Phosphorylated isothioureas. I. Preparation and properties of *N*-(*O*,*O*-dialkylthiophosphoryl)-*S*-alkyl substituted isothioureas

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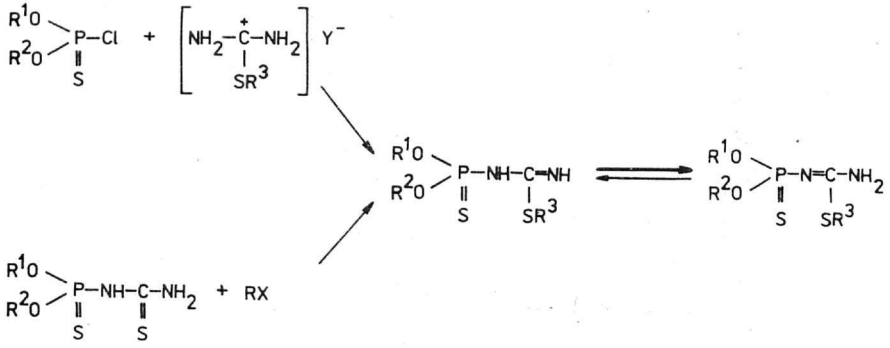
Synthesis and properties of new *N*-(*O*,*O*-dialkylthiophosphoryl)-*S*-alkyl and -aryl substituted isothioureas, prepared by the reaction of corresponding chlorothiophosphates with thiouronium salts or by the alkylation of appropriate thiophosphorylthioureas are described. Infrared, ultraviolet, ^{1}H-n.m.r., and mass spectra of compounds prepared are interpreted. Also, the results obtained by testing the compounds on pesticidal activity are discussed.

Описаны свойства новых *N*-(*O*,*O*-диалкилтиофосфорил)-*S*-алкил- и -арилпроизводных изотиомочевины, синтезированных реакцией соответствующих хлортиофосфатов с тиоуроновыми солями или алкилированием соответствующих тиофосфорилтиомочевин. Дана интерпретация ИК, УФ, ^{1}Н-ЯМР и масс-спектров полученных соединений. Обсуждаются данные по испытанию их пестицидных свойств.

Extraordinarily good insecticidal and acaricidal properties of *O*,*S*-dimethyl phosphoroamidothioate, known under the names of Tamaron, Monitor [1, 2] and its acetyl derivative *O*,*S*-dimethyl *N*-acetyl phosphoroamidothioate, known as Acephate, Orthene [3, 4] initiated further synthesis on the basis of phosphoroamidothioates and compounds having a characteristic P—N=C grouping [5—15] which is also characteristic of phosphorylated isothioureas.

Cramer and *Vollmar* [16] carried out the synthesis of *N*-(*O*,*O*-diarylphosphoryl)-*S*-methyl(ethyl)isothioureas, by the action of diaryl chlorophosphate with methyl thiouronium sulfate or ethyl thiouronium bromide, in a heterogeneous mixture benzene—water in the presence of sodium hydroxide. *Melnikov et al.* [17] prepared *N*-(*O*-alkyl *N*-alkylamidothiophosphoryl)-*S*-alkylisothioureas by the reaction of *O*-alkyl *N*-alkylamidochlorothiophosphates with alkyl thiouronium salts in benzene under reflux in the presence of triethylamine.

In the present work synthesis, structure, and properties of *N*-(*O*,*O*-dialkylthiophosphoryl)-*S*-alkyl or -aryl substituted thioureas are described. The compounds were prepared according to Scheme 1



Scheme 1

Experimental

O,*O*-Dimethyl chlorothiophosphate [18], *O*,*O*-diethyl chlorothiophosphate [18], *O*-methyl *O*-ethyl chlorothiophosphate [19], *O*-methyl *O*-isopropyl chlorothiophosphate [19], *O*-methyl *O*-isobutyl chlorothiophosphate [19], *O*-ethyl *O*-propyl chlorothiophosphate [20], *O*-ethyl *O*-isopropyl chlorothiophosphate [21], *O*,*O*-dipropyl chlorothiophosphate [22], *O*-propyl *O*-isopropyl chlorothiophosphate [20], *O*-ethyl *O*-phenyl chlorothiophosphate [23], *O*,*O*-diisopropyl chlorothiophosphate [24], *O*-isopropyl *O*-isobutyl chlorothiophosphate [20], *O*,*O*-diisobutyl chlorothiophosphate [24], and *O*,*O*-diphenyl chlorothiophosphate [25] were prepared according to the known methods, starting from phosphorus thiochloride and appropriate alcohol and phenol, respectively. Thiouronium salts were prepared by the reaction of thiourea with appropriate alkyl halogenides and dimethyl sulfate, respectively, in ethanol [26, 27]. *N*-(*O*,*O*-Diethylthiophosphoryl)thiourea was prepared by the reaction of *O*,*O*-diethylthiophosphoryl isothiocyanate [28, 29] with amonia [30]. *N*,*N*-Dimethyl *N*-(*O*,*O*-dimethylthiophosphoryl)formamidine [31] was prepared by the reaction of *O*,*O*-dimethyl amidothiophosphate with dimethylformamide dimethyl acetale in methanol.

