Original Article

## Behavior of Bifenox, a Diphenyl Ether Herbicide, Methyl 5-(2,4-Dichlorophenoxy)-2-nitrobenzoate, in Soil\*

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The behavior of bifenox, a diphenyl ether herbicide, methyl 5-(2,4-dichlorophenoxy)-2-nitrobenzoate, in soil was studied using two types of  ${}^{14}C$ -bifenox labeled at the nitrophenyl and dichlorophenyl rings, respectively. The evolution of  ${}^{14}CO_2$  occurred in a passable amount in non-flooded (upland moisture condition) soil, but scarcely in flooded soil. Organic volatile metabolites were hardly detected under either moisture condition. In the early stage of degradation, fair amounts of the degradation products were adsorbed by soil with noncovalent bonds. Degradation patterns obtained under various degradation conditions, such as sterilization before or after pre-incubation, long term pre-incubation, addition of glucose, and different concentration of the chemical, indicate that the hydrolysis of the ester bond is due mainly to microbial reaction and the reduction of the nitro group to amino group is mainly to chemical (non-biological) reaction.

#### INTRODUCTION

Bifenox, Modown<sup>®</sup>, methyl 5-(2,4-dichlorophenoxy)-2-nitrobenzoate, is a diphenyl ether herbicide developed by Mobil Chemical Company.

Reports regarding the behavior of bifenox in the environment have been made on the metabolism in upland crops and soil,<sup>1)</sup> degradation in soils,<sup>2)</sup> and solution-phase photodecomposition.<sup>3)</sup> Recently, bifenox was registered in Japan as an herbicide for rice culture in paddy fields. In our previous study,<sup>2)</sup> the degradation products extracted with acetone in the soils under flooded and upland conditions were examined. However, more detailed information on the fate and behavior of this compound in paddy soil environment is required for its safe use.

In this study, the volatile products from the soil and the soil residues after extraction with acetone were examined to clarify the total material balance. Additionally, in order to know the cause of the two major degradation reactions in flooded soil, the hydrolysis of ester bond and the reduction of the nitro group to the amino group, the behavior of bifenox in flooded soil under various degradation conditions was examined.

#### MATERIALS AND METHODS

#### 1. Chemicals

Two types of <sup>14</sup>C-bifenox labeled either at the nitrophenyl or dichlorophenyl ring were supplied by Mobil Chemical Company and purified as reported previously.<sup>2)</sup> The specific activity of <sup>14</sup>C-bifenox labeled at the nitrophenyl ring was  $50.3 \times 10^6$  dpm/mg or  $5.70 \times$  $10^6$  dpm/mg, and that at the dichlorophenyl

<sup>\*</sup> Studies on the Metabolism of Bifenox (Part 2)

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ring was  $5.32 \times 10^6$  dpm/mg. No radioactive impurity was detected by thin-layer chromatography (*tlc*) with any solvent systems used. Authentic compounds and *Rf* values on *tlc* were described previously.<sup>2)</sup>

#### 2. Soil Conditioning

Anjo soil, the same paddy soil used in the previous study,<sup>2)</sup> was used. The soil was crushed and passed through a 2-mm sieve. The physicochemical properties were described previously.<sup>2)</sup>

## 2.1 Flooded conditions

The sieved undried soil sample, equivalent to 50 g of oven-dry weight, was put in a 300-ml bottle with 5 cm i.d. and water was added up to the depth of 1 cm from soil surface. The soil was then pre-incubated at  $30^{\circ}$ C in the dark for 2 weeks before the chemical was applied, unless otherwise specified.

## 2.2 Upland conditions

Fifty grams of the soil sample was placed in a 300-ml bottle, water was added up to 60% of maximum water holding capacity, and it was pre-incubated at 30°C in the dark for 2 weeks.

### 3. Degradation of Bifenox in Soil 3.1 Radioactivity balance study

A half milliliter of acetone solution of  ${}^{14}C$ bifenox labeled at either the nitrophenyl ring or the dichlorophenyl ring was mixed into the soil at the rate of 10 ppm of the labeled compound on a dry soil basis. Each bottle was plugged with a rubber stopper having a gas inlet and an outlet. The outlet was connected with a trap containing 100 ml of toluene followed by another trap containing 100 ml of 2 N-NaOH solution. A slow stream of CO<sub>2</sub> free air (ca 1 ml/min) was passed through the inlet to the soil surface and then through the two traps. The system was kept at 25°C for Once every week, the traps were 30 days. renewed.

