Run-off and Mobility Studies on Benomyl in Soils and Turf

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The run-off and leaching characteristics of benomyl (active ingredient of Du Pont Benlate® Benomyl Fungicide) and its two soil metabolites, methyl 2-benzimidazolecarbamate (MBC) and 2-amino-benzimidazole (2-AB) were studied in the greenhouse and laboratory using ^{14}C-labeled materials on soil and turf plots and on soil thin-layer chromatographic plates. These studies show that benomyl, MBC and 2-AB are immobile in soil and do not leach or move significantly from the site of application.

INTRODUCTION

Soil run-off and leaching characteristics of agricultural chemicals and their metabolites are important for environmental considerations. The movement of compounds in soil has been studied by use of adsorption isotherms, soil columns, residue analyses of treated fields, soil cylinders in the field and more recently by soil TLC [HELLING and TURNER (1968), RHODES et al. (1970), HELLING (1970), HELLING et al. (1971), HELLING et al. (1971) and HELLING (1971 a,b,c)].

In this paper we present the techniques used and the results obtained from laboratory and greenhouse evaluations of the run-off and leaching characteristics of benomyl and its soil metabolites, MBC and 2-AB (BAUDE et al. 1974; KIRKLAND et al. 1973).

EXPERIMENTAL

A. Greenhouse Run-off and Leaching Studies

Galvanized steel containers to hold soil and turf samples were constructed (Figure 1). The containers

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were 36 inches long, 12 inches wide, 4 inches deep on the sides and upper end with a 3-inch barrier on the lower end. Gutters (3 inches wide, 12 inches long, and 1 inch deep) were attached to the lower end of each container and a 1/2-inch drain tube was attached to the center of each gutter to allow run-off water to drain into collection vessels. The bottoms of the trays were open, but had a one-inch rim around the inner circumference. Two-inch strips of 16 gauge galvanized steel, two lengthwise and three across, were used as supports in the bottom of the containers. The supports were covered with 4 mesh stainless steel screen and then cheesecloth to hold the soil or turf in the container and to allow water to percolate freely through the bottom of the soil layer into collection trays as shown in Figure 1.

The containers were filled with field soil (Keyport silt loam) or Kentucky bluegrass sod to a level of 3 inches, so that the soil surfaces were level with the lower edges of the containers. Each container was placed on a separate collection tray and the legs on each corner adjusted to give the soil surfaces a 5% slope and the turf surfaces a 24% slope. These slopes had been determined by earlier work to provide for both run-off and percolated water. The upper one-third (1 ft^2.) of each plot was treated by uniformly spraying the area with the appropriate compound mixed in ca. 100 ml of water. Treatments of four plots (A-D) are listed below.

A. Turf was treated with 2-^{14}C-benomyl-50% W.P. at the rate of 2 lb/A.

B. Soil was treated with 2-^{14}C-benomyl-50% W.P. at the rate of 2 lb/A.

C. Soil was treated with 2-^{14}C-benomyl-50% W.P. at the rate of 20 lb/A.

D. Soil was treated with 2-^{14}C-MBC-50% W.P. at the rate of 20 lb/A.

The radiolabeled materials were synthesized in our laboratories. The treated plots were allowed to stand 18 hours after treatment before the first simulated rain was applied. By using an artificial rain machine in a greenhouse, "rain" was applied to each plot on the first, third and seventh days after treatment. The amount and rate of "rain" (Table I) were adjusted for each plot to obtain both run-off and percolation water.

TABLE I

Artificial Rainfall Data

	Days After Treatment					
	1		3		7	
Plot	Rain (in.)	Rate (in./hr.)	Rain (in.)	Rate (in./hr.)	Rain (in.)	Rate (in./hr.)
A	2.0	0.50	1.25	1.7	1.0	1.0
B	1.0	0.33	1.0	0.33	1.0	0.33
C	1.5	0.75	1.0	0.75	1.0	0.75
D	1.5	0.75	1.0	0.75	1.0	0.75

All water that ran-off or percolated through the plots was collected and analyzed for total ^{14}C by counting 1 ml aliquots in a Nuclear Chicago liquid scintillation spectrometer (Model 6801).