The course of the reaction and the purity of compounds were investigated by t.l.c. [Silufol R with a UV 254 luminiscence indicator or Silufol R without an indicator (Lachema, Brno) were used]. Chloroform, benzene, and mixtures of petroleum ether with acetone or of chloroform with ethanol were used as eluents. Detection was carried out by 0.5% petroleum ether solution of 2,6-dibromo-*N*-chloro-*p*-benzoquinoneimine (DQC) at 120°C for 2—5 min as well as by ultraviolet light (λ 254 nm).

Liquid compounds were purified by column chromatography on Silica gel L 100/ /160 mesh (Lachema, Brno) using gradient elution of benzene from 0 to 30% in acetone or chloroform. The stability of *S*-substituted isothioureas was tested on a MON Derivatograph, type 3427, thermodynamic balance using *N*-(*O*,*O*-diethylthiophosphoryl)-*S*-benzylisothiourea (*XIV*) (Fig. 1).

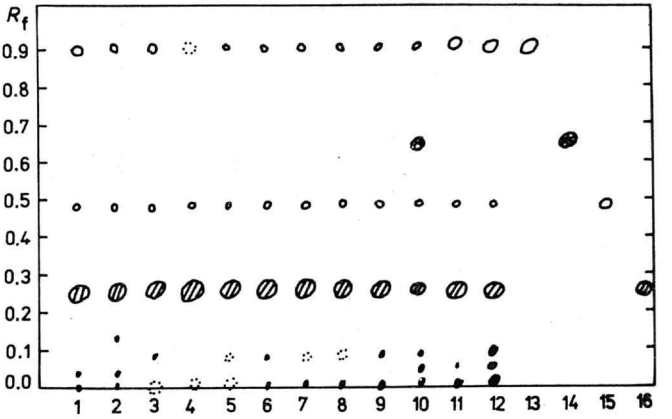


Fig. 1. Record of thermal stability of *XIV*.

Infrared spectra were recorded on either a Zeiss UR-20 or a Zeiss IR-71 instruments in the region 500—3800 cm^{-1} for carbon tetrachloride and chloroform solutions and for pure liquids. The wavenumber calibration was checked against the spectrum of polystyrene and wavenumber measurements are believed to be accurate to ± 1 cm^{-1}.

Ultraviolet spectra were recorded with a Unicam SP 8000 in 1.0 cm cells within concentrations of 10^{-4}—10^{-5} M in methanol.

^{1}H-n.m.r. spectra were recorded with a Tesla BS 487 C (80 MHz) with TMS as internal standard. Measurements were carried out for carbon tetrachloride, deuteriochloroform (99.5% of D isotope) and dimethyl sulfoxide solutions at 25°C.

Mass spectra were recorded with an AEI 902 S instrument operating at 70 eV, the temperature of the ionizing chamber 40°C.

Substituted isothioureas I—XXIX

A survey of compounds prepared according to one or two of the five methods described below is given in Table 1.

Method A

To a reaction mixture consisting of appropriate chlorothiophosphate (0.1 mole), thiouronium salt (0.1 mole), and potassium carbonate (0.1 mole) in a solvent as acetonitrile, acetone, ethyl methyl ketone, benzene or toluene, water (50 ml) was added with stirring.

Table 1

Characterization of the synthesized compounds

Compound	R^1	R^2	R^3	Formula	M	Calculated/found % N	% P	% S	Yield %	Method of preparation	Reaction time, h	T, °C	n_D^{20}	T.l.c. R_f
I	CH_3	CH_3	CH_3	$C_4H_{11}N_2O_2PS_2$	214.26	13.05	14.44	29.9	67.8	*A*	8	19	1.5631	0.06[a] 0.07[b]
						13.48	14.22	30.4						0.10[c]
II	CH_3	CH_3	$C_2H_5SCH_2CH_2$	$C_7H_{17}N_2O_2PS_3$	288.39	9.72	10.76	33.4	90.9	*A*	8	20	1.5958	0.07[a] 0.07[b]
						9.99	10.51	33.9						0.12[c]
III	CH_3	CH_3	$PhCH_2$	$C_{10}H_{15}N_2O_2PS_2$	290.35	9.64	10.61	22.09	51	*A*	3	21	1.6082	0.14[a] 0.09[b]
						9.91	10.40	22.65	43.1	*B*				0.17[c]
IV	CH_3	C_2H_5	CH_3	$C_5H_{13}N_2O_2PS_2$	228.29	12.28	13.56	28.12	69.3	*A*	7	20	1.5578	0.10[a] 0.18[b]
						12.50	13.90	28.60						0.16[c]
V	CH_3	C_2H_5	$PhCH_2$	$C_{11}H_{17}N_2O_2PS_2$	304.38	9.21	10.18	21.09	92.8	*A*	5	20	1.5868	0.15[a] 0.19[b]
						9.43	10.53	21.60						0.15[c]
VI	CH_3	i-C_3H_7	CH_3	$C_6H_{15}N_2O_2PS_2$	242.31	11.55	12.79	26.5	95.0	*A*	6	30	1.5299	0.10[a] 0.12[b]
						11.83	12.50	24.9						0.15[c]

