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Formamidine–S–Carbamates: A New Procarbamate Analogue with Improved Ovicidal and Acaricidal Activities

Bryan K. Eya and T. Roy Fukuto*

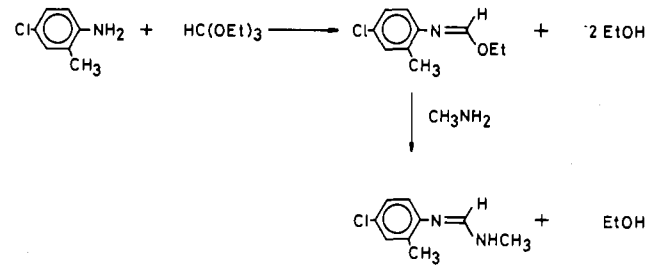
A series of [N^1-(4-chloro-2-methylphenyl)-N^2-methylmethanimidamido]thio and [N^1-(2,4-dimethylphenyl)-N^2-methylmethanimidamido]thio derivatives of methylcarbamate insecticides were prepared and examined for toxicity to houseflies, white mice, and a variety of agricultural pests. These compounds have the combined pesticidal activity of the parent formamidine (i.e., demethylchlordimeform and BTS-27271) and *N*-methylcarbamate, being active against acarines in addition to a wide variety of insects. The compounds also display activity as systemic pesticides.

INTRODUCTION

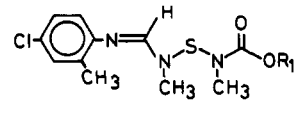
In previous papers from our laboratory, we described the favorable toxicological properties of sulfide derivatives of methylcarbamate insecticides (Black et al., 1973; Fahmy et al., 1974, 1978). Examples of these are carbosulfan, CGA-73,102, and benfuracarb, i.e. derivatives of carbofuran (2,3-dihydro-2,2-dimethylbenzofuranyl-7-yl methylcarbamate) that have insecticidal activity similar to that of carbofuran but are substantially less toxic to mammals (Fukuto, 1984). Also many sulfide derivatives of insecticidal and acaricidal formamidines have been described that usually retain the activity of the parent compound or in some cases are superior. For example, the phenylthio derivative of demethylchlordimeform [DCDM or *N'*-(4-chloro-2-methylphenyl)-*N*-methylmethanimidamide] was superior against the two-spotted spider mite (LC_{50} 6 ppm) compared to DCDM (12 ppm) and chlordimeform (19 ppm) (Knowles, 1982).

Carbamate esters are known to be effective against a broad spectrum of insects. However, they are generally relatively ineffective against mites, ticks, and other acarines. On the other hand, certain formamidines such as CDM, DCDM, and BTS-27271 [*N'*-(2,4-dimethylphenyl)-*N*-methylmethanimidamide] are known to be highly effective against acarines as well as insects (Atkinson and Knowles, 1974; Gemrich et al., 1976a,b; Hollingworth, 1976; Knowles, 1982). It would be desirable to combine the insecticidal activity of the carbamate and the acaricidal activity of the formamidine into a single pesticidal compound for the control of both insects and acarines.

Scheme I

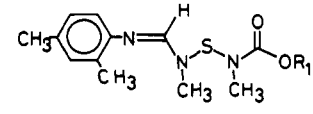


This report is concerned with the synthesis and toxicological properties of a series of DCDM–S–carbamates and (BTS-27271)–S–carbamates of the general structures I and II where R_1 is the phenolic moiety of carbofuran or



DCDM-S-carbamate

I



(BTS 27271)-S-carbamate

II

3-isopropylphenyl methylcarbamate or the oxime of methomyl [methyl *N*-[[(methylamino)carbonyl]oxy]ethan-

