31) and methylthiomethyl- (Compound 34) groups do not reach, and cannot shield, the Ph–S bond, whereas 2-alkyl groups with five or more carbon atoms in the main chain (Compounds 21–23, 27, 28) and 2-propoxymethyl-(Compound 32) or butoxymethyl-(Compound 33) can reach and shield the Ph–S bond. The unshielded bond is thus susceptible to attack and perhaps this may account for activity of Compounds 18–20, 24–26, 29, 31 & 34. Conversely, compounds whose Ph–S bond is shielded from attack would be expected to be inactive or less active (Compounds 21–23, 27, 28, 32 & 33).

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STUDIES IN FUNGITOXICITY

VII.*—Fungicidal activity of certain ethylenes and heterocyclic compounds substituted with the 2,4-dinitrophenylthio- group

By M. PIANKA

Certain ethylenes and heterocyclic compounds substituted with the 2,4-dinitrophenylthio- group were synthesised and tested for activity against *Venturia inaequalis*, *Botrytis cinerea*, *Fusarium bulbigenum* and *Cercospora melonis*. 1-Alkylthio-1-(2,4-dinitrophenylthio)-2-cyano-2-(ethoxycarbonyl or cyano) ethylenes in which the Ph-S bond is not shielded by the alkyl substituent from attack, perhaps by nucleophilic cell constituents, were found to be active against *Venturia*. 3,5-Di(methyl- or ethyl-thio)-4-cyanoisothiazoles were also active against *Venturia*. 2-Substituted-5-(2,4-dinitrophenylthio)-1,3,4-oxadiazoles had no or low fungicidal activity, and of several 2-(2,4-dinitrophenylthio) heterocyclic compounds that were tested 2-(2,4-dinitrophenylthio)-benzothiazole and -benzoxazole had good activity against *Venturia*. The infra-red and proton magnetic resonance spectra of several compounds were examined.

Introduction

In Part VI[1] the synthesis was reported of 2-(substituted thio)-5-(substituted nitrophenylthio)-1,3,4-thiadiazoles from the appropriate 1,3,4-thiadiazole derivatives and aryl chlorides. The resulting compounds cleave at the Ph-S bond with nucleophilic reagents. Only compounds derived from fungitoxic aryl chlorides in which the Ph-S bond was not shielded from attack were found to be fungicidally active.

In the present paper several 1-alkylthio-1-(2,4-dinitrophenylthio)-2-cyano-2-(ethoxycarbonyl)-(**II**; $R{=}CN$, $R^1{=}CO_2\text{-}Et$) and 2,2-di(cyano)-ethylenes (**II**; R, $R^1{=}CN$) were

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* Part VI: Previous paper

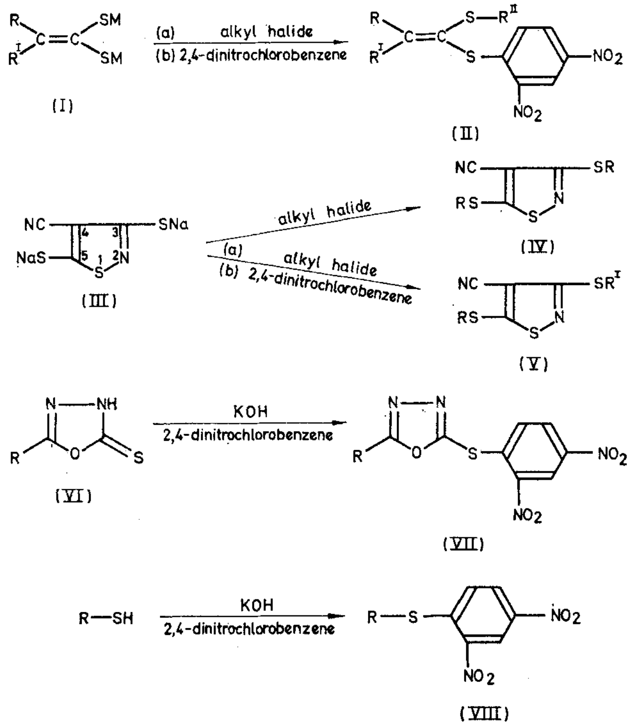
prepared and examined for their requirements for fungicidal activity.