## 3.2 Time course study

A half milliliter of acetone solution of  ${}^{14}C$ bifenox labeled at the nitrophenyl ring was used, except for comparative experiments between the two labeled types of the compound. After pre-incubation of the soil, the labeled compound was mixed into the soil in the bottle. Each bottle was plugged with a rubber stopper and incubated at 30°C for a designated period of time. Sterilization was carried out with an autoclave at 120°C for 30 min. In some experiments, 500 mg of glucose was added to the soil before pre-incubation.

#### 4. Analysis

## 4.1 Radioactivity measurement

The radioactivity was measured using a Packard 3320 liquid scintillation spectrometer. The scintillation solutions used were: (A) Dioxane system composed of 6 g of 2,5diphenyloxazole, 0.27 g of 1,2-bis-2-(5-phenyloxazolyl)benzene, and 112 g of naphthalene in 1 liter of dioxane, and (B) Bray's solution composed of 100 ml of methanol, 20 ml of ethyleneglycol, 4 g of 2,5-diphenyloxazole, 0.2 g of 1,4-bis-(5-phenyloxazolyl)benzene, and 60 g of naphthalene in 1 liter of dioxane.

## 4.2 Determination of volatile metabolites

One ml of toluene trap and 0.2 ml of alkaline trap for the radioactive volatiles were radioassayed with 15 ml of Bray's scintillation solution. A portion of alkaline trap solution was acidified with HCl to ascertain the disappearance of radioactivity of  ${}^{14}CO_2$ .

## 4.3 Extraction and determination of radioactive materials

Soil for the radioactivity balance study was extracted after incubation for 30 days and the soil for the time course study was extracted after designated periods of incubation. The whole sample in each bottle was extracted with acetone and concentrated, and the extracts were transferred to ether. The radioactive materials were identified and quantitatively determined by *tlc*. The soil residue was radioassayed by a wet combustion method. Details of the method were described in our previous paper.<sup>2)</sup>

# 4.4 Extraction of soil-bound radioactive materials

A soil sample treated with bifenox labeled at the nitrophenyl ring was employed in the radioactivity balance study. The soil residue after extraction with acetone was air dried, 1.00 g of the dried sample was placed into a 50 ml centrifugal glass tube, and 20 ml of each of the solvents listed in Table 4 was added.

For combined extractants, 1 ml of either 1 N-NaOH, 1 N-HCl or 5% NH4Cl was mixed with 20 ml of the organic solvent. The vessel was plugged with a glass stopper or equipped with a reflux condenser. Each sample was shaken for 2 hr at 28°C or heated at 80°C for 1 hr, and then centrifuged at 3,000 rpm for 10 min. The supernatant was collected and filled to 25 ml with the corresponding solvent and an aliquot was radioassayed. The extracts of acetone, methanol, benzene, tetrahydrofuran, ethyl acetate, and chloroform, respectively, were condensed and applied to the *tlc* and autoradio-Extracts with N,N-dimethylformgraphy. amide and dimethyl sulfoxide, respectively, were diluted with water, adjusted to pH 3, and extracted with benzene. The extracts with acetic acid, triethylamine and acetone-NH4Cl, respectively, were condensed, diluted with water, adjusted at pH 3 and extracted with ether. Extracts with acetone-NaOH, benzene-NaOH, acetone-HCl and benzene-HCl, respectively, were neutralized, condensed, added with water, adjusted to pH 3, and extracted with ether. The extracts with 0.2 N-NaOH, 1 N-NaOH, 5 N-NaOH, 0.2 N-HCl, 1 N-HCl, 5 N-HCl and 5% NH<sub>4</sub>Cl, respectively, were adjusted to pH 3 and extracted with ether. An aliquot of each extract was radioassayed. Another aliquot was condensed and applied to the *tlc* and autoradiography.

### RESULTS

## 1. Material Balance

The radioactivity balance of  ${}^{14}C$ -bifenox in Anjo soil at 30 days after incubation is shown in Table 1.

1.1  $^{14}CO_2$  and organic volatiles

A passable amount of the radioactivity was

evolved as  ${}^{14}\text{CO}_2$  in non-flooded soil (upland moisture condition), but only a small amount in flooded soil. The amount released from  ${}^{14}C$ bifenox labeled at the nitrophenyl ring was larger than that at the dichlorophenyl ring in flooded soil, but the situation was the opposite in non-flooded soil. The amount of the organic volatiles caught with the toluene trap was negligible.

