SITE 1												
1984	BAC	ACT	FUN	BAC	ACT	FUN	BAC	ACT	FUN	BAC	ACT	FUN
Carbofuran	0.409	0.668^{o}	0.360	0.256	0.718^{o}	-0.018	0.501	0.271	0.317	-0.413	-0.216	-0.286
Terbufos	0.684^{o}	0.349	0.016	-0.349	-0.056	-0.360	-0.366	0.444	0.282	0.356	0.100	0.580
Isophenfos	0.393	0.370	0.512	0.603	0.342	-0.503	0.627	0.106	-0.967*	0.242	-0.408	0.177
Cloethocarb	0.544	-0.225	0.053	0.837*	0.620	0.448	-0.084	-0.111	-0.664^{o}	0.546	-0.326	0.879*
Control	-0.434	0.511	0.439	-0.245	0.166	0.493	0.169	-0.223	-0.153	-0.392	0.809*	0.786*
SITE 1												
1985												
Carbofuran	0.812*	0.547	-0.403	0.911*	0.828*	-0.750*	0.635	0.685^{o}	0.278	0.885*	0.461	0.374
Terbofos	0.535	0.645	-0.660	0.838*	-0.110	0.204	0.765*	-0.321	-0.814*	0.816*	0.493	-0.865*
Isophenfos	0.646	0.684^{o}	-0.139	0.686^{o}	0.551	-0.197	0.840*	0.519	-0.021	0.733^{o}	0.713^{o}	-0.698^{o}
Cloethocarb	0.545	0.472	0.208	0.558	-0.038	-0.279	0.622	0.401	-0.532	0.089	0.732^{o}	-0.595
Control	0.194	0.890*	0.445	-0.139	-0.201	-0.257	0.869*	0.585	0.777*	-0.292	0.226	-0.122
SITE 2												
1984												
Carbofuran	0.735^{o}	0.631	0.407	0.044	-0.273	0.126	0.921*	-0.104	0.350	-0.096	-0.182	0.803*
Terbufos	0.496	-0.170	0.668^{o}	0.740^{o}	0.037	0.676^{o}	0.597	0.469	0.360	0.767*	-0.133	0.856*
Isophenfos	0.587	0.137	-0.063	0.192	0.059	0.543	0.166	0.015	0.658	0.482	0.379	0.233
Cloethocarb	0.212	-0.279	0.791*	0.650	0.256	0.352	0.628	0.112	-0.165	-0.052	-0.360	0.102
Control	-0.102	0.420	0.555	-0.031	0.065	-0.218	0.724^{o}	0.042	0.587	-0.222	-0.045	0.514
SITE 2												
1985												
Carbofuran	-0.189	0.102	-0.260	-0.167	0.209	0.246	0.439	0.754*	-0.035	0.653	0.383	0.539
Terbufos	-0.377	0.038	0.103	0.143	0.859*	0.597	-0.020	-0.543	0.677^{o}	0.195	0.806*	-0.419
Isophenfos	0.444	0.784*	0.050	0.334	0.116	0.341	-0.198	0.110	-0.432	-0.217	-0.159	0.008
Cloethocarb	-0.249	0.151	-0.280	0.443	0.915*	-0.382	-0.253	0.692^{o}	-0.273	-0.363	0.841*	0.356
Control	-0.158	-0.351	-0.476	0.064	0.483	0.306	0.016	0.449	0.181	-0.362	-0.138	0.042

^{o}=0.100

*=0.50

responsible for the erratic performance of soil insecticides presented in Table 1 (Reed et. al. 1987).

Soil bacteria counts correlated well in 1984 with the biological persistence of the cricket bioassay at Site 1. In 1985, the number of significant correlations increased substantially at both sites. Actinomycetes dominated the relationships of various degradation- bioassay curves at Site 2 in 1985. Since the cricket mortality data were adjusted according to Abbotts formula (Abbott, 1925) abiotic factors are not as likely to interfere with these results. Further, standard plate counts as an assay for a particular soil microbial class are more accurate than most probable numbers, hence most probable numbers technique was not used in this experiment (Wollum, 1982).

Similar studies have attempted to show a correlation between residue analysis by gas-liquid chromatography and evolution of $^{14}CO_2$ (labelled pesticides spiked in agressive soils). However, these studies did not show a strong correlation between $^{14}CO_2$ evolution and residue levels (Fox, 1983).

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