Table 1 (Continued)

Compound	R^1	R^2	R^3	Formula	M	Calculated/found % N	% P	% S	Yield %	Method of preparation	Reaction time, h	T, °C	n_D^{20}	T.l.c. R_f
VII	CH_3	i-C_3H_7	$C_2H_5SCH_2CH_2$	$C_9H_{21}N_2O_2PS_3$	316.48	9.52	9.90	32.2	92.8	*A*	5.5	40	1.5572	0.14[a] 0.17[b]
						9.83	10.23	31.9						0.14[c]
VIII	CH_3	i-C_3H_7	$PhCH_2$	$C_{12}H_{19}N_2O_2PS_2$	318.41	8.80	9.73	20.01	92.9	*A*	6	25	1.5820	0.18[a] 0.17[b]
						9.19	9.98	20.6						0.24[c]
IX	CH_3	i-C_4H_9	$PhCH_2$	$C_{13}H_{21}N_2O_2PS_2$	332.43	8.43	9.32	19. 3	81.2	*B*	13	81	1.5765	0.25[a] 0.41[b]
						8.87	8.98	19.57						0.51[c]
X	C_2H_5	C_2H_5	CH_3	$C_6H_{15}N_2O_2PS_2$	242.31	11.55	12.79	13.21	59.9	*A*	18	18	1.5437	0.09[a]
									58.0	*D*				0.10[b]
						11.86	12.48	13.66	95.1	*E*				0.13[c]
XI	C_2H_5	C_2H_5	C_3H_7	$C_8H_{19}N_2O_2PS_2$	270.36	10.37	11.48	23.7	86.7	*B*	6	81	1.5368	0.17[a] 0.16[b]
						10.64	11.15	23.3						0.25[c]
XII	C_2H_5	C_2H_5	$C_2H_5SCH_2CH_2$	$C_9H_{21}N_2O_3PS_3$	316.44	8.85	9.80	30.22	75.9	*A*	15	23	1.5587	0.09[a] 0.08[b]
						9.16	9.47	30.80						0.15[c]
XIII	C_2H_5	C_2H_5	$HOCH_2CH_2$	$C_7H_{17}N_2O_3PS_2$	272.34	10.30	11.39	23.58	73.5	*C*	12	75	1.5185	0.3[a] 0.09[b]
						10.63	11.09	23.91						0.10[c]

Table 1 (Continued)

Compound	R^1	R^2	R^3	Formula	M	Calculated/found % N	% P	% S	Yield %	Method of preparation	Reaction time, h	T, °C	n_D^{20}	T.l.c. R_f
XIV	C_2H_5	C_2H_5	$PhCH_2$	$C_{12}H_{19}N_2O_2PS_2$	318.41	8.80	9.73	20.01	83	*A*	2	40	1.5800	0.23[a] 0.17[b]
						9.10	9.64	20.39						0.68[c]
XV	C_2H_5	C_2H_5	NH_2COCH_2	$C_7H_{16}N_3O_3PS_2$	285.34	14.17	10.88	22.5	53.1	*C*	10	75		0.02[a] 0.07[b]
						14.51	11.06	22.8						0.04[c]
XVI	C_2H_5	C_2H_5	3,4-di-CH_3PhCH_2	$C_{14}H_{23}N_2O_2PS_2$	346.46	8.08	9.24	18.51	89.1	*A*	3	40	1.5912	0.26[a] 0.15[b]
						7.81	9.01	18.10						0.22[c]
XVII	C_2H_5	C_2H_5	$C_2H_5OCOCH_2$	$C_9H_{19}N_2O_4PS_2$	315.26	8.98	9.85	20.35	43.2	*C*	7	78		0.01[a] 0.02[b]
						8.70	10.18	20.81						0.02[c]
XVIII	C_2H_5	C_3H_7	$PhCH_2$	$C_{13}H_{21}N_2O_2PS_2$	332.43	8.43	9.32	19.3	91.4	*A*	4	40	1.5975	0.32[a] 0.69[b]
						8.75	9.24	19.61						0.33[c]
XIX	C_2H_5	i-C_3H_7	CH_3	$C_7H_{17}N_2O_2PS_2$	256.34	10.93	12.07	25.0	66.8	*A*	10	20	1.5406	0.12[a] 0.23[b]
						10.84	12.28	25.51						0.11[c]
XX	C_2H_5	i-C_3H_7	C_3H_7	$C_9H_{21}N_2O_2PS_2$	284.39	9.84	10.27	22.5	92.2	*A*	11	19	1.5288	0.18[a] 0.17[b]
						10.23	10.51	22.08						0.24[c]