After the last application of simulated rain, the plots were allowed to stand for 3 days to partially air dry and were then divided into increments for analysis. The samples were spread on trays, dried in a hood and then dry ballmilled for 48 hours. Duplicate 2 gram aliquots of each sample were analyzed for total ^{14}C by the wet combustion-liquid scintillation technique [SMITH *et al*. (1964)]. The grass from the turf samples was removed from the soil and homogenized for 10 minutes with methanol in a blender. The blended grass was added to the corresponding soil fraction and the resulting mixture was dried, ballmilled and analyzed as previously described.

B. Soil TLC Studies

The R_f values of benomyl and its two soil metabolites, MBC and 2-aminobenzimidazole, were determined on four different soils by the method described by HELLING and TURNER (1968), RHODES et al. (1970), and HELLING (1971 b).

RESULTS AND DISCUSSION

The greenhouse studies were designed to determine the leaching and run-off characteristics of benomyl and MBC under rigorous conditions. Small (3 ft X 1 ft), shallow (3 inches deep), sloped plots were treated with 2-^{14}C-benomyl 50% W.P. at about normal use rates, 2 lbs/A (corresponding to the total of a season-long foliar spray program on a crop such as peanuts), and at exaggerated rates, 20 lb/A. A similar plot was treated with 2-^{14}C-MBC 50% W.P. at 20 lbs/A for comparison purposes. Artificial rain was applied to the soil and turf plots at the rate of 0.33 to 1.7 inches per hour on the first, third and seventh days after soil treatment. Consequently, a large volume of water (3.0-4.5 inches) was passed through or over the soil in a short period of time immediately after treatment. The results show that benomyl and MBC are firmly bound to soil and do not leach or move significantly from the site of application.

No ^{14}C, i.e., less than 0.1% of applied ^{14}C or <0.01 ppm of benomyl in solution was detected in any run-off or percolation water from the turf plot (A) when a total of 4.25 inches of rain was applied in 7 days (Table II). In the soil experiments, trace amounts of ^{14}C were found in the run-off water. The level of ^{14}C in the run-off water corresponds to less than 0.1%, 0.1-0.7% and <0.1-0.39% of the amount applied for the 2 lb/A benomyl (B), 20 lb/A benomyl (C), and 20 lb/A MBC (D) treatments respectively. No ^{14}C (<0.1%) was found in the percolation water from plots C and D after the first two rain applications and none (less than 0.1%) in the percolation water from plot B after any rain application. Trace amounts were detected in the percolation water from plots C and D (0.15 and 0.19% respectively) after the last rain treatment.

Figure 1 - Simulated field soil and turf plots used in greenhouse run-off and leaching studies

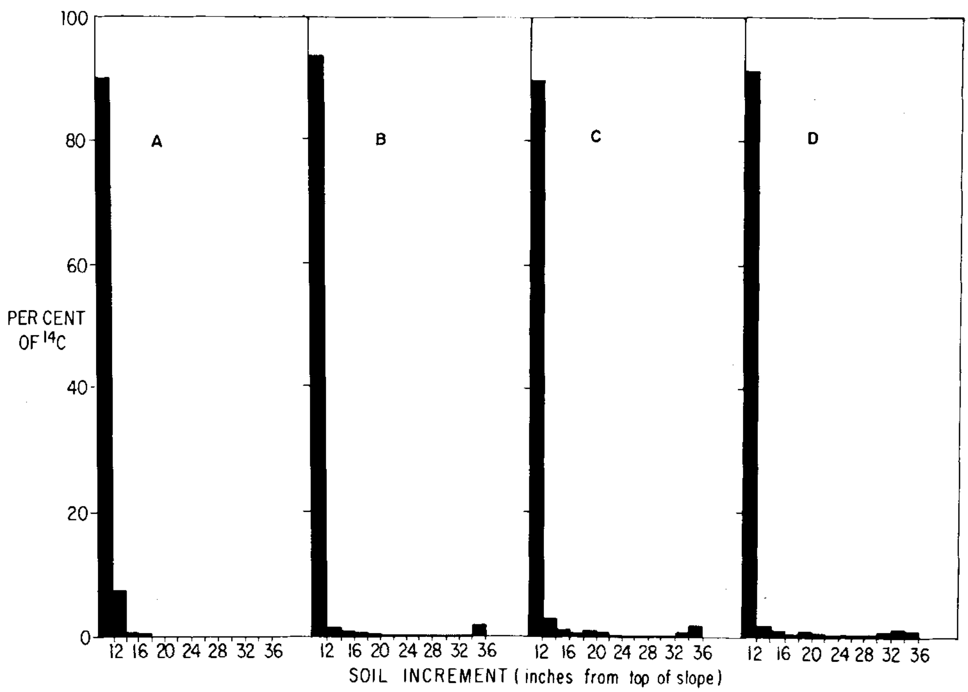

Figure 2 - Distribution of residues in soil increments, Application zone - 0-12"