### 1.2 Acetone extracts

Most of the radioactivity of acetone extracts was transferred to the ether fraction. The radioactive materials determined are listed in Table 2. Small differences from our previous results<sup>2)</sup> were caused probably because of the lower incubation temperature in this study. The major degradation products and ratios of constituents were about the same as described in our previous paper.<sup>2)</sup>

## 1.3 Soil-bound radioactive materials

To clarify the characteristics of adsorption or so-called "bound residue" of the radioactive materials in the soil, some extraction experiments were made to release the bound radioactive materials remaining in the soil after As shown in Table 3, acetone extraction. bound radioactive materials in non-flooded soil were not extracted readily with neutral organic solvents, and the ratios of the extracts did not exceed 20% of the bound activity even by heating. The extractions with acetic acid resulted in a greater extractable amount, but those with triethylamine were less. Of combined extraction systems, <sup>14</sup>C percentage of the extracts with acetone-HCl was the The extractions with the alkaline largest. solution also gave good results. A decreasing concentration of the alkaline solution in extraction at 80°C yielded more among the

Table 1 Radioactivity balance of <sup>14</sup>C-bifenox in Anjo paddy soil after 30 days incubation at 25°C.

Labeled position	Moisture condition	$^{14}C\%$ of total radioactivity			
		<sup>14</sup> CO <sub>2</sub>	Organic volatiles	Acetone extracts	Soil bound residues
Nitrophenyl ring	Flooded	0.6	<0.1	44.8	54.6
	Non-flooded	2.1	<0.1	66.3	31.6
Dichlorophenyl ring	Flooded	0.2	<0.1	44.7	52.1
	Non-flooded	4.6	0.1	65.2	30.1

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			$^{14}C_{00}^{0/}$ of total radioactivity			
Products	Soil conditions	Flooded		Non-flooded		
	<sup>14</sup> C-labeled at	Nitro- phenyl	Dichloro- phenyl	Nitro- phenyl	Dichloro- phenyl	
Bifenox		2.2	2.7	20.2	22.0	
5-(2,4-Dichlorophenoxy)-2-nitrobenzoic acid		3.2	3.8	39.8	33.3	
Methyl 5-(2,4-dichlorophenoxy)-anthranilate		7.5	8.4	0.9	1.8	
5-(2,4-Dichlorophenoxy)anthranilic acid		4.7	6.3	0.5	1.0	
5-(2,4-Dichlorophenoxy)salicylic acid		4.8	5.8	0.4	1.0	
Methyl 5-(2,4-dichlorophenoxy)-2-acetamido- benzoate		1.5	1.5	0.1	0.2	
Methyl 5-(2,4-dichlorophenoxy)-2-formamido- benzoate		2.1	1.6	0.1	0.2	
5-(2,4-Dichlorophenoxy)-2-acetamidobenzoic acid		5.4	5.5	0.5	0.7	
5-(2,4-Dichlorophenoxy)-2-formamidobenzoic acid		4.7	4.3	0.1	0.2	
5-Hydroxy-2-nitrobenzoic acid		0.2		0.3		
5-Hydroxyanthranilic acid		0.2		0.0		
Unknown M		1.6	1.4	0.4	0.5	
Aqueous layers		0.3	0.4	0.1	0.2	
Others		6.4	6.0	2.9	4.1	

Table 2 Amounts of bifenox and its degradation products extracted with acetone from the soil after 30 days incubation.

Table 3 Radioactivity extracted with various solvents from soil bound residues.<sup>a)</sup>

		$^{14}C_{0}^{0/}$ of soil bound radioactivity				
Extraction	Soil conditions Extraction temp.	Flooded		Non-flooded		
		28°C	80°C	28°C	80°C	
Acetone		1.4	2.4	3.9		
Methanol		2.7	5.8			
Benzene		1.8	4.6			
Tetrahydrofuran		3.4	15.7	10.4		
Ethyl acetate		1.2	1.6			
Chloroform		1.7	3.0	-		
N,N-Dimethylformar	nide	2.6	11.3			
Dimethyl sulfoxide		5.6	18.6			
Acetic acid		18.2	40.6	28.9		
Triethyl amine		1.8	2.5			
Acetone-NaOH		32.7		35.7		
Benzene-NaOH		1.9		1.9		
Acetone-HCl		67.3		62.0		
Benzene-HCl		15.2		13.8		
Acetone-NH <sub>4</sub> Cl		17.8				
0.2 и NaOH			93.1			
1 n NaOH		51.2	76.0	75.9	76.0	
5 n NaOH			18.3			
0.2 N HCl			19.1			
l n HCl		7.2	18.3	10.7	20.1	
5 n HCl			16.7			
5% NH4Cl		1.4		12.3		

a) 30 days incubation (nitrophenyl ring labeled).