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Scheme II

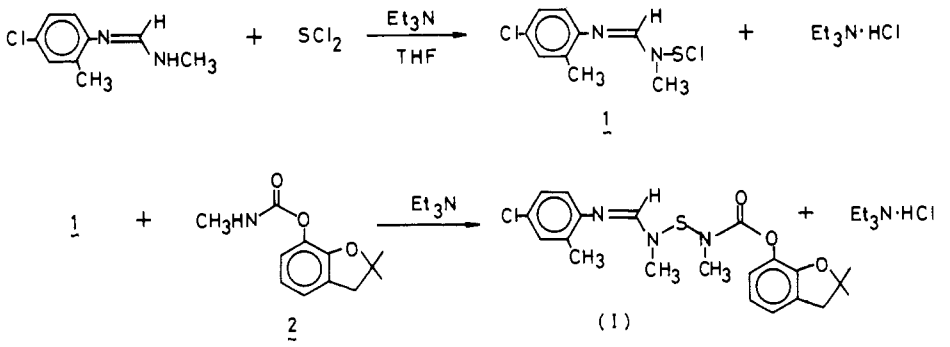
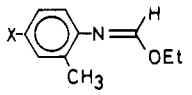
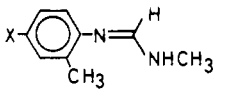


Table I. Physical Properties of Formimidates and Formamidines



X	bp, °C (mmHg)[a]
Cl	110–113 (13)
CH_3	105–130 (13.5)



X	bp, °C (mmHg)/mp,[b] °C
Cl	125–135 (0.7–0.9)/85
CH_3	90–125 (0.6)/67

[a] Boiling point of a product distilled using Kugelrohr. [b] Parenthetical numbers are the uncorrected melting points of the formamidines.

imidothioate] and oxamyl [methyl 2-(dimethylamino)-*N*-[[(methylamino)carbonyl]oxy]-2-oxoethanimidothioate]. These are a novel class of compounds having the pesticidal properties of both the carbamate and formamidine.

MATERIALS AND METHODS

Insecticidal methylcarbamates, i.e. carbofuran, methomyl, and oxamyl, were obtained from their respective manufacturers as technical materials and were purified further by recrystallization from appropriate solvents. 3-Isopropylphenyl methylcarbamate (MIP) was synthesized from the corresponding phenol and methyl isocyanate. The formamidines, i.e. DCDM and BTS-27271, were prepared from the corresponding formimidates which were prepared from ethyl orthoformate and the respective anilines as described by Taylor and Ehrhart (1963) (Scheme I). Boiling and melting points for the formimidates and formamidines are given in Table I.

Synthesis of DCDM–S–Carbamate. These derivatives of formamidine carbamates were synthesized by the reaction between the [N^1-(4-chloro-2-methylphenyl)-N^2-methylmethanimidamido]sulfenyl chloride (1) and methylcarbamate **2** in triethylamine. The following procedure for the synthesis of 2,3-dihydro-2,2-dimethylbenzofuran-7-yl [[N^1-(4-chloro-2-methylphenyl)-N^2-methylmethanimidamido]thio]methylcarbamate (I) according to Scheme II is typical of the synthesis of DCDM–S–carbamate analogues.

To a stirring mixture of 1 g (0.005 mol) of DCDM in 25 mL of anhydrous THF and 0.84 mL (0.006 mol) of triethylamine at 24 °C was added in one portion 0.38 mL (0.006 mol) of sulfur dichloride. Triethylamine hydrochloride separated within a few minutes after the addition. The mixture was stirred for 1 h and then cooled in ice to 6 °C for approximately 15 min. To the stirred chilled mixture was added 0.84 mL of triethylamine, immediately followed by addition of 1.1 g (0.005 mol) of carbofuran in a single portion. The reaction mixture was chilled in ice for 20 min, then 25 mL of ice-cooled carbon tetrachloride was added, and stirring was continued for 15 min. The chilled reaction mixture was vacuum filtered to remove triethylamine hydrochloride and unreacted carbamate, washed three times with an equal volume of water, and dried over magnesium sulfate. The solvent was removed under reduced pressure, and the residual oil was applied onto a flash chromatography column.

