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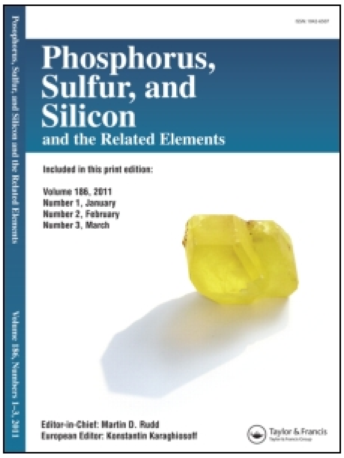

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ORGANOPHOSPHORUS COMPOUNDS AS POTENTIAL FUNGICIDES. PART IV.[1] THE PREPARATION AND PROPERTIES OF SOME NOVEL N-(1-SUBSTITUTED-2,2,2-TRICHLOROETHYL)PHOSPHORAMIDATES

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ORGANOPHOSPHORUS COMPOUNDS AS POTENTIAL FUNGICIDES. PART IV.[1] THE PREPARATION AND PROPERTIES OF SOME NOVEL N-(1-SUBSTITUTED-2,2,2-TRICHLOROETHYL)PHOSPHORAMIDATES

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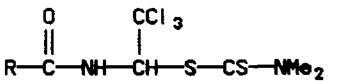
(Received April 4, 1995)

A series of diethyl N-(1-substituted-2,2,2-trichloroethyl)phosphoramidates has been prepared containing N-heterocyclic, carboxamide, phosphoramide, dithiocarbamate, xanthate, and hydroxyethylthio substituents in the 1-position of the 2,2,2-trichloroethyl group. Screening *in vitro* at 500 ppm showed the dithiocarbamates to be the most active, giving complete control of *Fusarium* spp., *Helminthosporium* spp., and *Ophiobolus graminis* under these conditions. High activity was also observed against *Fusarium culmorum* for the triazole, hydroxyethylthio, and xanthate derivatives, and for an imidazole analogue in which one ethoxy and one dimethylamino group were attached to phosphorus. The carboxamide derivatives were the least active. The dithiocarbamates also gave ca. 50% control of *Piricularia oryzae* and *Rhizoctonia solani* at 300 ppm *in vitro*. Lower levels of activity were recorded when the compounds were applied to seeds infected with *Drechslera teres* and *Septoria nodorum* and slight inhibition of germination and plant development was observed. The compounds were all weak inhibitors of acetylcholinesterase.

Key words: Organophosphorus, fungicides, phosphoramidates, N-heterocyclic, 2,2,2-trichloroethyl derivatives.

INTRODUCTION

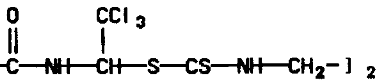
A number of carboxamide derivatives, in which the nitrogen atom carries a 1-substituted 2,2,2-trichloroethyl group (**1**, **2**), have been shown to have insecticidal[2] and fungicidal[3] activity. Among the N-(2,2,2-trichloroethyl)-formamide derivatives,[4] triforine (**3**) and chloraniformethan (**4**) have been developed commercially, although the latter is now superseded.[5] The trichloromethyl substituent is present in a variety of other active pesticides[6] and may enhance activity by increasing lipoid solubility.[3,7]



$$\mathrm{R{-}\overset{\overset{O}{\|}}{C}{-}NH{-}\overset{\overset{CCl_3}{|}}{CH}{-}S{-}CS{-}NMe_2}$$

(1)

R = CH_2Cl, Ph, CH_2CSNMe_2



$$\mathrm{[R{-}\overset{\overset{O}{\|}}{C}{-}NH{-}\overset{\overset{CCl_3}{|}}{CH}{-}S{-}CS{-}NH{-}CH_2{-}]_2}$$

(2)

R = CH_2F or CH_2Cl

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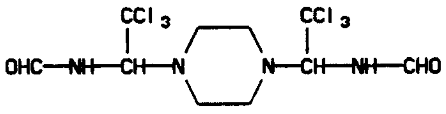
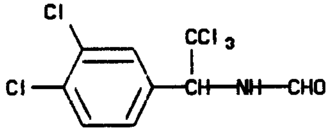
† Author for correspondence.



(3)



(4)

We now describe the preparation of a series of phosphoramidates (**5**), in which the amino nitrogen atom carries a 2,2,2-trichloroethyl group having a variety of substituents in the 1-position, and we report their properties and fungicidal activity. Compounds **5i**, **5k**, and **5o** have been reported previously[8]; all others in the series are new.