TABLE II

Analyses of Run-off and Percolation Water

Days After Application:	Volume Collected (ml.)			% of ^{14}C Applied			Concentration (ppm)		
	1	3	7	1	3	7	1	3	7
Plot									
A									
Run-off	235	215	43	<0.1	<0.1	<0.1	<0.01	<0.01	<0.01
Percolation	15,410	7100	6200	<0.1	<0.1	<0.1	<0.01	<0.01	<0.01
B									
Run-off	39	490	3350	<0.1	<0.1	<0.1	0.03	0.02	<0.01
Percolation	2480	5700	2750	<0.1	<0.1	<0.1	<0.01	<0.01	<0.01
C									
Run-off	238	3100	2020	0.10	0.70	0.29	0.47	0.17	0.15
Percolation	2940	4050	4600	<0.1	<0.1	0.15	<0.01	<0.01	0.03
D									
Run-off	176	2300	1375	<0.1	0.39	0.24	0.30	0.17	0.18
Percolation	3190	4900	5010	<0.1	<0.1	0.19	<0.01	<0.01	0.04

Analyses of increments from the turf and soil plots (Figure 2) show that 90.5%, 93.5%, 89.6% and 90.7% of the recovered ^{14}C remained in the treated areas of plots A-D respectively and 99.1%, 95.8%, 93.6% and 93.2% remained within 4 inches of the treated areas. Recoveries of total ^{14}C from the calculated amounts sprayed on the plots were 89%, 92%, 100% and 95% respectively. The two-inch increments at the bottom of the soil plots contained relatively high percentages of the small amounts of ^{14}C that actually moved from the treated areas. It was observed that soil, which eroded down the soil surface, settled out at the lower end of the plot, indicating that the small amount of lateral movement of benomyl and MBC was due predominately to soil erosion. This is supported by the fact that no ^{14}C (<0.1%) was found at the lower end of the turf plot wherein no erosion was observed.

Every third soil increment from the treated and untreated areas, was analyzed in 0-1.5 inch and 1.5-3 inch depths to check possible leaching effects. Greater than 95% of the ^{14}C was in the 0-1.5 inch depth, which demonstrates that benomyl and MBC have little or no tendency to move downward in soil, even under the rigorous conditions of this greenhouse experiment.

TABLE III

R_f Values on Soil TLC Plates

Soil	R_f		
	Benomyl	MBC	2-AB
Muck	0.00	0.00	0.00
Muscatine brown silt loam	0.10	0.04	0.07
Keyport silt loam	0.10	0.05	0.12
Cecil loamy sand	0.39	0.00	0.31

TABLE IV

Physical Properties of Soils Used

Soil	Location	pH	Organic Matter, %
Muck	Florida	6.7	83.5
Muscatine brown silt loam	Macomb, Ill.	6.4	6.0
Keyport silt loam	Newark, Del.	5.4	2.1
Cecil loamy sand	Raleigh, N.C.	5.8	0.7

The R_f values for benomyl, MBC and 2-AB on soil TLC plates (Table III) also demonstrate the relative immobility of benomyl and both MBC and 2-AB in soil. R_f data were obtained using four different soils, representing different soil types and geographic locations (Table IV). The R_f values for these compounds on Keyport silt loam are 0.10, 0.05 and 0.12 respectively. These R_f values would place MBC in mobility class 1 (immobile compounds, R_f 0.0-0.09) and benomyl and 2-AB in mobility class 2 (R_f 0.10-0.34) according to the mobility classification suggested by HELLING and TURNER (1968). Helling's classification method consists of five groups, with class 5 (R_f 0.90-1.00) being the most mobile. It was shown earlier [RHODES et al. (1970)] that the R_f values of compounds on Keyport silt loam and Helling's standard soils (Hagerstown silty clay loam and Chillum silt loam) are almost identical.

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