Table 1 (Continued)

Compound	R^1	R^2	R^3	Formula	M	Calculated/found % N	% P	% S	Yield %	Method of preparation	Reaction time, h	T, °C	n_D^{20}	T.l.c. R_f
XXI	C_2H_5	i-C_3H_7	$PhCH_2$	$C_{13}H_{21}N_2O_2PS_2$	332.43	8.43	9.32	19.3	94.1	*A*	9.5	20	1.5743	0.21[a] 0.20[b]
						8.65	9.01	19.72						0.23[c]
XXII	C_3H_7	C_3H_7	$PhCH_2$	$C_{14}H_{23}N_2O_2PS_2$	346.46	8.08	8.95	18.5	84.7	*B*	8	80	1.5709	0.28[a] 0.12[b]
						8.31	8.64	19.1						0.28[c]
XXIII	C_3H_7	i-C_3H_7	$PhCH_2$	$C_{14}H_{23}N_2O_2PS_2$	346.46	8.08	8.95	18.5	83.5	*B*	8	80	1.5660	0.26[a] 0.12[b]
						8.39	8.53	18.12						0.25[c]
XXIV	i-C_3H_7	i-C_3H_7	$PhCH_2$	$C_{14}H_{23}N_2O_2PS_2$	346.46	8.08	8.95	18.5	78.1	*B*	30	80	1.5610	0.20[a] 0.15[b]
						7.81	8.58	18.95						0.21[c]
XXV	i-C_3H_7	i-C_4H_9	$PhCH_2$	$C_{15}H_{25}N_2O_2PS_2$	360.49	7.77	8.62	17.81	90.0	*A*	12	40	1.5630	0.28[a] 0.23[b]
						7.42	8.93	18.2						0.24[c]
XXVI	i-C_4H_9	i-C_4H_9	$PhCH_2$	$C_{16}H_{27}N_2O_2PS_2$	374.51	7.48	8.27	17.12	73.3	*B*	20	80	1.5594	0.24[a] 0.17[b]
						7.83	8.55	17.64						0.23[c]
XXVII	Ph	C_2H_5	CH_3	$C_{10}H_{15}N_2O_2PS_2$	290.35	9.66	10.74	22.5	91.7	*A*	8	40	1.5927	0.28[a] 0.35[b]
						9.41	10.74	22.5						0.29[c]

Table 1 (Continued)

Compound	R^1	R^2	R^3	Formula	M	Calculated/found % N	% P	% S	Yield %	Method of preparation	Reaction time, h	T, °C	n_D^{20}	T.l.c R_f
XXVIII	Ph	C_2H_5	$PhCH_2$	$C_{16}H_{19}N_2O_2PS_2$	366.45	7.64	8.45	17.5	82.5	*A*	7	40	1.6121	0.28[a] 0.13[b]
						7.41	8.69	17.9						0.32[c]
XXIX	Ph	Ph	$PhCH_2$	$C_{20}H_{19}N_2O_2PS_2$	414.50	6.76	7.47	15.45	97.6	*A*	10	17		0.28[a] 0.08[b]
						6.79	7.23	15.83						0.30[c]

Mobile phase: *a*) benzene; *b*) petroleum ether—acetone 9:1; *c*) chloroform.

Compounds *II, VII, VIII, XIV, XVIII—XX, XXVII, XXVIII* prepared in CH_3CN—H_2O 1:1; *IV, VI, XII, XXV, XXIX*, and *XXI* (*B*) in CH_3CN—H_2O 3:2; *I, X (A)* in toluene—H_2O 2:1; *III (A)* in toluene—water 1:1; *III (B), IX, XI* in CH_3CN; *XIII, XV, XVII* in C_2H_5OH; *XXII—XXIV* in $CH_3COC_2H_5$; *XXI (A)* in benzene—water 1:1.

For *XV* m.p. 81—82°C; *XVII* m.p. 65°C (decomposition); *XXIX* m.p. 72—74°C (heptane).

The stirring was continued at 20—50°C and the course of the reaction was controlled by t.l.c. After completion of the reaction the product was extracted twice with chloroform (benzene) (50 ml), dried and the solvent was distilled off under reduced pressure. The excluded solid compounds were purified by crystallization and liquid compounds by column chromatography.