RESULTS AND DISCUSSION

Preparations

The compounds under investigation (**5a–5p**) were prepared by a sequence of reactions involving the condensation of diethyl phosphoramidate (**6**) with chloral,[9] replacement of the hydroxyl group of the condensation product (**7**) by chlorine, elimination of hydrogen chloride from the chlorinated intermediate (**8**), to give an imine (**9**), and addition to the imine *in situ* of a nucleophilic reagent containing active hydrogen (Scheme I).[10] The nucleophilic reagents employed in the earlier studies comprised water, hydrogen chloride, hydrogen sulfide, alcohols, phenols,

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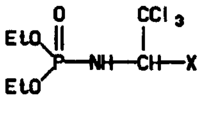
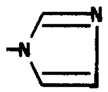


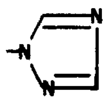
$(EtO)_2P(O)-NH-CH(CCl_3)-X$

(5)

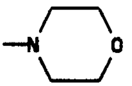
X =



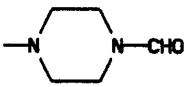
(5a)



(5b)



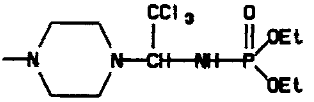
(5c)



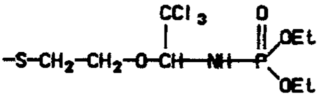
(5d)

$-S-CH_2-CH_2-OH$

(5e)



(5f)



$-S-CH_2-CH_2-O-CH(CCl_3)-NH-P(O)(OEt)_2$

(5g)

$-NH-CHO$

(5h)

$-NH-CO-CH_3$

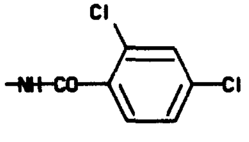
(5i)

$-NH-CO-CH_2Cl$

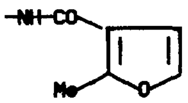
(5j)

$-NH-CO-CCl_3$

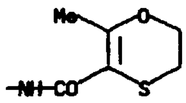
(5k)



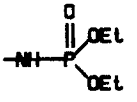
(5l)



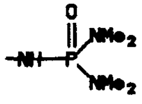
(5m)



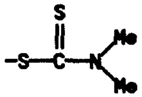
(5n)



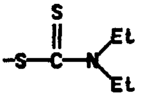
(5o)



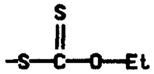
(5p)



(5q)



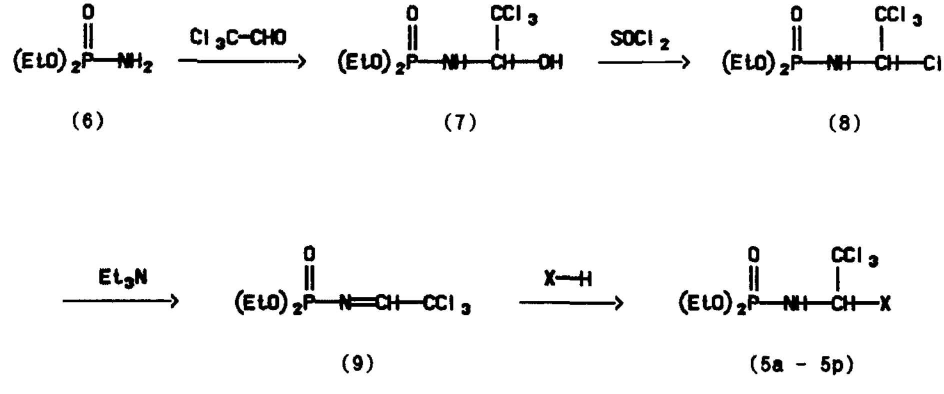
(5r)



(5s)

thiols, diethyl phosphite,[10] and certain amines and amides.[8] In the present work, additions were carried out with heterocyclic bases (imidazole, 1,2,4-triazole, morpholine, piperazine, N-formylpiperazine), 2-thioethanol, carboxamides (formamide, acetamide, chloroacetamide, trichloroacetamide, 2,4-dichlorobenzamide, 2-methylfuran-3-carboxamide, 5,6-dihydro-2-methyl-1,4-oxathiin-3-carboxamide), and the phosphoramides, $(EtO)_2P(O)NH_2$ and $(Me_2N)_2P(O)NH_2$. The N-heterocyclic structures, and also the furan- and oxathiin-carboxamides, were chosen for condensation with the phosphoramidates because of their presence in a number of known agricultural fungicides.[6]

A further series of compounds (**5q**–**5s**) was obtained by direct interaction of the chlorinated intermediate (**8**) with sodium N,N-dimethyldithiocarbamate, sodium N,N-diethyldithiocarbamate, and potassium ethyl xanthate. In these cases, a reaction involving addition of the appropriate nucleophile to the pre-formed imine (**9**) is not feasible as the free dithiocarbamic and xanthic acids are unstable. It is