Still's flash chromatography (1978) was carried out with use of 90 g of Merck silica gel Kieselgel 60 which was deactivated with triethylamine overnight. The solvent system used was petroleum ether–ethyl acetate–triethylamine (90:10:5). Approximately 1 g of product was applied to the column. The yield of product was 45%. NMR (chloroform-*d*, Me_4Si): δ 8.0 (s, 1 H, N=C*H*N), 6.5–7.2 (m, 6 H, aromatic protons), 3.3–3.6 (2 s, 6 H, 2 NCH_3), 2.9–3.0 (s, 2 H, CH_2), 2.1–2.2 (s, 3 H, CH_3), 1.3–1.5 [s, 6 H, *gem*-(CH_3)$_2$].

(BTS-27271)–S–carbofuran, [2,3-dihydro-2,2-dimethylbenzofuran-7-yl [N^1-(2,4-dimethylphenyl)-N^2-methylmethanimidamido]thio]methylcarbamate (II), and other (BTS-27271)–S–carbamate analogues with the N'-(2,4-dimethylphenyl)-N-methylmethanimidamide fragment were prepared by using the same procedure as described above.

Elemental analyses for the individual compounds are presented in Table II. NMR spectra were obtained with a Varian EM-390 spectrometer using chloroform-*d* and Me_4Si.

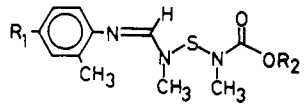
Toxicity to Houseflies and Mice. Insecticidal activities were determined against a susceptible (NAIDM) strain of houseflies, *Musca domestica*, according to usual procedure (March and Metcalf, 1949). Mammalian toxicity was determined orally with Swiss white mice with corn oil as the carrier according to a previously described procedure (Hollingworth et al., 1967).

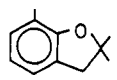
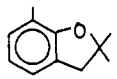
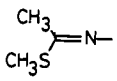
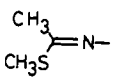
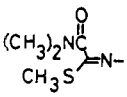
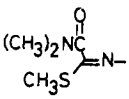
Toxicity to Agriculturally Important Pests. The pesticidal activities of the new procarbamate analogues were tested by American Cyanamid, Princeton, NJ, under a screening agreement with the University of California. The tests were performed by D. P. Wright, Jr.

The standard screening test procedures and rating scale were provided by Wright.

The standard screening procedure included tests with eight species of economically important insects and one mite species. Results for four species of insects are reported here, and these are the tobacco budworm (*Heliothis virescens*), southern armyworm (*Spodoptera eridania*), southern corn rootworm (*Diabrotica undecimpunctata howardi*), and western potato leafhopper (*Empoasca abrupta*). The mite species used was the organophosphorus-resistant strain of the two-spotted spider mite (*Tetranychus urticae*). Different stages of insect, i.e. eggs and larvae, were used for tobacco budworm tests. All tests were done at 27 °C. Any test showing greater than 50% mortality was repeated at progressively lower concentrations (usually 10× dilution) until no further activity was observed. The bioassays are designed to provide a rapid estimate of insecticidal or acaricidal activity. In the 0–9

Table II. Elemental Analyses of Formamidine-S-Carbamate



compd	R_1	R_2	mol formula	anal.[a]	calcd	found
1	Cl		$C_{21}H_{24}ClN_3O_3S$	C	58.12	58.31
				H	5.57	5.58
2	CH_3		$C_{22}H_{27}N_3O_3S$	C	63.90	63.74
				H	6.58	6.66
3	Cl		$C_{20}H_{24}N_3ClO_2S$	C	59.18	59.05
				H	5.96	6.18
4	Cl		$C_{14}H_{19}ClN_4O_2S_2$	C	44.85	44.41
				H	5.11	5.10
5	CH_3		$C_{15}H_{22}N_4O_2S_2$	C	50.82	51.18
				H	6.26	6.54
6	Cl		$C_{16}H_{22}ClN_5O_3S_2$	C	44.49	44.67
				H	5.13	5.21
7	CH_3		$C_{17}H_{25}N_5O_3S_2$	C	49.62	49.89
				H	6.12	6.39

[a] Elemental analyses were carried out by C. F. Geiger, Ontario, CA.

rating scale, every third number is considered to be significantly different from each other, e.g. 0, 3, 6, and 9.