Also 4-cyanoisothiazoles (**IV**; **V**), 2-substituted-5-(2,4-dinitrophenylthio)-1,3,4-oxadiazoles (**VII**) and several 2-(2,4-dinitrophenylthio)-heterocyclic compounds (**VIII**) were synthesised and their fungicidal activity was studied.

Experimental

Preparation of compounds

The compounds were synthesised by the following general routes:



1,1-Di(sodium thio)-2-cyano-2-(ethoxycarbonyl) ethylene pentahydrate (I; R=CN, $R^I=CO_2Et$, M=Na), $5H_2O$

This compound (no. 1) was prepared by the method of Söderbäck.[2] The di(potassium thio)-salt (Compound 2) was prepared as above, but using potassium ethoxide.

1,1-Di(sodium thio)-2,2-di(cyano)ethylene (I; R,R^I=CN, M=Na)

This compound (no. 3) was prepared by the method of Hatchard.[3]

Condensation of 1,1-di(sodium- or potassium-thio)-2-cyano-2-(ethoxycarbonyl) ethylene or 1,1-di(sodium thio)-2,2-di(cyano) ethylene with an alkyl halide and 2,4-dinitrochlorobenzene

The di(sodium thio) ethylene derivative (0·025 mole), the alkyl halide (0·025 mole) and methanol (60–150 ml) were heated under reflux for 1–2 h. The methanol was then distilled off under reduced pressure. Acetone (100–300 ml) and a little charcoal were then added and the mixture was filtered. 2,4-Dinitrochlorobenzene (0·025 mole) was added to the filtrate, the mixture was heated under reflux for 2–3 h, cooled to room temperature, treated with a little charcoal, filtered and the volatile components were removed from the filtrate under reduced pressure. The residue was extracted with hot benzene (20 ml), the benzene extract was washed with water (200 ml), dried (sodium sulphate) and the volatile components were removed under reduced pressure from the extract. The residue was crystallised from appropriate solvents. Tables I & II summarise the preparative details and physical properties of the compounds.

3,5-Di(methylthio)-4-cyanoisothiazole (IV; R=Me)

This compound (no. 9) was prepared by a modification of the method of Hatchard.[4] Compound 3 (4·6 g, 0·025 mole), methanol (50 ml) and sulphur (0·8 g, 0·025 mole) were heated under reflux for 30 min. To 3,5-di(sodium thio)-4-cyanoisothiazole (**III**) thus formed methyl iodide (7·1 g, 0·05 mole), in methanol (10 ml), was added and the mixture was heated under reflux for 2 h. The volatile components were removed from the reaction mixture (steam-bath), the residue was extracted with benzene–ether (1 : 1, 300 ml), washed with water (2 × 20 ml) and dried (sodium sulphate). The volatile components were then removed under reduced pressure and the residue was crystallised. The compound was obtained as white prisms (from methanol), m.p. 131–132° (Hatchard[4] reported m.p. 127–129° and 130–131·5°).

3,5-Di(ethylthio)-4-cyanoisothiazole (IV; R=Et)

This compound (no. 10) was prepared by the method used for Compound 9, but ethyl bromide (5·4 g, 0·05 mole) was used and the benzene-ether extract was washed with 2 N sodium carbonate. The compound was obtained as white prisms (from ethanol, then propan-2-ol), m.p. 47·5–48° (Found: N, 12·0. $C_8H_{10}N_2S_3$ requires N, 12·2%).