SCHEME I

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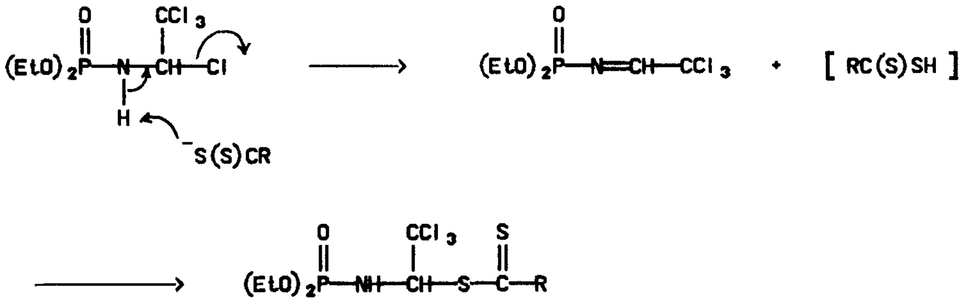
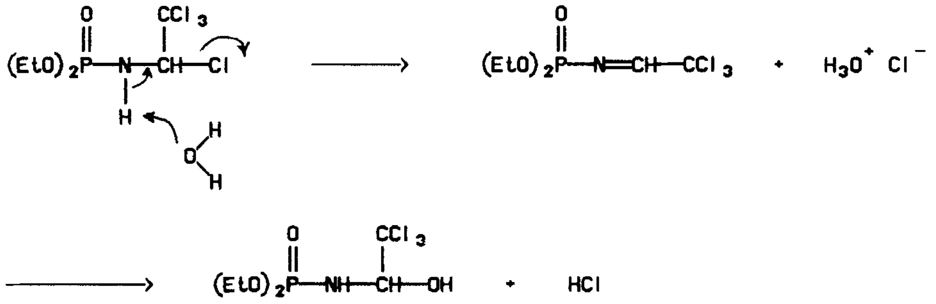
possible, however, that these unstable acids are formed as transient intermediates, together with the imine, in an initial elimination reaction which is followed rapidly by addition (Scheme II). Direct nucleophilic substitution is considered less likely, in view of the steric effect of the adjacent trichloromethyl group. An analogous elimination-addition reaction was demonstrated in the course of hydrolysis of the chloro derivative (**8**) (Scheme III). On shaking a solution of the chloro compound (**8**) in deuterochloroform with a few drops of water in an nmr tube, the reaction was readily followed by observing the disappearance of the methine proton signal of the CH—CCl_3 group (δ_H 5.95, dd, $^3J_{PNCH}$ 9.5 Hz, $^3J_{HNCH}$ 12.7 Hz) and the initial appearance of a downfield doublet (δ_H 8.45, d, $^3J_{PNCH}$ 27.1 Hz), characteristic of the methine proton of the imine (**9**). With continued shaking of the reaction mixture the latter signal was replaced by that of the methine proton of the hydroxy compound (7), δ_H 5.2 (dd, $^3J_{PNCH}$ 8.0 Hz, $^3J_{HNCH}$ 11.3 Hz). The ready elimination of hydrogen chloride by the action of water, acting as a weak base, is of interest and may possibly be attributed to the combined electron-withdrawing effects of the adjacent trichloromethyl and diethoxyphosphoryl groups.

In view of the presence of the bis(dimethylamino)phosphoryl group in a number of organophosphorus fungicides,[11] including triamphos (the first reported organophosphorus fungicide),[12] and the increase in fungicidal activity that occurs in certain dinitroaryl phosphates when at least one dimethylamino group is attached



R = Me_2N (5q); R = Et_2N (5r); R = EtO (5s)

SCHEME II



SCHEME III

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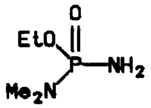
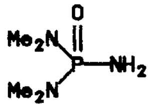
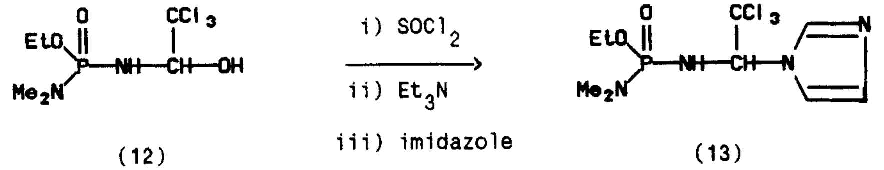


(10)



(11)



SCHEME IV

to phosphorus, [13] an attempt was made to make analogues of the above series (**5**) in which one or both of the ethoxy groups was replaced by dimethylamino. The interactions of chloral with the corresponding phosphorodiamidate (**10**) or phosphoric triamide (**11**) were, however, complicated by the occurrence of phosphorus-nitrogen fission, which led to complex mixtures of products.[14] The condensation product (**12**) was, nevertheless, isolated in moderate yield from the reaction of chloral with ethyl N,N-dimethylphosphorodiamidate (**10**) and was converted to the imidazolyl derivative (**13**) by stepwise reaction with thionyl chloride, triethylamine, and imidazole (Scheme IV). In addition, a chloral derivative containing the bis(dimethylamino)phosphoryl group (**5p**) was obtained by the interaction of N,N,N′,N′-tetramethylphosphoric triamide (**11**) with diethyl N-(2,2,2-trichloroethylidene)phosphoramidate (**9**) as shown in Scheme I [X = $(Me_2N)_2P(O)NH$-].

Products were characterized by elemental analysis, infrared and ^{1}H nmr spectroscopy.

Spectroscopy

The infrared spectra of all compounds containing the $(EtO)_2P(O)NHCH(CCl_3)$-group showed characteristic absorptions at 3130–3200, 1230–1295, and 1030–1050 cm^{-1}, due to stretching modes of the N—H, P═O, and P—OEt bonds, respectively.[15] In addition, individual compounds showed bands characteristic of the other groups present.[16] Strong carbonyl absorptions were shown by the N-formylpiperazine, formamide, acetamide, chloracetamide, and oxathiin derivatives, in the range 1670–1678 cm^{-1}. Conjugation of the carbonyl group with the aromatic ring in the dichlorobenzamide and furancarboxamide derivatives was associated with a shift to slightly longer wavelength (1662 and 1642 cm^{-1}, respectively), whilst the trichloroacetamide derivative exhibited a carbonyl absorption at higher frequency (1700 cm^{-1}), due presumably to the inductive effect of the three chlorine atoms. Absorptions assigned to the N—H stretching mode of the carboxamide groups were observed in the region of 3200–3400 cm^{-1} and the thioethanol derivative showed a typical OH absorption at 3310 cm^{-1}.