Test I. Tobacco Budworm (H. virescens) Eggs. Tobacco budworm eggs were collected on cheesecloth that was cut into 1–2-cm squares with approximately 50–100 eggs (6–30 h old)/square. The eggs and a young cotton leaf, 6–7 cm long, were dipped into the test solution of appropriate concentration with agitation for 3 s. The treated eggs were placed on the leaf, dried in the hood, and placed in a 8-oz Dixie cup, 2168-ST (240 mL, 6 cm tall, top diameter 9.5 cm, bottom diameter 8 cm), with a 5-cm-length damp dental wick. The cup was covered with a plastic lid, and mortality was counted 3 days after treatment.

Test II. Southern Armyworm (S. eridania) Third Instar Larvae. The third instar larvae were placed in a 100 × 10 mm Petri dish lined with damp filter paper. An expanded Sieva lima bean leaf, 7–8 cm in length, was dipped into the test solution with 3-s agitation and dried in a hood. The treated leaf was then placed in the dish containing larvae and maintained for 5 days, and observations were made on mortality, reduced feeding, or any interference with normal moulting of the larvae.

Test III. Tobacco Budworm (H. virescens) Third Instar Larvae. Cotton cotyledons were dipped into test solution and allowed to dry in a hood. Then each cotyledon was cut into quarters, and 10 sections were placed individually into 30-mL plastic medicine cups containing a damp dental wick 5–7 cm long. A third instar larva was placed in each cup and a cardboard lid was placed on the cup. Mortality counts and feeding reduction estimates were assessed 3 days after treatment.

Test IV. Organophosphorus-Resistant Strain, Two-Spotted Spider Mite (T. urticae). The main colony of mites was kept on Sieva lima bean plants. A test plant (Sieva lima beans) with at least two primary leaves, expanded to 7–8-cm length, was selected and cut back to one plant/pot. Approximately 2 h before the test, a small piece of cut leaf from the main colony with about 100 mites was transferred to a bean plant with primary leaves. During the 2 h the mites moved over to the test plant to lay eggs. The piece of leaf used for mite transfer was removed from the test plant, and the mite-infested plant was dipped in the test solution for 3 s with agitation and dried in the hood. The adult mortality was counted on the first leaf after 2 days, and the mortality of eggs and the emerged nymphs were counted on the second leaf after 5 days.

Test V. Southern Corn Rootworm (D. undecipunctata howardi) Third Instar Larvae. One milliliter of test compound in acetone (1.25, 0.25 mg/mL) was added to 30-mL wide-mouth screw-top glass jars containing 1 mL of fine talc. The acetone was evaporated under a gentle stream of air, and 1 mL of millet seed and 25 mL of moist soil were added to each jar. The jars were capped and contents mixed thoroughly with a Vortex mixer. To this preparation were added 10 third instar larvae/jar and the jars were loosely capped to allow ample air exchange. The treatments were held for 6 days before mortalities were counted. The concentrations of 1.25 and 0.25 mg/jar represent approximately 50 and 10 kg/ha, respectively. Missing larvae, attributable to rapid decomposition in the soil, were presumed to be dead.

Test VI. Western Potato Leafhopper (E. abrupta) Adults. A Sieva lima bean leaf approximately 5 cm long was dipped into a test solution for 3 s with agitation and dried in a hood. The leaf was placed in a Petri dish (100 × 10 mm) lined with a damp filter paper on the bottom. Ten adult leafhoppers were added to the dish, and mortality counts were made after 3 days.