5(3)-Ethylthio-3(5)-(2,4-dinitrophenylthio)-4-cyanoisothiazole (V; R, R^I=Et or 2,4-dinitrophenyl) (Compound 11)

Compound 3 (9·3 g, 0·05 mole), methanol (200 ml) and sulphur (1·6 g, 0·05 mole) were heated under reflux for 30 min. To 3,5-di(sodium thio)-4-cyanoisothiazole (**III**) thus formed ethyl bromide (5·4 g, 0·05 mole) was added and the mixture was heated under reflux for 2 h. The volatile components were distilled off under reduced pressure and acetone (200 ml) was added. The mixture was filtered. 2,4-Dinitrochlorobenzene (10·1 g, 0·05 mole) was added to the filtrate. The mixture was heated under reflux for 2·5 h, cooled and filtered. The volatile components were removed under reduced pressure from the filtrate. Benzene (200 ml) was added to the residue, washed with water (3 × 100 ml) and dried (sodium sulphate). The residue that remained on removing the benzene was crystallised. The compound was obtained as yellow prisms (from propan-2-ol and ethanol), m.p. 130–132° (Found: N, 14·7. $C_{12}H_8N_4O_4S_3$ requires N, 15·2%). The alkyl group can enter position 3 or 5 of Compound (**III**) and therefore Compound 11 is named as above.

*Condensation of 2-substituted-4*H*-1,3,4-oxadiazoline-5-thiones and of various heterocyclic thiols with 2,4-dinitrochlorobenzene*

To the heterocyclic compound (0·02 mole) in methanol (80–200 ml) potassium hydroxide (1·12 g, 0·02 mole) was added and the mixture was heated under reflux until all dissolved (~10 min). The volatile components were then removed under reduced pressure. To the residue, acetone (200–400 ml) and 2,4-dinitrochlorobenzene (4·05 g, 0·02 mole) were added. The mixture was heated under reflux for

TABLE I

No. of compound		R^{II}	From alkyl halide	Amount of methanol (ml) added; period (h) of reflux after addition of alkyl halide	Amount of acetone (ml) added; period (h) of reflux after addition of 2,4-dinitrochlorobenzene	M.p., °c	Appearance
1-Alkylthio-1-(2,4-dinitrophenylthio)-2-cyano-2-(ethoxycarbonyl)ethylenes (II; R = CN, R^{I} = CO_2Et) obtained from [I; R = CN, R^{I} = CO_2Et, M = Na (cpd 1) or K (cpd 2)], alkyl halide and 2,4-dinitrochlorobenzene							
4	*1-Ethylthio-1-(2,4-dinitrophenylthio)-2-cyano-2-(ethoxycarbonyl)ethylene*	Et	Ethyl bromide*	60; 1	100; 2	144–145^{a,b}	Pale yellow prisms
5	*1-Butylthio-1-(2,4-dinitrophenylthio)-2-cyano-2-(ethoxycarbonyl)ethylene*	Butyl	Butyl bromide†	150; 2	300; 2	95–97^{a,c}	Yellow prisms
6	*1-Pentylthio-1-(2,4-dinitrophenylthio)-2-cyano-2-(ethoxycarbonyl)ethylene*	Pentyl	1-Iodopentane‡	125; 2	250; 3	95·5–96·5^{a,c}	Yellow prisms
1-Alkylthio-1-(2,4-dinitrophenylthio)-2,2-di(cyano)ethylenes (II; R, R^{I} = CN) obtained from [I; R, R^{I} = CN; M = Na (cpd 3)], alkyl halide and 2,4-dinitrochlorobenzene							
7	*1-Ethylthio-1-(2,4-dinitrophenylthio)-2,2-di(cyano)ethylene*	Et	Ethyl bromide	60; 1	100; 2‡	113–113·5^{a,b}	Yellow prisms
8	*1-Butylthio-1-(2,4-dinitrophenylthio)-2,2-di(cyano)ethylene*	Butyl	Butyl bromide	125; 1	165; 3	98–99^{d,c,a}	Pale yellow prisms