Method B

The reaction mixture of chlorothiophosphate (0.1 mole), thiouronium halogenide (0.1 mole), and triethylamine (0.2 mole) in organic solvent as ethyl methyl ketone, acetone or acetonitrile (100 ml) was heated to reflux. After completion of the reaction the salt formed was filtered off and the filtrate concentrated under reduced pressure. Chloroform (benzene) (100 ml) was added to the residue, washed with water and dried. The solvent was evaporated under reduced pressure. Technical products obtained were purified by column chromatography.

Reaction conditions were investigated with compound *XIV* (Table 2; Fig. 2).

Table 2

Conditions of preparation of compound *XIV*

Experiment	Medium	Ratio of solvents	HCl bonding agent	*T*, °C	Reaction time, h	Yield %
1	Ethyl methyl ketone		$NaHCO_3$	50 + 80	12 + 1.5	83.3
2	Benzene—water	1:1	$NaHCO_3$	80	4	5—10
				(25)	(5)	(80.2)
3	Acetonitrile—water	1:1	K_2CO_3	50	3	83
4	Acetonitrile—water	1:1	K_2CO_3	25	5	84.3
5	Acetonitrile—water	3:2	$NaHCO_3$	50	3.5	86
6	Acetonitrile—water	3:2	$(NH_4)_2CO_3$	50	4	54.7
7	Acetonitrile—water	3:2	K_2CO_3	40	3.5	86.8
8	Acetonitrile		$(C_2H_5)_3N$	81	6	85.5
9	Acetonitrile—water	3:2	K_2CO_3	25	4.5	87.1
10	Benzene—water	1:1	NaOH	20	1.5	–
11	Benzene—water	1:1	K_2CO_3	25	8.5	72.9
12	Acetone (dried)		$2Na_2CO_3$	56	10	69.3

Method C

To *N*-(*O*,*O*-diethylthiophosphoryl)thiourea (0.1 mole), ethanol (acetone, acetonitrile, ethyl methyl ketone) (100 ml), and potassium carbonate (0.1 mole), alkyl halogenide (0.11 mole) was added under stirring and the reaction mixture was heated to reflux. After completion of the reaction the solid compound was filtered off, the solvent distilled off under

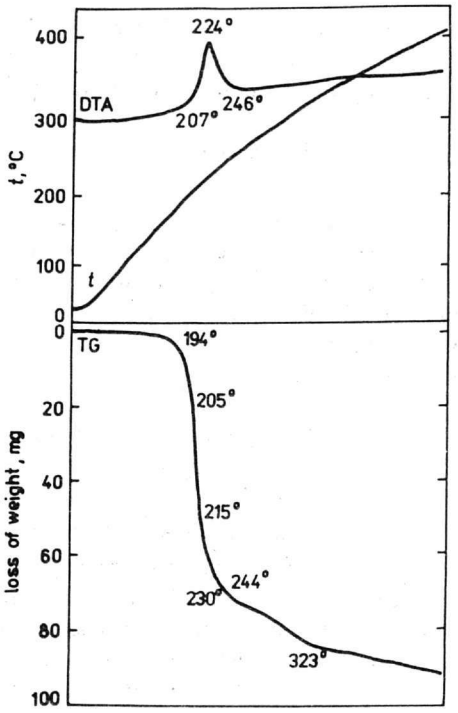


Fig. 2. T.l.c. of the technical products obtained by reaction of *O,O*-diethyl phosphorochloridothioate with *S*-benzylthiouronium chloride under conditions as shown in Table 2. Numbers of experiments *1—12*; *13.* $(PhCH_2S)_2$; *14.* $(C_2H_5O)_2P(S)Cl$; *15.* $(C_2H_5O)_3PS$; *16. XIV.*

reduced pressure and benzene (chloroform) (100 ml) was added. After washing the solution with water and drying, the solvent was distilled off under reduced pressure and compounds were purified by column chromatography.

Method D

To *N*-(*O,O*-diethylthiophosphoryl)thiourea (0.1 mole) and potassium carbonate (0.11 mole) in acetone (200 ml) dimethyl sulfate (0.11 mole) was added and the reaction mixture was heated to reflux. After completion of the reaction, the salt formed was filtered off, the filtrate was concentrated under reduced pressure. To the residue benzene (100 ml) was added and after washing with water and drying, benzene was evaporated under reduced pressure.

The crude product was purified by column chromatopraphy to afford 14.1 g (58%) of compound which is identical with compound *X* prepared according to methods *A* and *E*.

Method E

To *N*-(*O,O*-diethylthiophosphoryl)thiourea (0.1 mole) dissolved in ether (100 ml) ethereal solution (150 ml) of diazomethane (0.12 mole) was added at room temperature under

stirring. After 2 h mixing ether was distilled off and a viscous liquid was obtained (22.9 g) which was purified. Its n_D^{20}, R_f value, and infrared spectra were identical with those of compound *X* prepared according to methods *A* and *D*.

