

# Synthesis and insecticidal and acaricidal activities of *O,O*-dialkyl *S*-(5-methyl-5,6-dihydro-1,4-dithiin-2,3-dicarboximidomethyl)thio- and dithiophosphates

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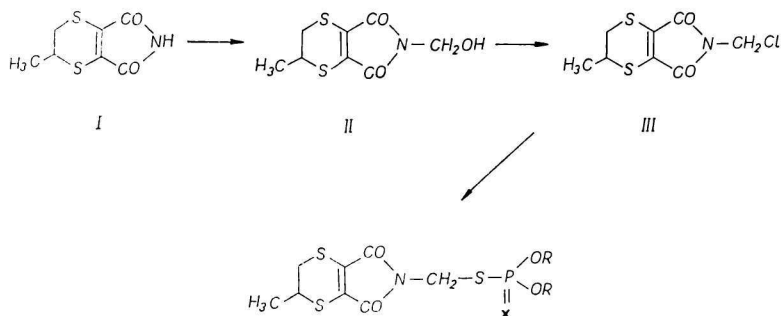
*O,O*-Dialkyl *S*-(5-methyl-5,6-dihydro-1,4-dithiin-2,3-dicarboximidomethyl)thio- and dithiophosphates were prepared from *N*-chloromethyl-5-methyl-5,6-dihydro-1,4-dithiin-2,3-dicarboximide and potassium *O,O*-dialkyl thio- and dithiophosphates, respectively. Electronic and infrared spectra of the prepared thio- and dithiophosphates were evaluated. It was found that each of the synthesized compounds showed lower insecticidal, acaricidal, and systemic activities than the used standard "Imidan".

In this work we synthesized further compounds structurally similar to the known insecticide "Imidan" (*O,O*-dimethyl *S*-phthalimidomethyl dithiophosphate) and tested their pesticidal activity. In [1] we described the synthesis of *O,O*-dialkyl *S*-(5,6-dihydro-1,4-dithiin-2,3-dicarboximidomethyl)thio- and dithiophosphates and found that their pesticidal activity values did not achieve those of the "Imidan". On the other hand, it was stated that these compounds prepared by the reaction of *S*-chloromethyl thio- and dithiophosphates with 5,6-dihydro-1,4-dithiin-2,3-dicarboximide [2] showed significant pesticidal effects. It was evident that the obtained activities were due to the impurities of the starting *S*-chloromethyl thio- and dithiophosphates, respectively, present in the final products which were known to possess excellent pesticidal properties.

In order to examine pesticidal activities of further compounds of this group, we synthesized *O,O*-dialkyl *S*-(5-methyl-5,6-dihydro-1,4-dithiin-2,3-dicarboximidomethyl)thio- and dithiophosphates (*IV*–*XIII*) (Scheme 1).

## Experimental

The i.r. spectra were measured on a UR-20 (Zeiss Jena) spectrophotometer in chloroform. Concentrations of the measured compounds were chosen so that the absorption maximum was 75% in the region of 1900–1600 cm<sup>-1</sup>. Cells of 0.1 cm thickness were used and the spectrophotometer was calibrated with polystyrene foil. Wavenumbers were read with ±0.5 cm<sup>-1</sup> accuracy.



Scheme 1

Electronic spectra were measured on a Perkin—Elmer 450 spectrophotometer in the region of 215—750 nm; concentrations of compounds in dry methanol were  $10^{-3}$ — $10^{-4}$  M.

The n.m.r. spectra were measured on a Tesla BS-487 A spectrometer at 80 MHz.

Results of the laboratory tests for biological activity are presented in Table 3.

#### *N*-Hydroxymethyl-5-methyl-5,6-dihydro-1,4-dithiin-2,3-dicarboximide (II)

5-Methyl-5,6-dihydro-1,4-dithiin-2,3-dicarboximide (I) (20.13 g; 0.1 mole) [3] and 15% water solution of formaldehyde (61 g; 0.3 mole) were refluxed for 1 1/2 hour under stirring. The reaction mixture was cooled to 10°C and stirred for an additional hour at this temperature. The formed oil of compound II became solid within one hour. It was crystallized from 50% ethanol and the resulting product had m.p. 132—135°C.