Solvents for crystallisation: ^{a}propan-2-ol; ^{b}methanol; ^{c}butanol; ^{d}ethanol.
*Compound 1 was used. †Compound 2 was used. ‡The extraction was carried out with a mixture of benzene and ether (1 : 1; 200 ml)

TABLE II

Analyses of compounds 4–8

No. of compound	Formula	Nitrogen, %	
		Found	Required
4	$C_{14}H_{13}N_3O_6S_2$	11·1	11·0
5	$C_{16}H_{17}N_3O_6S_2$	9·9	10·2
6	$C_{17}H_{19}N_3O_6S_2$	6·3§	6·6
7	$C_{12}H_8N_4O_4S_2$	17·0	16·7
8	$C_{14}H_{12}N_4O_4S_2$	14·7	15·4

§Determined as aromatic nitro-groups by reduction with titanous chloride.

2–4 h, cooled, treated with a little charcoal and filtered (in certain preparations, the solid that was filtered off contained, in addition to potassium chloride, the expected condensation product; the filtered solid was therefore triturated with water and the water-insoluble part was combined with the residue obtained on removal of the volatile components from the filtrate, or the filtered solid was extracted with acetone and the extract was added to the filtrate). The volatile components were removed from the filtrate under reduced pressure and the residue was crystallised from suitable solvents. The results are summarised in Tables III–VI.

Infra-red measurements

The infra-red absorption bands of Compounds 4–14, 16 and 17 are summarised in Table VII. The measurements were conducted as described previously.[19]

Proton magnetic resonance (p.m.r.) measurements

These were conducted as described previously.[20] Multiplicity and *J* (c/sec) are given in parentheses. P.m.r. spectra in deuteriochloroform of Compound 9 showed peaks centred at τ 7·28 & 7·32 (methyl groups) and of Compound 10 at τ 6·73 (*q*, 7·5) & 8·58 (*t*, 7·5) and at τ 6·83 (*q*, 7·5) & 8·52 (*t*, 7·5) (ethyl groups). Compound 11 gave peaks centred at τ 6·66 (*q*, 7·5) & 8·52 (*t*, 7·5) (ethyl) and τ 0·85 (*d*, 2·5), 1·65 (*dd*, 9, 2·5) & 2·80 (*d*, 9) (protons of the benzene ring in 3-, 5- and 6- positions, respectively).

Compound 12 showed peaks at τ 2·64 (*d*, 3·5), 3·18 (*dd*, 1·5, 3·5) & 1·90 (*d*, 1·5) (protons of the furan ring in the 3-, 4- and 5- positions, respectively) and at τ −0·86 (broad) indicative of NH. This and the presence of the infra-red band at 1260 cm^{-1} (C=S) suggests structure (VI) for this compound, corresponding to the structures assigned to related compounds.[8,21]

Compounds 13, 14, 16 & 17 in deuterated dimethyl sulphoxide solutions showed water peaks at τ 6·65–6·68. Compound 13 showed a peak at 7·32 (methyl), and Compound 14 gave peaks at 2·44 (*d*, 3·5), 3·12 (*dd*, 2, 3·5) & 1·83 (*d*, 2) (protons of the furan ring in the 3-, 4- and 5-positions, respectively). All these compounds showed the expected peaks for the protons of the benzene rings confirming the substitution patterns.