Tests VII and VIII. Systemic Uptake. Mortality of southern armyworms and two-spotted spider mites from the plant systemic uptake tests was assessed as follows. Sieva lima beans grown in a potted soil with primary leaves (7–8-cm expanded length) were cut 3 cm above the soil level. The cut stems were placed in the test emulsions in a bottle, and each stem was wrapped with a bit of cotton to hold the stem off the bottom and to limit evaporation and volatilization of the compound. The emulsion contained 0.1 g of test compound, 0.2 g of Emulphor EL-620 emulsifier, 10 mL of acetone, and 90 mL of water. This mixture was diluted 10-fold with water to give a 100 ppm emulsion. The bean stem was maintained for 3 days at 27 °C to allow uptake of test compound.

Test VII. Southern Armyworm, Third Instar Larvae. A leaf was removed from the plant after 3 days and placed in a Petri dish with 10 southern armyworms as described for test II. Observations on feeding damage and mortality counts were made after 3–5 days.

Test VIII. Two-Spotted Spider Mite Adults. The remaining leaf on the plant from test VII was infested with about 50–100 adult mites from the rearing colony by the method described for test IV. The mortality of the mites was determined 3 days later under a 10× binocularscope.

RESULTS

Synthesis of DCDM-S-Carbamate and BTS-S-Carbamate. The reaction between the formamidine, i.e. DCDM or BTS-27271, and sulfur dichloride in the presence of triethylamine to give the *N*-chlorosulfenyl derivative of DCDM or BTS-27271 was carried out in THF (eq 2). The ^1H NMR spectrum of the reaction product showed a downfield shift of the N=C*H* proton to δ 7.9, which for DCDM or BTS-27271 occurs at δ 7.5. The disappearance

of this singlet at δ 7.5 and appearance of the peak at δ 7.9 indicated that the reaction had gone to completion.

The same reaction was carried out in carbon tetrachloride to observe the chemical shift of the NCH_3 and NH protons of DCDM and BTS-27271, which are otherwise unobservable with THF as the solvent. The ^1H NMR spectrum of the *N*-chlorosulfenylated DCDM or BTS-27271 showed the following absorptions (Me_4Si, CCl_4): δ 7.9 (s, 1 H, N=C*H*), 6.6–7.2 (m, 3 H, aromatic protons), 3.4–3.5 (s, 3 H, NCH_3), 2.2 (s, 3 H, CH_3). The downfield shift of the formamidine NCH_3 protons from δ 2.9–3 to δ 3.4–3.5 and disappearance of the broad N*H* peak at δ 4.4–5 was consistent with the substitution of the $NHCH_3$ proton.

The N-chlorosulfenylated DCDM or BTS-27271 was used directly, in situ, for the next reaction. Attempts to isolate the *N*-chlorosulfenyl derivatives by distillation as described for the *N*-(chlorosulfenyl)carbamates (Fahmy et al., 1978) resulted in decomposition of the product back to the starting formamidine, i.e. DCDM or BTS-27271.

The reaction of N-chlorosulfenylated DCDM or BTS-27271 with *N*-methylcarbamate proceeded with the downfield shift of the NCH_3 doublet protons between δ 2.7 and 2.95 into a singlet at δ 3.3–3.6. This was consistent with the substitution of the proton of the carbamoyl moiety.

Separation of the DCDM–S–carbamates and BTS-27271–S–carbamates from the starting materials by column chromatography was the most difficult part of the preparation of purified products. These compounds were acid sensitive and decomposed to the starting materials upon prolonged contact with silica gel. Chromatography using basic and deactivated alumina also did not afford the purified product.

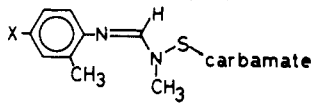
Purification was achieved by flash chromatography using triethylamine-treated silica gel (Still et al., 1978). This method was originally developed for the purification of leukotriene analogues with acid-sensitive epoxide and thiirane groups (Corey et al., 1979, 1980). Protection from decomposition of the product by minimizing the contact time with silica during elution and deactivating the silica gel afforded recovery of the purified compounds.

Toxicity to Houseflies and Mice. Toxicity data against houseflies and mice of the DCDM–S–carbamates and BTS-27271–S–carbamates are presented in Table III. These toxicological evaluations were conducted at the University of California, Riverside. In order to account for the differences in molecular weights of the compounds, toxicity data also are expressed on a mole or molar basis as well as on a weight basis; i.e., LD_{50} is given in terms of micromole/gram or millimole/kilogram.