Preparation of N-(O,O-dimethylthiophosphoryl)-S-benzylisothiourea (III)

To *S*-benzylisothiourea (33.2 g; 0.2 mole), water (200 ml), and toluene (200 ml) dimethyl chlorothiophosphate (16.1 g; 0.1 mole) was added at room temperature within 10 min under stirring. After 2 h mixing a toluene layer was separated, dried and toluene was distilled off under reduced pressure affording a viscous liquid (17.8 g; 61.4%). Its n_D^{20}, R_f value, and infrared spectra were identical with those of compound *III* prepared according to methods *A* and *B*.

Preparation of N-[N'-(O,O-diethylthiophosphoryl)thiocarbamoyl]-N'',N''-dimethylformamidine

To *N*-(*O*,*O*-diethylthiophosphoryl)thiourea (11.4 g; 0.05 mole) in methanol (100 ml) dimethylformamide dimethyl acetale (6.6 g; 0.55 mole) was added under stirring within 10 min while the temperature was increased from 16 to 24°C. The stirring was continued for further 4 h at room temperature and after standing overnight a white crystalline compound was filtered off, yield 13.4 g (94.7%), m.p. 109—111°C.

For $C_8H_{18}N_3O_2PS_2$ (283.36) calculated: 14.85% N, 10.92% P, 22.7% S; found: 14.41% N, 10.63 % P, 23.1% S.

Evaluation of pesticidal activity

Insecticidal activity of compounds studied was tested on *Musca domestica* L., *Calandra granaria* L., systemic insecticidal activity on *Macrosyphoniella sanborni* THEOB., acaricidal activity on *Tetranychus urticae* KOCH, ovicidal activity on eggs of *Tetranychus urticae* KOCH, and contact insecticidal activity on *Aphis fabae* SCOP. Fungicidal activity was tested *in vitro* as well as *in vivo*. The inherent activity was tested on the spores of fungi *Sclerotinia fructicola* WINT., *Aspergillus niger* TIEGH, *Fusarium nivale* (FR.) CES., *Alternaria* sp., *Stemphylium sarcinoformae* (CAV.) WITHSHIRE using the Sharvell method. The antipowdery mildew activity was tested on the living plants of barley, variety of Dunajský trh (*Erysiphe graminis* DC.), on cucumbers, variety of Znojemské (*Erysiphe cichoracearum* DC.), and on tomatoes (*Phytophtora infestans* DE BY). Herbicidal activity was tested on *Avena sativa*, *Polygonum persicaria* L., *Fagopyrum sagitatum* L., and *Sinapis alba* L. using a preemergence method into the soil as wel as a postemergence method into the leaf. Methods for testing pesticidal activity on the individual test objects were reported previously [32, 33].

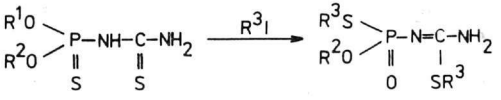
Results and discussion

By methods *A* and *B*, starting from chlorothiophosphates and thiouronium salts, concomitant impurities, *O*,*O*,*O*-trialkyl thiophosphates, were removed from the

products by distillation under reduced pressure. The influence of reaction conditions on the course of the reaction was followed in detail by the reaction of *O,O*-diethyl chlorothiophosphate with benzyl thiouronium chloride (Fig. 1; Table 2). The spot with R_f 0.9 was found to be dibenzyl disulfide which was proved by comparing melting points, R_f value in various systems, and infrared spectra with those of standard. The reaction first led to the formation of phenyl methanethiol which under influence of atmospherical oxygen is very readily oxidized to dibenzyl disulfide especially if amines are present [33]. The formation of thioles from thiouronium salts in alkaline medium is utilized in their preparation [34, 35], as alkaline hydroxide is not suitable for bonding hydrogen chloride. Therefore, the optimum medium was found to be acetonitrile—water, in the presence of potassium carbonate to bond hydrogen chloride. The amount of dibenzyl disulfide linearly increases with temperature and reaction time.

As it appears from the data listed in Table 2, the influence of water on the course of the reaction is primarily important since water is a highly polar solvent and thiouronium salts and carbonates are readily soluble in water. This has been confirmed by experiment No. *8* (Table 2) where acetonitrile and triethylamine were used as a reaction medium. Since the reaction was carried out at 81°C, 6 h were necessary for the reaction to be completed.

Thiophosphorylisothioureas were alkylated by alkyl halogenides (*C*), dimethyl sulfate (*D*), and diazomethane (*E*). Ethanol and potassium carbonate were found to be the most suitable reaction medium. By using alkyl iodides and dimethyl sulfate, the compounds were the most contaminated by products formed by side reactions since the second nucleophilic centre can react



The purest compounds were obtained by using diazomethane. Thiophosphorylisothioureas prepared according to methods *C* and *D* had to be purified by column chromatography.