Fungitoxicity tests

All the tests were carried out by the Montgomery-Moore[22] slide germination technique using *Venturia inaequalis* (Cooke) Wint., *Botrytis cinerea* Pers., *Fusarium bulbigenum*, Cooke & Massee, var. *lycopersici* (Brushi) Wollenw. and *Cercospora melonis* Cooke. The values of LD_{95} were determined as described in Part I.[23]

TABLE III

2-Substituted-5-(2,4-dinitrophenylthio)-1,3,4-oxadiazoles (VII) prepared from 2-substituted-4*H*-1,3,4-oxadiazolines and 2,4-dinitrochlorobenzene

No. of compound	Name of compound	R	Obtained from heterocyclic compound
13	*2-Methyl-5-(2,4-dinitrophenylthio)-1,3,4-oxadiazole*	Me	2-Methyl-4*H*-1,3,4-oxadiazoline-5-thione[a]
14	2-(2-Furyl)-5-(2,4-dinitrophenylthio)-1,3,4-oxadiazole	2-Furyl	2-(2-Furyl)-4*H*-1,3,4-oxadiazoline-5-thione[b,c]
15	*2-Phenyl-5-(2,4-dinitrophenylthio)-1,3,4-oxadiazole*	Ph	2-Phenyl-4*H*-1,3,4-oxadiazoline-5-thione[b]
16	*2-(p-Chlorophenyl)-5-(2,4-dinitrophenylthio)-1,3,4-oxadiazole*	*p*-Cl·Ph	2-(*p*-Chlorophenyl)-4*H*-1,3,4-oxadiazoline-5-thione[b]
17	*2-(p-Nitrophenyl)-5-(2,4-dinitrophenylthio)-1,3,4-oxadiazole*	*p*-NO_2·Ph	2-(*p*-Nitrophenyl-4*H*-1,3,4-oxadiazoline-5-thione[d]

[a] Prepared by the method of Hoggarth[5] [b] Prepared by the method of Young & Wood[7]
[c] Designated as Compound 12 [d] Prepared by the method of Ainsworth.[8]

TABLE IV

Physical data and analyses of compounds 13–17

No. of compound	M.p., °c	Appearance	Formula	Nitrogen, % Found	Nitrogen, % Required
13	186–188*	Yellow prisms	$C_9H_6N_4O_5S$	9·8§	9·9
14	150–151†,[a]	Yellow prisms			
15	185–188*	Pale green needles	$C_{14}H_8N_4O_5S$	8·2§	8·2
16	200–201*	Pale yellow needles	$C_{14}H_7ClN_4O_5S$	14·7	14·8
17	207–209*	Yellow prisms	$C_{14}H_7N_5O_7S$	18·0	18·0

Solvents for crystallisation: *acetone; †butanol
§Determined as aromatic nitro-groups by reduction with titanous chloride
[a] Turilli & Gandino[6] reported m.p. 150–151°c

TABLE V

Compounds (VIII) obtained on condensing various 2-thiols with 2,4-dinitrochlorobenzene

No. of compound	Name of compound	2-R	Obtained from heterocyclic compound
18	*2-(2,4-Dinitrophenylthio)benzoxazole*	Benzoxazolyl	Benzoxazole-2-thiol[a]
19	2-(2,4-Dinitrophenylthio)benzothiazole	Benzothiazolyl	Benzothiazole-2-thiol[b]
20	2-(2,4-Dinitrophenylthio)-6-nitrobenzothiazole	6-Nitrobenzothiazolyl	6-Nitrobenzothiazole-2-thiol[c]
21	2-(2,4-Dinitrophenylthio)benzimidazole[e]	Benzimidazolyl	Benzimidazole-2-thiol[d]
22	2-(2,4-Dinitrophenylthiomethyl)benzimidazole	Methylbenzimidazolyl	Benzimidazole-2-methanethiol
23	2-(2,4-Dinitrophenylthio)quinoline	Quinolyl	Quinoline-2-thiol
24	*2-(2,4-Dinitrophenylthio)-4(3H)-quinazolinone*	4(3*H*)-Quinazolinonyl	4(3*H*)-Quinazolinone-2-thiol[f]

[a] Prepared by the method of Desai *et al.*[9] and designated as Compound 25 [b] Compound 26 was obtained commercially [c] Prepared by the method of Teppema & Sebrell[11] [d] Compound 27 was prepared by the method of van Allan & Deacon[13] [e] The acetone mixture was filtered hot as the compound is sparingly soluble in cold acetone [f] Prepared according to Howard & Klein[18]