For  $C_8H_8NO_3S_2$  (231.30) calculated: 41.54% C, 3.92% H, 6.06% N, 27.79% S; found: 41.40% C, 3.88% H, 6.30% N, 27.81% S.

$\nu(\text{CO})$  1778, 1716,  $\nu(\text{C}=\text{C})$  1557,  $\nu(\text{OH})$  3606;  $\lambda$  ( $\epsilon$ ) 207 (5680), 253 (10150), 408 (3160).

#### *N*-Chloromethyl-5-methyl-5,6-dihydro-1,4-dithiin-2,3-dicarboximide (III)

Freshly distilled thionyl chloride (118.97 g; 1 mole) and II (23.13 g; 0.1 mole) were refluxed for 2 hrs under stirring. Then the reaction mixture was poured onto crushed ice (600 g) and stirred for 20—30 min. The formed oil became solid within 1—2 hrs. Crystallization from carbon disulfide or ethyl acetate gave a product of m.p. 77—79°C.

For  $C_8H_8NO_2Cl$  (249.74) calculated: 38.48% C, 3.23% H, 5.61% N, 25.68% S, 14.19% Cl; found: 38.28% C, 3.26% H, 5.80% N, 25.82% S, 14.32% Cl.

$\nu(\text{CO})$  1784, 1726,  $\nu(\text{C}=\text{C})$  1551;  $\lambda$  ( $\epsilon$ ) 208 (8000), 253 (3300), 259 (9700); H-n.m.r.  $\delta$  (p.p.m.) ( $\text{CH}_3$ ) 1.48; ( $\text{CH}_2-\text{S}$ ) 3.08; ( $\text{CH}_2\text{Cl}$ ) 5.25; ( $\text{CH}$ ) 3.58.

#### *O,O*-Dialkyl *S*-(5-methyl-5,6-dihydro-1,4-dithiin-2,3-dicarboximidomethyl)thiophosphates (IV—VIII) and *O,O*-dialkyl *S*-(5-methyl-5,6-dihydro-1,4-dithiin-2,3-dicarboximidomethyl)dithiophosphates (IX—XIII)

Potassium salts of *O,O*-dialkyl thiophosphoric and dithiophosphoric acids (0.018 mole) and III (4.0 g; 0.016 mole) were heated at 60°C in ethyl methyl ketone (20 ml) for 6 hrs. The reaction mixture was cooled to 20°C and poured into water (150 ml) under stirring.