The structure of synthesized compounds was determined by i.r., u.v., ^{1}H-n.m.r., and mass spectroscopy. In the infrared spectra of thiophosphorylisothioureas having a free amido group four absorption bands are observed in the region 3200—3500 cm^{-1}. These bands can be assigned to the stretching N—H vibrations of amido and imido groups (Table 3).

Table 3

Infrared spectral data of the studied compounds (in CCl_4)

Compound	$\tilde{\nu}$, cm^{-1}					
	$\delta(NH)_2$	$\nu(C{=}N)$	$\nu(=NH)$	$\nu_s(NH_2)$	$\nu(NH)$	$\nu_{as}(NH_2)$
III	1552	1627	3207	3276	3372	3468
V	1556	1629	3208	3276	3370	3474
VI	1551	1622	3204	3260	3376	3462
VII	1554	1626	3208	3276	3372	3473
IX	1550	1626	3196	3262	3368	3462
X	1556	1628	3203	3270	3368	3470
XI	1553	1626	3200	3273	3370	3472
XII	1550	1624	3198	3264	3371	3469
XIV	1550	1622	3205	3250	3372	3470
XVI	1553	1626	3205	3275	3378	3475
XX	1552	1626	3200	3264	3377	3470
XXI	1551	1630	3205	3255	3377	3472
XXII	1557	1621	3203	3262	3377	3470
XXIII	1544	1622	3200	3265	3373	3470
XXIV	1548	1626	3200	3270	3370	3474
XXV	1547	1624	3204	3272	3369	3472
XXVI	1550	1623	3202	3274	3367	3473
XXVII	1553	1618	3195	3270	3380	3471
XXVIII	1549	1615	3200	3270	3379	3475
XXIX	1543	1620	3200	3268	3380	3471

Compounds investigated can exist in two tautomeric forms

a *b*

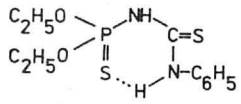
$\nu_s(NH_2) \sim 3270\ cm^{-1}$ $\nu(NH) \sim 3370\ cm^{-1}$
$\nu_{as}(NH_2) \sim 3470\ cm^{-1}$ $\nu(=NH) \sim 3205\ cm^{-1}$

Tautomer *a* seems to be thermodynamically more stable than tautomer *b* in consequence of the presence of conjugated system. The large wavenumber difference between the $\nu_{as}(NH_2)$ and $\nu_s(NH_2)$ bands can be explained by the contribution of the structure *c*

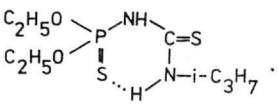
a *c*

The conditions for intramolecular hydrogen bond formation seem to be better in the case of tautomer *a* since hydrogen bond is a part of the conjugated system (prolonged conjugation).

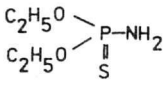
In assigning the bands in the region of 3200—3500 cm^{-1} we used the spectra of model compounds in CCl_4



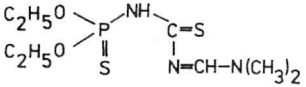
ν(NH) = 3370 cm^{-1}
ν(NH ...) = 3205 cm^{-1}



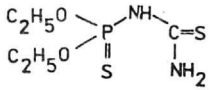
ν(NH) = 3378 cm^{-1}
ν(NH...) = 3252 cm^{-1}



$\nu_{as}(NH_2)$ = 3476 cm^{-1}
$\nu_{s}(NH_2)$ = 3390 cm^{-1}
$\Delta\tilde{\nu}$ = 86 cm^{-1}



ν(NH) = 3384 cm^{-1} (in $CHCl_3$)



$\nu_{as}(NH_2)$ = 3476 cm^{-1}
$\nu_{s}(NH_2)$ = 3274 cm^{-1}
ν(NH) = 3380 cm^{-1} (in $CHCl_3$)

The $\nu_s(NH_2)$ and $\nu_{as}(NH_2)$ bands are observed at higher (by $\sim$20 cm^{-1}) and lower (by $\sim$10 cm^{-1}) wavenumbers in chloroform, respectively, compared with those in carbon tetrachloride. However, the intensity of the bands differs only slightly in these solvents. On the other hand, a significant change of the NH bands is observed in dioxan and tetrahydrofuran. The band at 3470 cm^{-1} is not present in the spectra, however a significantly strong band is observed at 3350 cm^{-1}. The intensity of the NH_2 band at 3280 cm^{-1} recorded for chloroform solution has been