TABLE VI

Physical data and analyses of compounds 18–24

No. of compound	M.p., °c	Appearance	Formula	Nitrogen, % Found	Nitrogen, % Required
18	163–165*†	Cream coloured prisms	$C_{13}H_7N_3O_5S$	13·4	13·2
19	162[a]	Yellow prisms	$C_{13}H_7N_3O_4S_2$	8·4§	8·4
20	190–191*‡[b]	Yellow prisms	$C_{13}H_6N_4O_6S_2$	10·8§	11·1
21	230¶[c]	Yellow prisms	$C_{13}H_8N_4O_4S$	8·9§	8·8
22	260–263‡¶[d]	Yellow prisms	$C_{14}H_{10}N_4O_4S$	16·6	16·9
23	158–159*[e]	Yellow prisms	$C_{15}H_9N_3O_4S$	8·5§	8·6
24	229–230*‡	Yellow prisms	$C_{14}H_8N_4O_5S$	8·2§	8·1

Solvents for crystallisation: *acetone; †butanol; ‡ethanol; ¶propan-2-ol
§Determined as aromatic nitro-groups by reduction with titanous chloride
[a] Cherntsov & Chalykh[10] reported m.p. 160–162° [b] Taniyama[12] reported m.p. 187° [c] Angelini[14] reported m.p. 181° and Duffin and Fry[15] reported m.p. 120–122° [d] Fedorov & Mamedov[16] reported m.p. 249–251° [e] Leandri & Tundo[17] obtained this compound as yellow needles, m.p. 160–161° (from ethanol)

Results and Discussion

Table VIII shows the results of fungitoxicity tests with 1-alkylthio-1-(2,4-dinitrophenylthio)-2-cyano-2-(ethoxycarbonyl or cyano) ethylenes, Table IX those with 3,5-di-(substituted thio)-4-cyanoisothiazoles, Table X those with 2-substituted-5-(2,4-dinitrophenylthio)-1,3,4-oxadiazoles and Table XI presents tests with several 2-(2,4-dinitrophenylthio)-heterocyclic compounds.

All the compounds examined had low activity against *Botrytis*, *Fusarium* or *Cercospora* (LD$_{95}$ was > 100 or > 1000 ppm). An examination of Table VIII shows that certain condensation products with 2,4-dinitrochlorobenzene (Compound 28), itself active against *Venturia*, were active against this organism (Compounds 4 & 7). These compounds yielded, with potassium hydroxide in methanol, brilliant orange-red suspensions indicative of an aci-salt.[24] As with 2-(substituted thio)-5-(2,4-dinitrophenylthio)-1,3,4-thiadiazoles discussed in Part VI,[1] cleavage of the Ph–S bond occurs here under a nucleophilic attack and perhaps one may postulate that activity of 1-alkylthio-1-(2,4-dinitrophenylthio)-2-cyano-2-(ethoxycarbonyl or cyano)ethylenes (II) depends on

TABLE VII

Infra-red absorption bands (cm^{-1}) for bromoform solutions

No. of compound	Infra-red bands					
	CN	–C=C–COOR	NO$_2$	*p*-Disubstituted benzene	NH	C=S?
4	2230	1714; 1275	1536; 1345	832		
5	2222	1708; 1270	1530; 1342	832		
6	2222	1702; 1268	1532; 1340	830		
7	2234		1536; 1345	832		
8	2225		1532; 1340	830		
9	2240					
10	2235					
11	2244		1534; 1340	826		
12					3375	1260
13			1532; 1342	830		
14			1530; 1340	830		
16			1536; 1342	832		
17			1528; 1342	832		

TABLE VIII

Results of fungitoxicity tests with 1-alkylthio-1-(2,4-dinitrophenylthio)-2-cyano-2-(ethoxycarbonyl or cyano) ethylenes (II) and with their precursors