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In the 60 MHz proton nmr spectra, the ethoxy groups give rise to signals which are typical of those for diethoxyphosphoryl compounds in general,[17] with the terminal methyl groups appearing as a triplet at δ 1.2–1.4 ppm and the methylene protons approximating to a quintet at δ 3.9–4.3 ppm ($J_{HCCH} \approx J_{POCH}$ = 6.9–7.1 Hz). The methylene signal may also be complicated by the influence of the prochiral phosphorus atom, which gives rise to anisochronous methylene protons,[18] and by the chiral methine carbon atom (—NH—$\underline{C}$H—) which may cause non-equivalence of the two ethoxy groups.[19] In either case a complex multiplet is seen. The effect of the chiral methine carbon atom is less than in those cases in which the chiral centre is attached directly to phosphorus[19] but the effect was evident in certain examples by the presence of separate overlapping signals for the methyl protons in each of the two ethoxy groups. The maximum separation observed between methyl signals was 4.7 Hz (for compounds **5a**, **5q**); compounds **5e**, **5i**, and **5n** showed a difference of ca. 1 Hz, whilst no detectable difference was seen in other cases.

The proton of the methine group resonates within the range δ 4.4–6.9 ppm depending on the nature of the substituent group X and generally appears as a doublet of doublets (J_{HCNH} 10–13 Hz; J_{PNCH} 8–11 Hz) in $CDCl_3$. The chemical shift of the NH proton, which gives rise to a broad signal, varies somewhat with concentration (4–6 ppm) and is frequently overlapped by the methylene signal of the ethoxy groups, as shown by shaking with D_2O.

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Fungicidal Activity

The most generally active compounds were the dithiocarbamate derivatives (**5q**, **5r**) which gave complete, or almost complete (>99%) control of *Fusarium culmorum, Fusarium oxysporum, Ophiobolus graminis, Helminthosporium sativum*, and *Helminthosporium avenae*, after incubation for one week *in vitro* at 500 ppm. Under similar conditions, extensive inhibition (>80%) was shown against *Fusarium culmorum* by the triazole (**5b**), hydroxyethylthio (**5e**), and ethyl xanthate (**5s**) compounds and by the imidazole derivative (**13**) which contained one ethoxy group and one dimethylamino group attached to phosphorus. The diethoxy imidazole derivative (**5a**), however, showed only about 50% control of *Fusarium culmorum*, as did the compound derived from formylpiperazine (**5d**), and the bis-(diethoxyphosphorylamino) derivatives, **5g** and **5o**. The morpholine (**5c**), disubstituted piperazine (**5f**), bis(dimethylamino)phosphoryl (**5p**), and carboxamide (**5h**–**5n**) derivatives showed little or no activity against the above named pathogens.

At 300 ppm, all compounds (**5a**–**5s**, and **13**) showed measurable *in vitro* activity (mainly between 10 and 50% control) against *Piricularia oryzae*, the most active being the diethyldithiocarbamate derivative (**5r**) and the imidazole derivative (**13**), both of which gave approximately 50% control under these conditions. The latter compound (**13**), which has an ethoxy and a dimethylamino substituent on phosphorus, was again significantly more active than the imidazole derivative with two ethoxy groups present (**5a**), which gave only 18% control. This observation is in line with a previous finding, indicated above, that an increase in fungicidal activity occurs in certain dinitroaryl phosphates when at least one dimethylamino group is attached to phosphorus.[13] The dithiocarbamate compounds (**5q** and **5r**) gave ca.

50% control of *Rhizoctonia solani* at 300 ppm *in vitro* and the acetamide derivative 40%, but other compounds showed little or no activity against this organism.

The compounds were also tested *in vivo* as seed dressings for the control of *Drechslera teres* (using seeds of spring barley, Tellus 374) and *Septoria nodorum* (using seeds of winter wheat, Holme 3055). At an application rate of 400 ppm, the imidazole derivatives (**5a** and **13**) and the dithiocarbamates (**5q** and **5r**), showed 60–70% of the activity of the reference fungicide, guazatine, against *D. teres*; the acetamide (**5i**), oxathiin (**5n**), and xanthate (**5s**) derivatives showed about 50% activity, and the morpholine (**5d**), hydroxyethylthio (**5e**), formamide (**5h**), trichloroacetamide (**5k**) and 3-methylfuran-2-carboxamide (**5m**) derivatives each showed about 30% of the activity of guazatine.

Against *S. nodorum*, the most active compound *in vivo* was the imidazole derivative (**5a**) which gave about 40% of the control shown by guazatine, whilst approximately 30% of the control shown by guazatine was achieved with the triazole (**5b**), morpholine (**5c**), hydroxyethylthio (**5e**), piperazine (**5f**), formamide (**5h**), dimethyldithiocarbamate (**5q**), and xanthate (**5s**) derivatives.