Table 1

Characterization of the prepared organophosphorus compounds

No.	R	X	Formula	M	Calculated/found					Yield [%]	M.p. [°C] Solvent $n_D^{20}$	$R_F$
					% C	% H	% N	% P	% S			
IV	CH <sub>3</sub>	O	C <sub>10</sub> H <sub>14</sub> NO <sub>5</sub> PS <sub>3</sub>	355.39	33.89	3.97	3.94	8.71	27.06	95	83—84 Methanol	0.120
					33.94	3.91	3.92	8.60	27.09			
V	C <sub>2</sub> H <sub>5</sub>	O	C <sub>12</sub> H <sub>18</sub> NO <sub>5</sub> PS <sub>3</sub>	383.44	37.58	4.73	3.65	8.08	25.09	92	67—69 Methanol	0.176
					37.46	4.70	3.65	7.93	25.25			
VI	<i>n</i> -C <sub>3</sub> H <sub>7</sub>	O	C <sub>14</sub> H <sub>22</sub> NO <sub>5</sub> PS <sub>3</sub>	411.50	40.86	5.39	3.41	7.53	23.37	92	1.5770	0.284
					40.93	5.28	3.46	7.21	23.96			
VII	·C <sub>3</sub> H <sub>7</sub>	O	C <sub>14</sub> H <sub>22</sub> NO <sub>5</sub> PS <sub>3</sub>	411.50	40.86	5.39	3.41	7.53	23.37	79	1.5690	0.256
					40.96	5.25	3.44	7.89	24.00			
VIII	·C <sub>4</sub> H <sub>9</sub>	O	C <sub>16</sub> H <sub>26</sub> NO <sub>5</sub> PS <sub>3</sub>	439.55	43.68	5.95	3.18	7.04	21.86	77	1.5558	0.396
					43.39	6.01	3.03	6.85	21.62			
IX	CH <sub>3</sub>	S	C <sub>10</sub> H <sub>14</sub> NO <sub>4</sub> PS <sub>1</sub>	371.45	32.33	3.80	3.77	8.34	34.52	90	75—77 Methanol	0.495
					32.44	3.91	3.70	8.31	34.14			
X	C <sub>2</sub> H <sub>5</sub>	S	C <sub>12</sub> H <sub>18</sub> NO <sub>4</sub> PS <sub>4</sub>	399.51	36.07	4.54	3.51	7.75	32.10	86	49—51 Methanol	0.548
					35.92	4.59	3.51	7.69	32.26			
XI	<i>n</i> -C <sub>3</sub> H <sub>7</sub>	S	C <sub>14</sub> H <sub>22</sub> NO <sub>4</sub> PS <sub>4</sub>	427.56	39.32	5.19	3.28	7.24	30.06	88	1.5910	0.590
					39.50	5.08	3.30	7.44	29.76			
XII	·C <sub>3</sub> H <sub>7</sub>	S	C <sub>14</sub> H <sub>22</sub> NO <sub>4</sub> PS <sub>4</sub>	427.56	39.32	5.19	3.28	7.24	30.06	81	82—83 Methanol	0.556
					39.09	5.07	3.29	7.01	29.82			
XIII	·C <sub>4</sub> H <sub>9</sub>	S	C <sub>16</sub> H <sub>26</sub> NO <sub>4</sub> PS <sub>4</sub>	455.62	42.18	5.75	3.08	6.80	28.14	83	1.5836	0.595
					42.33	5.61	3.20	6.60	27.99			

Table 2

Infrared and electronic spectral data of the synthesized organophosphorus compounds

No.	$\nu_s(\text{CO})$	$\nu_{as}(\text{CO})$	$\nu(\text{C}=\text{C})$	$\nu(\text{P}=\text{X})$	$\nu(\text{P}-\text{O}-\text{C})$	$\lambda_{\text{max}}(\epsilon)$ [nm]	
IV	1777	1721	1554	1255	1026	216 (8 900)	265 (10 000) 420 (3200)
V	1778	1720	1556	1251	1016	214 (10 800)	265 (11 620) 420 (3600)
VI	1778	1719	1556	1250	1000	213 (11 200)	265 (11 650) 420 (3600)
VII	1778	1720	1556	1245	988	212 (10 200)	265 (10 800) 420 (3240)
VIII	1778	1720	1556	1249	1003	213 (10 800)	265 (11 600) 420 (3600)
IX	1776	1717	1553	650	1020	215 (13 100)	268 (10 400) 420 (3200)
X	1777	1720	1556	652	1014	215 (12 100)	268 (9 700) 420 (2900)
XI	1777	1719	1554	658	990	215 (11 800)	267 (9 600) 420 (2840)
XII	1777	1720	1557	646	971	215 (11 200)	267 (9 100) 420 (2600)
XIII	1777	1720	1556	663	996	215 (11 600)	267 (9 500) 420 (2800)

The formed oil was extracted with dichloromethane. The organic layer was separated, dried with anhydrous sodium sulfate, and filtered. Then the solvent was distilled off under reduced pressure and the obtained viscous oil was further dried at 80°C/0.2 torr. The product was purified on a column of silica gel L 40/100 (Lachema, Brno) using ethyl acetate—benzene (1 : 1) as eluent.

Characterization of the prepared thiophosphates and dithiophosphates and their spectral data are given in Tables 1 and 2.

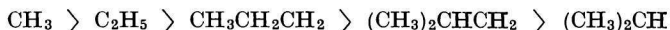
The purity of the prepared organophosphorus compounds was verified on a thin layer of Silufol (Kavalier, Sázava) in the system benzene—cyclohexane—ethyl acetate (25 : 25 : 50). The obtained  $R_F$  values are presented in Table 1.