Most of the compounds in the table showed activities that were weak to moderate against houseflies. Compared to the parent methylcarbamate insecticides, on a micromole/gram basis, the compounds were 1.4- to 2.3-fold less active.

The DCDM–S–carbamates and BTS-27271–S–carbamates varied in toxicity to the white mouse. With the exception of the oxamyl derivatives, the results indicate that the compounds were substantially less toxic to mice than the parent methylcarbamates. For example, on a weight basis DCDM–S–carbofuran was 76-fold less toxic than carbofuran. In general, the data were similar to those reported previously for the *N,N'*-thiodicarbamate (Fahmy et al., 1978) and N-sulfinylated carbamate derivatives (Fahmy and Fukuto, 1981).

Table III. Toxicity of DCDM–S–Carbamate and BTS–S–Carbamate to Houseflies (HF) and Mice



			HF LD_{50}		mouse (oral) LD_{50}	
X	carbamate	MW	μg/g	μmol/g	mg/kg	mmol/kg
Cl	carbofuran	433.96	18.5	0.043	152 (2)[a]	350
			(6.7)[a]	(0.030)[a]	[117–197][c]	(9)[a]
	MIP	405.95	194	0.478	130 (16)	320
			(41)	(0.212)	[100–168]	(83)
	methomyl	374.91	15.5	0.041	98.0 (10)	261
			(3.7)	(0.023)	[77.3–124]	(62)
	oxamyl	431.97	9.52	0.022	14.9 (5)[b]	34
			(3.6)	(0.016)	[10.5–21.0]	(23)
CH_3	carbofuran	413.54	21.8	0.053	35.4 (2)	86
			(6.7)	(0.030)	[21.7–57.7]	(9)
	methomyl	354.50	16.8	0.047	157 (10)	443
			(3.7)	(0.023)	[114–215]	(62)
	oxamyl	411.55	10.3	0.025	25.0 (5)[b]	61
			(3.6)	(0.016)	[14.7–42.6]	(23)

[a] Parenthetical numbers are the LD_{50} values of the parent methylcarbamates from Fahmy et al. (1978). [b] LD_{50} values obtained on rats (Fahmy et al., 1978). [c] The numbers in brackets are the 95% confidence intervals of the toxicity data.

Bioassay of DCDM–S–Carbamates and BTS–S–Carbamates against Economically Important Agricultural Pests. Bioassay against a variety of economically important agricultural pests revealed a number of interesting results (Table IV).

DCDM–S–oxamyl and DCDM–S–carbofuran were more effective than their parent carbamates against tobacco budworm eggs and organophosphorus-resistant spider mites (P.-res. mites). DCDM–S–carbofuran was active at 1 ppm against tobacco budworm eggs where it showed 46–55% control (rating scale 4). Compared to DCDM–S–carbofuran, carbofuran did not show any activity at 1 ppm and mortality of eggs was observed only at 10 ppm. DCDM–S–oxamyl showed activity against budworm eggs at 100 ppm, giving 26–35% control (rating scale 2), whereas oxamyl in comparison showed no activity even at 300 ppm. DCDM–S–carbofuran also showed superiority over carbofuran against tobacco budworm third instar larvae (TBW).

DCDM–S–carbofuran was also effective against organophosphorus-resistant mites. It was equal to chlordimeform at 10 ppm, i.e. DCDM–S–carbofuran 36–45% control (rating scale 3) vs. chlordimeform 26–35% control (rating scale 2). Carbofuran in comparison had no activity against these mites. Both DCDM–S–carbofuran and DCDM–S–methomyl also showed activity in their systemic action in plants against mites. The miticidal activity of DCDM–S–carbofuran is desirable since use of methylcarbamate insecticides alone in the field often results in a resurgence of the mite population owing to their detrimental effect on natural mite predators. Combination of DCDM and carbofuran via a sulfur linkage afforded a pesticide that is effective against both insects and acarine.