Table 4

^{1}H-n.m.r. spectral data of the studied compounds

Compound	δ(p.p.m.)							Solvent
III	NH_2	CH_3O	SCH_2	Ph				$CDCl_3$
	6.82 (2H, bs)	3.60 (d)	4.12 (s)	7.2 (m)				
VIII	NH_2	CH_3CH	CHO	CH_3O	CH_3CH_2	CH_3CH_2	CH_2S	$CDCl_3$
	7.00 (2H, bs)	1.36 (d)	4.79 (m)	3.73 (d)	1.31 (t)	2.64 (m)	2.80 (m)	
XVIII	NH_2	CH_3CH_2	CH_2O	CH_2S	Ph			$CDCl_3$
	6.9 (2H, bs)	1.29 (t)	4.02 (m)	4.16 (s)	7.24 (m)			
XXI	NH_2	CH_3	CH_2O	CHO	CH_2S	Ph		$CDCl_3$
	6.95 (2H, bs)	1.2	4.05 (m)	4.66 (m)	4.15 (s)	7.23 (m)		
XXVIII	NH_2	CH_3CH_2	CH_2O	CH_2S	Ph			$CDCl_3$
	7.08 (2H, bs)	1.19 (t)	4.05 (m)	3.98 (s)	7.08 (m)			
XXIX	NH_2	CH_2S	Ph					DMSO
	7.77 (2H, bs)	4.05 (s)	7.24 (m)					

Observed multiplicities: s – singlet, d – doublet, bs – broad singlet, t – triplet, m – multiplet.

Table 5

Ultraviolet spectral data of the studied compounds (in methanol)

Compound	λ_{max} nm	log ε	λ_{max} nm	log ε
III	205	4.28	233	4.05
VII	211	4.24	230	4.04
XIV	212	4.26	235	3.97
XV	211	4.32	239	3.97
XVII	212	4.26	239	3.90
XIX	208	4.02	230	4.01
XXI	210	4.25	235	4.02
XXII	205	4.24	235	3.96
XXIII	207	4.32	236	4.01
XXIV	205	4.23	236	3.90
XXVII	210	4.20	232	4.05
XXVIII	211	4.35	236	4.08
XXIX	211	4.47	236	4.12

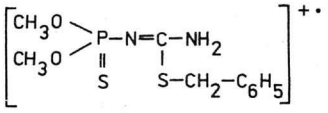
ε in l mol^{-1} cm^{-1}.

found to differ slightly showing that the observed change of tautomeric equilibrium has not occurred. Thus, the $\nu_{as}(NH_2)$ band, in consequence of the interaction of the NH bonds with the oxygen atom of dioxan and tetrahydrofuran has been shifted to lower wavenumbers. From the comparison of the infrared spectra of prepared and model compounds it appears that compounds studied exist mainly in structure *a*.

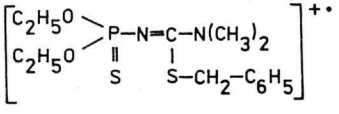
^{1}H-n.m.r. spectra of compounds investigated point out to the presence of the NH_2 groups. A wide two-proton resonance signal at 7.0 p.p.m. observed in the spectra supports this conclusion. No significant changes are observed in the ^{1}H-n.m.r. spectra on changing the polarity of the solvent (Table 4).

In the ultraviolet spectra of compounds studied (Table 5) very intense absorption bands are observed in the region of 220—240 nm ($\log \varepsilon = 3 \rightarrow 4$), which adds a further evidence that compounds exist mainly in structure *a*.

In the mass spectra of compounds

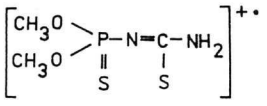


m/e 290

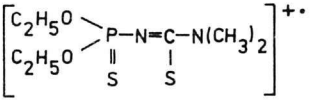


m/e 346

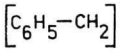
these significant peaks are observed



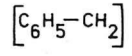
m/e 199



m/e 255



m/e 91



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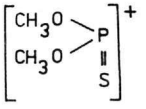
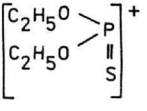
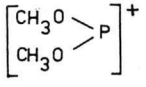


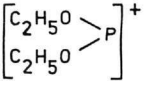
m/e 125



m/e 153



m/e 93



m/e 121

The intensity of the peak with *m/e* 125 is much higher than that of the peak with *m/e* 153, which points out to the higher strength of the P—N bond in the case of the compound with *m/e* 346, which is consistent with electron effects of the substituents.

An acaricidal-ovicidal activity of thiophosphorylisothioureas was found to be higher than that of thiophosphorylthioureas. However, none of the compounds synthesized reached the activity of standards used (fenitrothion, malathion, and carbophenothion). In the tests for ovicidal activity (on eggs of *Tetranychus urticae* KOCH) compound *XIV* was found to be most active and somewhat weaker activity was shown by compounds *V, XI, XV, XVI, XXI,* and *XXVIII.* In the tests for acaricidal activity (on *Tetranychus urticae* KOCH) compounds *III, VII, XIV, XVII, XX,* and *XXI* were the most active but they did not reach the activity of the standards used.

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