No. of compound	Name of compound		R	R^{I}	R^{II}	*Venturia*	*Botrytis*	*Fusarium*	*Cercospora*
							LD$_{95}$ values, ppm		
1	1,1-(Disodium thio)-2-cyano-2-(ethoxycarbonyl)ethylene	(I) M=Na	CN	CO$_2$Et		> 100	> 1000	> 1000	> 1000
3	1,1-(Disodium thio)-2,2-di(cyano)ethylene	(I) M=Na	CN	CN		> 1000	> 1000	> 1000	> 1000
4	1-Ethylthio-1-(2,4-dinitrophenylthio)-2-cyano-2-(ethoxycarbonyl)ethylene	(II)	CN	CO$_2$Et	Et	25	> 100	> 100	> 100
5	1-Butylthio-1-(2,4-dinitrophenylthio)-2-cyano-2-(ethoxycarbonyl)ethylene	(II)	CN	CO$_2$Et	Bu^n	> 1000	> 1000	> 1000	> 1000
6	1-Pentylthio-1-(2,4-dinitrophenylthio)-2-cyano-2-(ethoxycarbonyl)ethylene	(II)	CN	CO$_2$Et	Pentyl	> 1000	> 1000	> 1000	> 1000
7	1-Ethylthio-1-(2,4-dinitrophenylthio)-2,2-di(cyano)ethylene	(II)	CN	CN	Et	90	> 1000	> 100	> 100
8	1-Butylthio-1-(2,4-dinitrophenylthio)-2,2-di(cyano)ethylene	(II)	CN	CN	Bu^n	> 100	> 1000	> 100	> 1000
28	2,4-Dinitrochlorobenzene					45	> 100	> 100	> 100
29	2,4-Dinitrophenol					> 100	> 100	> 100	> 100

TABLE IX

Results of fungitoxicity tests with 3,5-di(substituted thio)-4-cyanoisothiazoles (IV, V)

No. of compound	Name of compound		R	R^{I}	*Venturia*	*Botrytis*	*Fusarium*	*Cercospora*
						LD$_{95}$ values, ppm		
9	3,5-Di(methylthio)-4-cyanoisothiazole	(IV)	Me		40	> 1000	> 1000	> 1000
10	3,5-Di(ethylthio)-4-cyanoisothiazole	(IV)	Et		35	> 100	> 100	> 100
11	5(3)-Ethylthio-3(5)-(2,4-dinitrophenylthio)-4-cyanoisothiazole	(V)	Et or 2,4-dinitrophenyl		25	> 1000	> 100	> 100

TABLE X

Results of fungitoxicity tests with 2-(2-furyl-4*H*-1,3,4-oxadiazoline-5-thione and 2-substituted-5-(2,4-dinitrophenylthio)-1,3,4-oxadiazoles (VII)

No. of compound	Name of compound	R	*Venturia*	*Botrytis*	*Fusarium*	*Cercospora*
			LD$_{95}$ values, ppm			
12	2-(2-Furyl)-4*H*-1,3,4-oxadiazoline-5-thione (VI)	2-Furyl	> 100	> 100	> 100	> 100
13	2-Methyl-5-(2,4-dinitrophenylthio)-1,3,4-oxadiazole (VII)	Me	> 1000	> 1000	> 1000	> 1000
14	2-(2-Furyl)-5-(2,4-dinitrophenylthio)-1,3,4-oxadiazole (VII)	2-Furyl	94	> 1000	> 1000	> 100
15	2-Phenyl-5-(2,4-dinitrophenylthio)-1,3,4-oxadiazole (VII)	Ph	> 1000	> 1000	> 1000	> 1000
16	2-(*p*-Chlorophenyl)-5-(2,4-dinitrophenylthio)-1,3,4-oxadiazole (VII)	*p*-Cl·Ph	> 100	> 100	> 100	> 100
17	2-(*p*-Nitrophenyl)-5-(2,4-dinitrophenylthio)-1,3,4-oxadiazole (VII)	*p*-NO_2·Ph	100	> 100	> 1000	> 100