DCDM–S–oxamyl showed superiority over both oxamyl and chlordimeform against the southern armyworm third instar larvae. At 100 ppm, DCDM–S–oxamyl showed 86–99% control (rating scale 8) compared to no activity at the same concentration for either chlordimeform or oxamyl.

Compared to the parent compounds, DCDM–S–methomyl showed equal or higher activity against the leafhopper and tobacco budworm larvae. Against the leafhopper, DCDM–S–methomyl showed 100% control (rating

Table IV. Bioassay of DCDM-S-Carbamate and BTS-S-Carbamate Derivatives against Economically Important Agricultural Pests[a]

	tobacco budworm (TBW) eggs, ppm				southern armyworms (3rd instar), ppm				TBW, ppm			P-res mite, ppm			SCRW, kg/ha			leaf hopper, ppm			systemic, ppm					
																					SAW			mite		
	300	100	10	1	1000	100	10	1	1000	100	10	300	100	10	50	10	1	100	10	1	100	10	1	100	10	1
DCDM-S-carbofuran		9				9			8			9			9			9			9			9		
			9				2			9			9			0			9			9		5		
				4				0			4 (0)[b]			3						0			0			0
BTS-S-carbofuran		9				9			9			8			9			9			9			9		
			3				0			0			5			9			9			0		9		
				0				0			0			0			7			2						0
carbofuran		9				9			9			0			9			9			9			9		
			9				9			7						9			9			9		3		
				0				0			0						9 (0)[b]			0			0			0
DCDM-S-MIP		9				9			8			7			9			9			9			9		
			3				0			0			3			9			9			9		5		
				0										0			4			6 (0)[b]			0			0
DCDM-S-methomyl		9				9			9			9			0			9			9			9		
			9				9			9			9							9			9		3		
				7 (0)[b]				0			0			0						0			0			0
BTS-S-methomyl		9				9			9			9			9			9			9			9		
			3				4			8			9			0			9			9		9		
				0				0			0			0						3			0			0
methomyl		9				9			9			8			9			9			9			9		
			9				9			8			9			8				2			9		0	
				7 (0)[b]				0			0			0			0			0			3			
DCDM-S-oxamyl	7				9				0			9			7			9			0			0		
		2				8							4			2			0							
			0				0							0												
BTS-S-oxamyl	9				9				9			9			8			9			0			9		
		1				0							8			2			0						9	
			0											0			0									0
oxamyl	0				3				0			9			9			9			0			9		
						0							0			0			0					3		
																										0
chlordimeform		9			9				0			9			0			0			0			0		
			5			0							6													
				0										2												

[a] Ratings: 0 = no kill; 1 = 10–25% kill; 2 = 26–35% kill; 3 = 36–45% kill; 4 = 46–55% kill; 5 = 56–65% kill; 6 = 66–75% kill; 7 = 76–85% kill; 8 = 86–99% kill; 9 = 100% kill.
[b] No kill at next 10-fold dilution.

scale 9) at 10 ppm compared to 26–35% control (rating scale 2) with methomyl at the same dosage. Against the tobacco budworm larvae, 100 ppm of DCDM-S-methomyl gave 100% control while methomyl showed 86–99% control (rating scale 8).

The BTS-S-carbamates had a wider spectrum of activity than either chlordimeform or the carbamates and showed the combined action of the two compounds. All of the derivatives showed activity above 86–99% control (rating scale 8) against the southern corn rootworm (SCRW) when the soil was treated at a rate of 50 kg/ha, and at this dosage chlordimeform was inactive. The BTS-S-carbofuran showed miticidal activity against organophosphorus-resistant mites at 100 ppm, giving 56–65% control (rating scale 5) compared to carbofuran, which was totally inactive at all concentrations used. Also BTS-S-oxamyl showed improvement over oxamyl against organophosphorus-resistant mites, i.e. 86–99% control (rating scale 8) vs. no kill, at 100 ppm.