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Other Aspects of Biological Activity

Further tests with seeds of winter wheat and spring barley showed that most compounds caused slight inhibition of germination (ca. 5%) of either one or both types of seed, when applied at a dosage of 400 ppm. The maximum effect occurred for the formylpiperazine (**5d**), morpholine (**5c**), imidazole (**5a**), and triazole (**5b**) derivatives, which inhibited the germination of winter wheat by 10, 15, 20, and 20%, respectively. No inhibitory effect was recorded for the chloroacetamide (**5j**) and hydroxyethylthio (**5e**) derivatives, whilst the dimethylamido derivative (**13**) gave a slight improvement (ca. 5%) in germination. Early plant development was not affected significantly by the amido compounds (**5h**–**5o**) but was impaired slightly by other types of compound.

In addition, cholinesterase inhibition was measured by the method of Ellman *et al.*,[20] in order to gain a preliminary insight into the possible toxic hazards of compounds of these types. Compared to parathion as a reference compound, the inhibitory effects were generally low, being <1% in most cases. The highest levels of activity were shown by the dithiocarbamate (**5q**, **5r**) and xanthate (**5s**) derivatives, whose inhibitory effects in comparison with that of parathion were 1.28, 1.28, and 2.27%, respectively, and the disubstituted thioethanol derivative (**5g**) for which a relative inhibition of 1.82% was recorded.

EXPERIMENTAL

Solvents and Reagents

Starting materials were obtained commercially. Hydrocarbons were redistilled and stored over sodium wire. Diethyl ether was dried and stored over sodium wire. Carbon tetrachloride was distilled from phosphorus pentoxide. Chloroform was heated under reflux with phosphorus pentoxide (to remove traces of ethanol), decanted, distilled from fresh phosphorus pentoxide and stored in the dark. Phosphorus trichloride, thionyl chloride, and anhydrous chloral were redistilled before use. Triethylamine, pyridine, and morpholine were fractionally distilled through a 25 cm column packed with glass helices. Ethyl potassium xanthate was recrystallized from acetone/diethyl ether, and imidazole from chloroform.

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Sodium dimethyl- and diethyl-dithiocarbamates were dried at 120°C *in vacuo*. Other reagents were used as supplied.

Analytical Methods

Chlorine was determined by combustion in oxygen, absorption of the gases into aqueous sodium hydroxide, and potentiometric titration with silver nitrate. Phosphorus was determined gravimetrically by digestion in concentrated sulfuric and nitric acids, followed by dilution and precipitation as magnesium ammonium phosphate.[21] Carbon, hydrogen and nitrogen were determined with a Perkin-Elmer 240 micro-analytical instrument.

Melting points were recorded on a Gallenkamp apparatus with mercury in glass thermometer and are uncorrected.

Spectroscopy

Nmr spectra were recorded in $CDCl_3$ or DMSO-d_6 on a Perkin-Elmer R12B instrument operating at 60 MHz, with TMS as internal standard. Infrared spectra were obtained on a Pye-Unicam SP 2000 spectrometer, using samples prepared as Nujol mulls (for compounds **5a–5g**, **5i**, **5n–5p**), or KBr discs (for compounds **5h**, **5j–5m**).

Preparations of Intermediates

Described methods were used to prepare the following:

Diethyl phosphoramidate (**6**),[22] m.p. 45–46°C (lit.[22] m.p. 50–51°C) (Found C, 31.1; H, 7.7; N, 9.0. Calc. for $C_4H_{12}NO_3P$: C, 31.4; H, 7.9; N, 9.1%).

Diethyl N-(1-hydroxy-2,2,2-trichloroethyl)phosphoramidate (**7**),[9] m.p. 93–95°C (lit.[9] m.p. 96–97°C) (Found: C, 23.8; H, 4.5; N, 4.4. Calc. for $C_6H_{13}Cl_3NO_4P$: C, 24.0: H, 4.4; N, 4.7%), δ_H ($CDCl_3$) 1.35 (6H, t, CH_3, $^3J_{HH}$ 7.2 Hz, 4.25 (4H, m, CH_2, $^3J_{PH}$ 7.2 Hz), overlapping 4.0 (1H, br, NH), 5.2 (1H, dd, CH, $^3J_{HCNH}$ 11.3 Hz, $^3J_{PNCH}$ 8.0 Hz), 6.4 (1H, br s, OH).

Diethyl N-(1,2,2,2-tetrachloroethyl)phosphoramidate (**8**),[10] m.p. 104–106°C (lit.[10] m.p. 95–110°C) (Found: C, 22.9; H, 3.9; N, 4.4. Calc. for $C_6H_{12}Cl_4NO_3P$: C, 22.6: H, 3.8; N, 4.4%), δ_H ($CDCl_3$) 1.35 (6H, t, CH_3, $^3J_{HH}$ 7.2 Hz, 4.20 (4H, m, CH_2, $^3J_{PH}$ 7.2 Hz), overlapping 4.6 (1H, br, NH), 5.95 (1H, dd, CH, $^3J_{HCNH}$ 12.7 Hz, $^3J_{PNCH}$ 9.5 Hz).