### Results and discussion

*N*-Chloromethyl-5-methyl-5,6-dihydro-1,4-dithiin-2,3-dicarboximide (*III*) and the appropriate potassium salts of *O,O*-dialkyl thiophosphoric and dithiophosphoric acids, respectively (prepared according to [4–7]) were the starting compounds for preparation of the thiophosphates (*IV–VIII*) and dithiophosphates (*IX–XIII*) (see Table 1). The mentioned *N*-chloromethyl derivative (*III*) reacted with these salts almost quantitatively.

By reaction of 5-methyl-5,6-dihydro-1,4-dithiin-2,3-dicarboximide (*I*) (its synthesis was described in [3]) and formaldehyde, *N*-hydroxymethyl-5-methyl-5,6-dihydro-1,4-dicarboximide (*II*) was obtained from which *III* was prepared in two ways. In the first procedure the reaction was accomplished in chloroform while in the second one (described in Experimental) the reaction proceeded in tenfold excess of thionyl chloride. The second procedure was more advantageous regarding the yield and isolation of the product.

In the i.r. spectra of all prepared organophosphorus compounds (Table 2) a band belonging to the stretching vibration of the double bond of 5,6-dihydro-1,4-dithiine ring was observed at 1554–1556  $\text{cm}^{-1}$ . In the region of the stretching vibration of C=O, two absorption bands were observed similarly as with *N*-*X*-phenyl-5-methyl-5,6-dihydro-2,3-dicarboximides [3]. The more intensive band at 1720–1718  $\text{cm}^{-1}$  belonged to the asymmetrical and the less intensive one at 1779–1777  $\text{cm}^{-1}$  to the symmetrical vibrations of the dicarbonyl system [8]. An absorption band of medium intensity, characteristic of all organophosphorus compounds, appeared in the region of 1026–988  $\text{cm}^{-1}$  with thiophosphates (*IV–VIII*) and at 1020–971  $\text{cm}^{-1}$  with dithiophosphates and was attributed to the stretching P—O—C vibration [9]. From the data in Table 2 it can be seen that the P—O—C band position depended strongly on the nature of the alkyl in the alkoxy groups. The wavenumber values of this vibration decreased with the prepared thio- and dithiophosphates in the following order



*i.e.*, in the same order as the Taft  $\sigma^*$  constants. The relation between the wave number of the P=O bond at 1255–1247  $\text{cm}^{-1}$  and the Taft  $\sigma^*$  constants was analogous. With dithiophosphates, a band of medium intensity belonging to P=S bond was observed at 663–650  $\text{cm}^{-1}$ .

The solutions with benzene, chloroform as well as other solvents were intensively fluorescent in the u.v. light. The prepared thio- and dithiophosphates showed a band in the visible region of the electronic spectra at 420 nm; its position was

Table 3

Pesticidal activity (LC<sub>50</sub>) of the prepared organophosphorus compounds

No.	Insecticidal activity		Acaricidal activity	Acaricide- ovicidal activity	Ovicidal activity	Systemic activity
	<i>Musca domestica</i>	<i>Calandra granaria</i>	<i>Tetranychus urticae</i>	<i>Tetranychus urticae</i>	<i>Aphis fabae</i>	<i>Macrosyphoniella sanborni</i>
IV	0.50	0.1	0.071	0.50	0.10	0.50
V	0.086	0.1	0.007	0.50	0.051	0.50
VI	0.10	0.1	0.10	0.50	0.054	0.50
VII	0.23	0.1	0.10	0.50	0.058	0.17
VIII	0.50	0.1	0.051	0.50	0.10	0.50
IX	0.50	0.1	0.10	0.50	0.048	0.50
X	0.50	0.1	0.006	0.50	0.015	0.50
XI	0.50	0.1	0.10	0.50	0.10	0.50
XII	0.50	0.1	0.10	0.50	0.10	0.50
XIII	0.095	0.1	0.10	0.50	0.10	0.50
Standard — —“Imidan”	0.01	0.043	0.0016	0.50	0.002	0.50

not influenced by the alkyl groups. In the u.v. region two bands were observed at 213–216 nm and at 265–268 nm. With thiophosphates the values of  $\epsilon$  of the first band were higher than those of the second band.

It is evident from the results given in Table 3 that none of the tested compounds had higher values of insecticidal, acaricidal, acaricide-ovicidal, ovicidal, and systemic activities than the used standard “Imidan”

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