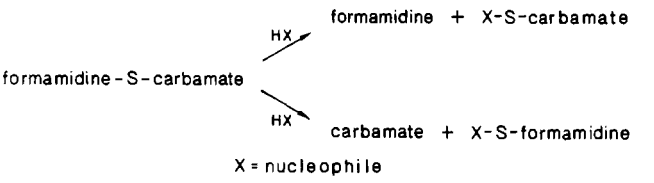
Against the southern corn rootworm, the BTS-S-carbamates appeared to be superior to the DCDM-S-carbamates. At 1 kg/ha, BTS-S-carbofuran showed 76–85% control (rating scale 7) compared to no activity at the same concentration for DCDM-S-carbofuran. Also at 50 kg/ha, BTS-S-methomyl showed 100% control (rating scale 9) whereas DCDM-S-methomyl showed no control of the southern corn rootworm. BTS-S-oxamyl also showed activity at 10 kg/ha, controlling 26–35% of the rootworm (rating scale 2), compared to no control with DCDM-S-oxamyl at the same concentration. However, the BTS-S-carbamate derivatives were generally less active than the parent carbamates in controlling the southern corn rootworm.

The BTS-S-carbamate derivatives were equal or slightly more effective against leafhoppers than the DCDM-S-carbamates and parent carbamates. At 1 ppm, BTS-S-carbofuran showed 26–35% control (rating scale 2) compared to no control with either DCDM-S-carbofuran or carbofuran, and BTS-S-methomyl showed 36–45% control (rating scale 3) compared to no control with either DCDM-S-methomyl or methomyl. However, in general, the BTS-S-carbamates were less active than either the parent carbamates or DCDM-S-carbamates.

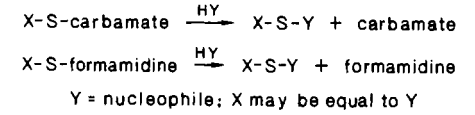
DISCUSSION

For insecticidal and acaricidal activity, DCDM-S-carbofuran was the preferred formamidine and carbamate combination over other DCDM- or BTS-S-carbamate derivatives. This derivative showed superiority over both carbofuran and chlordimeform in at least three tests; i.e., tobacco budworm eggs, organophosphorus-resistant mites, and tobacco budworm third instar larvae. Its activity was equivalent to the parent carbamate (carbofuran) in three other tests; i.e., the leafhopper, southern armyworm (SAW), and mite plant systemic uptake tests. The formamidin-S-carbamate derivatives were less active than the parent carbamates against the bean aphid, tarnished plant bug (lygus), and German cockroach (data not presented).

It was surprising to find that in many cases the derivatives were more effective than the parent compounds against both insects and mites while showing the combined action of the formamidine acaricide and carbamate, especially since on a weight basis there is only about half as much carbamate and formamidine in each derivative. The results suggest that two different bonds are being cleaved in the test animals, i.e. cleavage between the formamidine–sulfur bridge to give the free formamidine and cleavage between the carbamate–sulfur bridge to give the free carbamates.



In addition to this, it is likely that the X-S-carbamate or X-S-formamidine is further broken down to release carbamate and formamidine, respectively.



The improved or sustained insecticidal activity may be attributed to the improved lipophilicity of the derivatives compared to the parent pesticides, resulting in compounds that penetrate faster into the pest. The instability of these derivatives in biological systems to release readily the two parent pesticides within the pest accounts for the combined insecticidal and acaricidal activities observed for these compounds.

Studies on the metabolism and mode of action of derivatized methylcarbamate esters have shown that their lower mammalian toxicities are attributable to the preferential metabolic detoxication of the derivatives to nontoxic products (Black et al., 1973; Miskus et al., 1969; Krieger et al., 1976; Fahmy et al., 1978). In the target species, however, in the case of the formamidine-S-carbamate, the active methylcarbamate as well as the formamidine is most likely generated in vivo, resulting in intoxication. It is reasonable to suspect that the lower mammalian toxicity of the DCDM-S-carbamates and BTS-S-carbamates are also attributable to this differential metabolism.

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