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		$^{14}C_{00}^{0}$ of extracted radioactivity ( $^{14}C_{00}^{00}$ of applied radioactivity)				
Products Soil condition		Floo	ded	Non-flooded		
	Extraction temp.	28°C	80°C	28°C	80°C	
Bifenox <sup>a</sup> )		— ( — )	— (—)	1.2(0.3)	— ( — )	
5-(2,4-Dichlorophenoxy)- acid	-2-nitrobenzoic	3.1 ( 0.9)	2.1 ( 0.9)	76.0 (18.2)	10.2 ( 2.4)	
Methyl 5-(2,4-dichlorophenoxy)anthrani- late		3.9 (1.1)	— ( — )	— (—)	— ( — )	
5-(2,4-Dichlorophenoxy)anthranilic acid		9.2 (2.6)	7.3 ( 3.0)	1.8(0.4)	10.9 ( 2.6)	
5-(2,4-Dichlorophenoxy)salicylic acid		11.8 (3.3)	3.6 (1.5)	— ( — )	12.4 ( 2.9)	
5-(2,4-Dichlorophenoxy)-2-acetamido- benzoic acid		13.0 ( 3.6)	7.4 ( 3.1)	— ( — )	— ( — )	
5-(2,4-Dichlorophenoxy)-2-formamido- benzoic acid		8.3 (2.3)	8.6 ( 3.6)	4.0 ( 1.0)	— ( — )	
Unknown M		14.7 (4.1)	11.0 ( 4.6)	2.7(0.6)	4.7 ( <b>1</b> .1)	
Origin		18.1 ( 5.1)	27.6 (11.5)	4.3(1.0)	21.0 ( 5.0)	
Aqueous layers		2.9(0.8)	12.9 ( 5.4)	1.9(0.5)	18.0(4.3)	
Others		15.0 ( 4.2)	19.5 ( 8.1)	8.1 (1.9)	22.8 ( 5.5)	

Table 4 Soil bound materials extracted with 1 N-NaOH after 30 days incubation.

—: Below the limit of detection (less than  $0.1^{\circ}_{0}$ ).

a) nitrophanyl ring labeled.

0.2, 1, and 5 N solutions. Extraction with the acid solutions yielded lower recoveries and this was not affected by the concentration of extractant and the extraction temperature. The extraction from the non-flooded soil was about the same as that from the flooded soil.

The radioactive materials extracted with 1 N NaOH are shown in Table 4. Major compounds taken from the acetone-extracted residue of flooded soil were 5-(2,4-dichlorophenoxy)anthranilic acid, 5-(2,4-dichlorophenoxy)salicylic acid, 5-(2,4-dichlorophenoxy)-2acetamidobenzoic acid, 5-(2,4-dichlorophenoxy)-2-formamidobenzoic acid and some un-From the non-flooded soil known products. residue, 5-(2,4-dichlorophenoxy)-2-nitrobenzoic acid was mainly extracted. In general, although the amounts of the extracts increased by heating, the ratio of each identified compound to the total radioactivity of the extracts decreased.

In the cases of organic solvents such as acetone, methanol, benzene, ethyl acetate and chloroform, methyl 5-(2,4-dichlorophenoxy)-anthranilate and bifenox were about 40 and 10% of the extracted radioactivity, respectively, although these were small percentages of the total radioactivity. By extraction with

tetrahydrofuran, N,N-dimethylformamide, dimethyl sulfoxide, acetic acid, benzene-HCl and acetone-NH4Cl, many kinds of degradation products were detected and the constituent compounds were similar to those of the extract with 1 N-NaOH at 28°C. In acetone HCl and acetone-NaOH extractions, a considerable amount of mesityl oxide was formed during operations, and the identification could not be achieved because of tailing on thin-layer plates.