TABLE XI

Results of fungitoxicity tests with several 2-(2,4-dinitrophenylthio) heterocyclic compounds (VIII) and with their precursors

No. of compound	Name of compound	2-R	*Venturia*	*Botrytis*	*Fusarium*	*Cercospora*
			LD$_{95}$ values, ppm			
18	2-(2,4-Dinitrophenylthio)benzoxazole	Benzoxazolyl	89	> 100	> 100	> 100
19	2-(2,4-Dinitrophenylthio)benzothiazole	Benzothiazolyl	10	> 1000	> 1000	> 1000
20	2-(2,4-Dinitrophenylthio)-6-nitrobenzothiazole	6-Nitrobenzothiazolyl	> 1000	> 1000	> 1000	> 1000
21	2-(2,4-Dinitrophenylthio)benzimidazole	Benzimidazolyl	> 1000	> 1000	> 1000	> 1000
22	2-(2,4-Dinitrophenylthiomethyl)benzimidazole	Methylbenzimidazolyl	> 1000	> 1000	> 1000	> 1000
23	2-(2,4-Dinitrophenylthio)quinoline	Quinolyl	> 1000	> 1000	> 1000	> 1000
24	2-(2,4-Dinitrophenylthio)-4(3*H*)-quinazolinone	4(3*H*)-Quinazolinonyl	> 1000	> 1000	> 1000	> 1000
25	Benzoxazole-2-thiol		> 100	> 100	> 100	> 100
26	Benzothiazole-2-thiol		> 100	> 100	> 100	> 100
27	Benzimidazole-2-thiol		> 1000	> 1000	> 1000	> 1000

the ability of these compounds to suffer nucleophilic attack by the fungal cell constituents.[1] The parallel between activity and structure of compounds (**II**) and of compounds discussed in Part VI[1] becomes even closer on examination of the molecular models of compounds (**II**). The size of the 1-alkyl substituent determines the activity of ethylenes (**II**): whereas the 1-ethyl group cannot shield the Ph–S bond from attack and Compounds 4 & 7 are active, the 1-butyl group in Compounds 5 & 8 and the 1-pentyl group in Compound 6 can reach and shield the Ph–S bond from attack and the compounds are inactive. Perhaps therefore the steric effects discussed here influence activity against *Venturia* of ethylenes (II) and of 1,3,4-thiadiazoles of Part VI.[1] Steric effects may also affect activity of 2,6-dinitro-4-alkylphenols against mildews.[25]

Other effects obviously come into play and influence activity: the lower activity of the 2,2-di(cyano) compound (no. 7) than that of the 2-cyano-2-(ethoxycarbonyl) analogue (no. 4) in which the ethoxycarbonyl group is capable of some steric interference with the Ph–S bond is a case in point, and so is the generally low activity of 2-substituted-5-(2,4-dinitrophenylthio)-1,3,4-oxadiazoles (Table X) and of compounds of Table XI. It is surprising to note that the 4-nitro-substituent in Compound 17 renders the unsubstituted Compound 15 more active, whereas substitution with a 6-nitro-group (Compound 20) annuls the high activity of the unsubstituted Compound 19.

3,5-Di(methyl- or ethyl-thio)-4-cyanoisothiazoles (Compounds 9 & 10) are themselves active against *Venturia* as is Compound 11 in which the one alkyl group has been replaced by the 2,4-dinitrophenyl group (Table IX).

2-(2,4-Dinitrophenylthio)benzothiazole (Compound 19) proved much more active against *Venturia* than its benzoxazole (no. 18) analogue in contrast to the results obtained with carbocyanines[23] or anilinovinyl quaternaries[26] where the oxa- were more active than the thia-compounds.

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