N,N,N′,N′-Tetramethylphosphoric triamide (**11**),[23] m.p. 100–105°C from petroleum (b.p. 100–120°C) (lit.[23] m.p. 108°C) (Found: C, 30.4; H, 9.0; N, 28.2. Calc for $C_4H_{14}N_3OP$: C, 31.8: H, 9.3; N, 27.8%).

1-Formylpiperazine[24] b.p. 111–112°C at 1 mmHg (lit.[24] b.p. 115–120°C at 4 mmHg) (Found: C, 53.1; H, 8.6; N, 24.6. Calc. for $C_5H_{10}NO_2$: C, 52.6: H, 8.8; N, 24.5%).

5,6-Dihydro-2-methyl-1,4-oxathiin-3-carboxamide,[25] m.p. 174.5–175°C (lit.[25] m.p. 172–174°C) (Found: C, 45.4; H, 5.6; N, 8.2. Calc. for $C_6H_9NO_2S$: C, 45.3: H, 5.7; N, 8.8%).

2-Methylfuran-3-carboxamide[26] m.p. 85–86°C (lit.[26] m.p. 90°C) (Found: C, 58.9; H, 5.8; N, 11.4. Calc. for $C_6H_7NO_2$: C, 57.6: H, 5.6; N, 11.2%).

General Method for the Preparation of Diethyl N-(1-substituted-2,2,2-trichloroethyl)phosphoramidates (**5a–5p**): Triethylamine (1 mol. equiv.) was added to a solution of diethyl N-(1,2,2,2-tetrachloroethyl)phosphoramidate (**8**) in benzene (ca. 20% w/v), whereupon the temperature of the solution rose to ca. 35°C. After 10–15 min the white precipitate of triethylammonium chloride was filtered off and washed with benzene. The filtrate and washings were combined and the nucleophilic reagent (X—H) (1 mol. equiv. for compounds **5a–5e**, **5h–5p**, or 0.5 mol equiv. for compounds **5f**, **5g**) was added to give a clear solution which was allowed to stand at room temperature (10–15 min for **5a**, **5c**, **5f**, **5g**; 30 min for **5b**; overnight for **5e**; 2 days for **5d**, **5o**; 2 weeks for **5i**), or heated under reflux (1 h for **5p**, 3 h for **5h**, **5j**, **5n**; 6–8 h for **5k**, **5l**, **5m**). Solid product which separated from solution during the reaction period (**5e**, **5h–5p**) or after further concentration to half volume (**5d**, **5f**) or the addition of petroleum (b.p. 30–40°C) (**5g**) was filtered off, washed with solvent and/or recrystallized as specified below. Total removal of the solvent under reduced pressure (**5a–5c**) gave a residue from which the product was obtained by recrystallization from the solvent indicated below.

Diethyl N-[2,2,2-trichloro-1-(imidazol-1-yl)ethyl]phosphoramidate (**5a**) (4.9 g, 93%), m.p. 118–120°C from chloroform/benzene/petroleum (b.p. 60–80°C) (Found: C, 30.7; H, 4.3; Cl, 30.3; N, 12.0; P, 8.8. $C_9H_{15}Cl_3N_3O_3P$ requires: C, 30.8; H, 4.3; Cl, 30.3; N, 12.0; P, 8.8%); δ_H ($CDCl_3$) 1.2 (m, CH_3, $^3J_{HH}$ 6.9 Hz), 3.97 (m, CH_2, J_{POCH} 6.9 Hz), 5.95 (m, $C\underline{H}CCl_3$, J_{PNCH} 10.0 Hz, $^3J_{HNCH}$ 11.3 Hz), 6.4 (br m, PNH), 7.05 (s), 7.35 (s), 7.92 (s) (imidazole ring protons); ν_{max}/cm^{-1} 3140 (PN—H), 1260 (P═O), 1047 (P—OEt).

Diethyl N-[2,2,2-trichloro-1-(1,2,4-triazol-1-yl)ethyl]phosphoramidate (**5b**) (20.7 g, 48%), m.p. 123–126°C from chloroform/petroleum (b.p. 60–80°C) (Found: C, 27.5; H, 4.3; Cl, 30.5; N, 15.5; P, 9.0. $C_8H_{14}Cl_3N_4O_3P$ requires: C, 27.3; H, 4.0; Cl, 30.0; N, 15.9; P, 8.8%); δ_H ($CDCl_3$) 1.2 (t, CH_3, $^3J_{HH}$ 6.9 Hz), 3.95 (m, CH_2, J_{POCH} 6.9 Hz), 5.7 (br m, PNH), 6.23 (m, $C\underline{H}CCl_3$, J_{PNCH} 10.0 Hz, $^3J_{HNCH}$ 11.3 Hz), 7.95 (s), 8.55 (s) (triazole ring protons); ν_{max}/cm^{-1} 3130 (PN—H), 1249 (P═O), 1026 (P—OEt).