2. Time Course for Degradation in Flooded Soil

## 2.1 Comparison of the degradation patterns between nitrophenyl- and dichlorophenylring labeled bifenox

The time course of amounts of bifenox and its major degradation products in 10 ppm dose levels are shown in Fig. 1. For the acetone extracts, no differences in the decreasing rates of bifenox or the behavior of the major degradation products were observed in either type of labeled bifenox.

## 2.2 Effects of sterilization

The patterns of bifenox degradation in sterilized soil are shown in Fig. 2. In the soil sterilized before pre-incubation, the decrease of acetone extracts was small, and 86% of the 22



Fig. 1 Degradation of bifenox in Anjo soil under flooded conditions (10 ppm).  $\Box$ : acetone extracts,  $\bigcirc$ : bifenox,  $\bigcirc$ : 5-(2,4-dichlorophenoxy)-2-nitrobenzoic acid,  $\triangle$ : methyl 5-(2,4-dichlorophenoxy)anthranilate,  $\blacktriangle$ : 5-(2,4-dichlorophenoxy)anthranilic acid.



Fig. 2 Degradation of bifenox in the sterilized soil. Lines and symbols are the same as in Fig. 1.

applied radioactivity was extracted from the soil sample on the 60th day. A small amount of the free acid of bifenox was found at 8 and 16 days. Other degradation products were hardly detected during the whole period of incubation.

In the soil sterilized after pre-incubation, the free acid of bifenox was not detected even in the early stage of incubation. The amount of the amino derivative of ester form increased with time and reached 43% of the applied radioactivity on the 60th day, but that of the amino derivative of free acid form did not exceed 5% of the applied radioactivity.



Fig. 3 Degradation of bifenox in the soil pre-incubated for 6 weeks and in the soil added glucose up to 1% before pre-incubation.

Lines and symbols are the same as in Fig. 1.



Fig. 4 Degradation of bifenox under 1 and 100 ppm dose levels. Lines and symbols are the same as in Fig. 1.

## 2.3 Degradation in soil pre-incubated for 6 weeks

As shown in Fig. 3, bifenox was degraded rapidly and the half-life shortened to a half, 2 from 4 days. The lag period before initiation of the reduction of the nitro group disappeared. In this case, the reduction of the nitro group was prior to the hydrolysis of the ester, and a fair amount of the amino derivative of ester

#### form was produced.

#### 2.4 Effects of addition of glucose

As shown in Fig. 3, bifenox was degraded rapidly and decreased to less than 10% of the applied radioactivity within 2 days. A large amount of the amino derivative of ester form was produced and reached 60% of applied radioactivity by the 2nd day of incubation. Little free acid of bifenox accumulated during

### the incubation.

#### 2.5 Effects of concentration

As shown in Fig. 4, the rate of decrease of bifenox was slower in the high dose level, and its half-life applied at 1, 10, and 100 ppm was about 2, 4, and 8 days, respectively. The amount of the free acid of bifenox was about the same in the applications at 1 and 10 ppm, but was lower at 100 ppm. On the contrary, the amounts of the amino derivatives were larger at 100 ppm and the amount of the amino derivative of ester form reached 37% of the applied radioactivity by the 16th day.

#### DISCUSSION

The difference in the amount of <sup>14</sup>CO<sub>2</sub> evolved between the two types of ring labeled bifenox suggests cleavage of the ether linkage, as already stated on the degradation of  ${}^{14}C$ fluorodifen by soil microorganisms.4) Since the phenol derivatives produced by the cleavage of ether linkage of bifenox were hardly detected, the complete oxidation of these derivatives to CO<sub>2</sub> must be rapid in the nonflooded soil. The fact that the patterns of the degradation of <sup>14</sup>C-bifenox in the flooded soil were almost the same in both label types of the material indicates the stableness of the ether bond under flooded conditions. The amounts of radioactivity extracted with acetone-HCl and benzene-HCl from the soil residues after acetone extraction were larger than those with acetone-NaOH and benzene-These results suggest NaOH, respectively. that the radioactive materials adsorbed on soil particles have an acidic character, such as carboxylic acid and/or phenol. Fair amounts of radioactivity were extracted with acetone-HCl and acetic acid at 28°C from the acetoneextraction residues of soil. Since these solvent systems are considered to have little possibility of breaking the covalent bond during the extraction, a large part of the radioactivity extracted was absorbed by the non-covalent Although extraction with 1 N NaOH bond. at 28°C has little possibility for the partial hydrolysis of a weak bond, such as methyl ester, many of the bound materials exist in the free acid form, as described above, and the extraction of this system is not considered to produce artifacts to any great extent. By