Diethyl N-[2,2,2-trichloro-1-(4-morpholino)ethyl]phosphoramidate (**5c**) (1.95 g, 78%), m.p. 127.5–128.5°C from chloroform/petroleum (b.p. 60–80°C) (Found: C, 32.0; H, 5.4; Cl, 28.9; N, 7.5; P, 8.4. $C_{10}H_{20}Cl_3N_2O_4P$ requires: C, 32.5; H, 5.4; Cl, 28.8; N, 7.6; P, 8.4%); δ_H ($CDCl_3$) 1.33 (t, CH_3, $^3J_{HH}$ 6.9 Hz), 2.89 (m), 3.69 (t), (morpholine ring protons), 3.7 (br m, PNH), 4.12 (m, $CH_3C\underline{H}_2$, J_{POCH} 7.3 Hz), 4.45 (dd, $C\underline{H}CCl_3$, J_{PNCH} 9.3 Hz, $^3J_{HH}$ 11.2 Hz); ν_{max}/cm^{-1} 3200 (PN—H), 1247 (P═O), 1047 (P—OEt).

Diethyl N-[2,2,2-trichloro-1-(4-formylpiperazine-1-yl)ethyl]phosphoramidate (**5d**) (1.84 g, 59.7%) (precipitated product, washed with benzene), m.p. 102–107°C (Found: C, 33.7; H, 5.4; Cl, 26.9; N, 10.5; P, 7.6. $C_{11}H_{21}Cl_3N_3O_4P$ requires: C, 33.3; H, 5.3; Cl, 26.8; N, 10.6; P, 7.8%); δ_H ($CDCl_3$) 1.3 (t, CH_3, $^3J_{HH}$ 6.9 Hz), 2.9 (br m), 3.37 (t), (morpholine ring protons), 3.7 (br m, PNH), 4.09 (m, $CH_3C\underline{H}_2$, J_{POCH} 7.1 Hz), 4.52 (dd, $C\underline{H}CCl_3$, J_{PNCH} 10.0 Hz, $^3J_{HNCH}$ 11.3 Hz), 8.05 (s, CHO); ν_{max}/cm^{-1} 3150 (PN—H), 1677 (C═O), 1240 (P═O), 1054 (P—OEt).

Diethyl N-[2,2,2-trichloro-1-(2-hydroxyethylthio)ethyl]phosphoramidate (**5e**) (3.76 g, 81%) (precipitated product, washed with benzene), m.p. 91.5–100.5°C (Found: C, 25.5; H, 4.9; Cl, 30.9; N, 4.9; P, 8.8. $C_7H_{17}Cl_3NO_4PS$ requires: C, 24.1; H, 4.9; Cl, 30.5; N, 4.9; P, 8.9%); δ_H ($CDCl_3$) 1.32 (m, CH_3, $^3J_{HH}$ 7.0 Hz), 3.0 (t, SCH_2, $^3J_{HH}$ 6.0 Hz), 3.86 (m, $C\underline{H}_2OH$), 4.0 (br m, $PN\underline{H}$), 4.0 (br s, OH), 4.12 (m, $CH_3C\underline{H}_2$, J_{POCH} 8.3 Hz) 5.20 (dd, $C\underline{H}CCl_3$, J_{PNCH} 9.5 Hz, $^3J_{HNCH}$ 11.2 Hz); ν_{max}/cm^{-1} 3310 (O—H), 3125 (PN—H), 1228 (P═O), 1050 (P—OEt).

1,4-Bis[2,2,2-trichloro-1-(diethoxyphosphorylamino)ethyl]piperazine (**5f**) (1.15 g, 75%) (precipitated product, washed with benzene), m.p. 162–165°C (decomp.) (Found: C, 29.2; H, 4.9; N, 8.5. $C_{10}H_{32}Cl_6N_4O_6P_2$ requires: C, 29.5; H, 4.9; N, 8.6%; δ_H ($CDCl_3$) 1.33 (t, CH_3, $^3J_{HH}$ 6.9 Hz), 2.9 (br m) (morpholine ring protons), 3.5 (br m, PNH), 4.12 (m, $CH_3C\underline{H}_2$, J_{POCH} 6.9 Hz), 4.48 (m, $C\underline{H}CCl_3$, J_{PNCH} 9.6 Hz, $^3J_{HNCH}$ 11.2 Hz); ν_{max}/cm^{-1} 3180 (PN—H), 1250 (P═O), 1039 (P—OEt).

1-[2,2,2-Trichloro-1-(diethoxyphosphorylamino)ethoxy]-2-[2,2,2-trichloro-1-(diethoxyphosphorylamino)ethylthio]ethane (**5g**) (0.82 g, 57%) (precipitated product, washed with petroleum, b.p. 30–40°C, and recrystallized from water), m.p. 178.5–180°C (Found: C, 25.6; H, 4.7; Cl, 33.5; N, 3.6; P, 9.7. $C_{14}H_{28}Cl_6N_2O_7PS$ requires: C, 26.1; H, 4.4; Cl, 33.1; N, 4.4; P, 9.6%); δ_H ($CDCl_3$) 1.32 (t, CH_3, $^3J_{HH}$ 6.9 Hz), 3.1 (m, SCH_2CH_2O), 4.0 (br m, PNH), 4.13 (m, $CH_3C\underline{H}_2$, J_{POCH} 6.9 Hz), 4.98 (m, $C\underline{H}CCl_3$); ν_{max}/cm^{-1} 3160 (PN—H), 1233 (P═O), 1050 (P—OEt).