this extraction, a relatively large quantity of the amino derivatives, salicylic acid derivative, and acylamino derivatives were obtained under Also, the free acid of flooded conditions. bifenox was mainly detected under nonflooded conditions. All these derivatives were consistent with the degradation products clarified in acetone extracts. In a relatively early stage of the degradation, namely, the first 30 days of incubation, a fair amount of the degradation products of bifenox was extracted with acid-organic solvent as in the first acetone extracts. These are presumed to be adsorbed weakly on soil particles with noncovalent bond. The result of the radioactive materials determined in 1 N NaOH extracts being decreased by heating and the radioactivity extracted with 5 N NaOH being decreased remarkably by heating are supposed to have been caused by decomposition or polymerization of the degradation products.

Cationic adsorption<sup>5)</sup> is supposed on the basic group, but the  $pK_a$  value of the amino derivatives of bifenox is 2.23 and 2.05 in the ester and free acid forms, respectively.<sup>6)</sup> Even if the pH value of the surface of soil particles is lower than that of the soil-water (pH 6.2), the amino derivatives of bifenox cannot take the cationic form. Thus the contribution of cationic adsorption is presumed to be small. Hydrophobic bonding has been thought to contribute to the adsorption of non-protonated amino compounds with soil organic matter to a great extent.<sup>7)</sup> This mechanism may be applied to both the amino derivatives and the acylamino derivatives of bifenox. On the other hand, considering the anionic character of soil, adsorption of the acidic group is considered to be a much lower contribution than that of the basic group, but van der Waals adsorption and hydrogen bonding are known on acidic groups<sup>5)</sup> and these may be applied to the adsorption of carboxy and hydroxy groups of the degradation products of bifenox. However, further studies are necessary to clarify the bonding mechanism precisely.

On the hydrolysis of carboxylic ester bond of pesticides in soils, both microbial<sup>8)</sup> and chemical hydrolysis<sup>9)</sup> have been reported. The finding that the hydrolysis rarely occurred in sterilized soil suggests that microbial hydrolysis was primary and that chemical hydrolysis was minor or negligible.

On the other hand, the reduction of the nitro group occurred to a large extent in soil sterilized after pre-incubation. This suggests that the reduction occurred chemically but not The mechanism of reducmicrobiologically. tion of the nitro group to the amino group was described in previous paper,<sup>2)</sup> and the ferrous iron which was transformed from ferric iron by microbes in reduced soil was presumed to play an important role of the reduction. The extent of the change to the reduced state of the soil by flooding is dependent on the kind and amount of organic matter, as well as the nature and contents of electron acceptors, temperature and the duration of flooding.<sup>10)</sup> In the highly reduced soil such as that preincubated for 6 weeks, and by the addition of glucose, the reduction occurred prior to hydrolysis. A large amount of the ester type of amino derivative was also obtained.

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#### 約

ジフェニルエーテル系除草剤ビフェノックス [methyl 5-(2,4-dichlorophenoxy)-2-nitrobenzoate] の土壌中における挙動\*

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ジフェニルエーテル系除草剤ビフェノックス [Modown®, methyl 5-(2,4-dichlorophenoxy)-2-nitrobenzoate]の土壌中における挙動を,<sup>14</sup>C-ニトロベンゼン環お よびジクロルベンゼン環標識化合物を用いて調べた. <sup>14</sup>CO<sub>2</sub>の放出は非湛水土壌(畑水分条件)ではかなり認め られたが,湛水土壌ではきわめて少なかった. 有機の揮 散性物質は両水分条件とも認められなかった. 各種溶媒 による抽出実験から,分解の早い時期においては,ビフ ェノックスの分解物の土壌吸着形態は非共有結合的なも のがかなり多くあるものと推定された. 殺菌土壌等,数 種の異なった分解条件での分解様式は,エステル結合の 加水分解は主として微生物反応によるものであり,ニト ロ基のアミノ基への還元は主として化学(非生物)反応に よることを示唆した.

\* ビフェノックスの代謝に関する研究(第2報)