Diethyl N-[2,2,2-trichloro-1-(formamido)ethyl]phosphoramidate (**5h**) (10.3 g, 70%) (precipitated product, washed with benzene and diethyl ether), m.p. 146–147°C (Found: C, 26.5; H, 4.4; Cl, 32.5; N, 8.3; P, 9.2. $C_7H_{14}Cl_3N_2O_4P$ requires: C, 25.6; H, 4.3; Cl, 32.5; N, 8.5; P, 9.5%); δ_H (DMSO-d_6) 1.20 (t, CH_3, $^3J_{HH}$ 7.1 Hz), 3.95 (m, $CH_3C\underline{H}_2$), 5.94 (m, $PN\underline{H}C\underline{H}$, J_{PNCH} 10.7 Hz), 8.16 (d, CHO), 8.83 (br d, NHCO, $^3J_{HNCH}$ 9.3 Hz); ν_{max}/cm^{-1} 1670 (C═O), 1240 (P═O).

Diethyl N-[2,2,2-trichloro-1-(acetamido)ethyl]phosphoramidate (**5i**) (1.0 g, 66%) (precipitated product, washed with benzene), m.p. 182–185°C (lit.[8] 184–185°C) (Found: C, 28.4; H, 5.0; Cl, 31.3; N, 8.2; P, 9.1. Calc. for $C_8H_{10}Cl_3N_2O_4P$: C, 28.1; H, 4.7; Cl, 31.1; N, 8.2; P, 9.1%); δ_H ($CDCl_3$) 1.32 (m, $C\underline{H}_3CH_2$, $^3J_{HH}$ 7.1 Hz), 2.07 (CH_3CO), 4.0 (br m, PNH), 4.13 (m, $CH_3C\underline{H}_2$, J_{POCH} 7.1 Hz), 5.80 (m, $C\underline{H}CCl_3$ J_{PNCH} 10.0 Hz), 7.1 (m, NHCO); ν_{max}/cm^{-1} 3325 (CON—H), 3200 (PN—H), 1675 (C═O), 1295 (P═O), 1045 (P—OEt).

Diethyl N-[2,2,2-trichloro-1-(chloroacetamido)ethyl]phosphoramidate (**5j**) (4.9 g, 33%) (precipitated product, washed with hot diethyl ether, and recrystallized from benzene), m.p. 183–184°C (Found: C, 25.5; H, 4.2; Cl, 37.9; N, 7.6; P, 8.2. $C_8H_{15}Cl_4N_2O_4P$ requires: C, 25.5; H, 4.0; Cl, 37.5; N, 7.5; P, 8.2%); δ_H (DMSO-d_6) 1.21 (t, CH_3, $^3J_{HH}$ 7.1 Hz), 4.0 (m, $CH_3C\underline{H}_2$), 4.25 (s, CH_2Cl), 5.88 (m, $PN\underline{H}C\underline{H}$, J_{PNCH} 10.7 Hz), 8.89 (d, NHCO, $^3J_{HNCH}$ 8.8 Hz); ν_{max}/cm^{-1} 1670 (C═O), 1230 (P═O).

Diethyl N-[2,2,2-trichloro-1-(trichloroacetamido)ethyl]phosphoramidate (**5k**) (10.1 g, 67%) (precipitated product, washed with hot diethyl ether, and recrystallized from benzene), m.p. 183–185°C (lit.[8] m.p. 183–185°C) (Found: C, 21.3; H, 3.1; Cl, 47.9; N, 6.3; P, 7.1. Calc. for $C_8H_{13}Cl_6N_2O_4P$: C, 21.6; H, 2.9; Cl, 47.9; N, 6.3; P, 7.0%); δ_H (DMSO-d_6) 1.24 (t, CH_3, $^3J_{HH}$ 7.1 Hz), 4.0 (m, $CH_3C\underline{H}_2$), 5.64 (br m, $PN\underline{H}C\underline{H}$, J_{PNCH} 12.2 Hz), 9.32 (br, NHCO); ν_{max}/cm^{-1} 1700 (C═O), 1245 (P═O).

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Diethyl N-[2,2,2-trichloro-1-(2,4-dichlorobenzamido)ethyl]phosphoramidate (**5l**) 4.66 g, 62%) (precipitated product, recrystallized from aqueous ethanol), m.p. 203–204°C (Found: C, 33.1; H, 3.4; Cl, 37.8; N, 6.0; P, 6.5. $C_{13}H_{16}Cl_5N_2O_4P$ requires: C, 33.0; H, 3.4; Cl, 37.6; N, 5.9; P, 6.6%); δ_H (DMSO-d_6) 1.23 (t, CH_3, $^3J_{HH}$ 7.1 Hz), 4.0 (m, $CH_3C\underline{H}_2$), 5.91 (m, $PN\underline{H}C\underline{H}$, J_{PNCH}11.2 Hz), 7.54 (m, Ar), 9.33 (d, NHCO, $^3J_{HNCH}$ 7.8 Hz); ν_{max}/cm^{-1} 1662 (C=O), 1245 (P=O).

Diethyl N-[2,2,2-trichloro-1-(2'-methylfuran-3'-carboxamido)ethyl]phosphoramidate (**5m**) (9.6 g, 64%) (precipitated product, recrystallized from benzene), m.p. 169–170°C (Found: C, 36.5; H, 4.8; Cl, 26.1; N, 6.9; P, 7.7. $C_{12}H_{18}Cl_3N_2O_5P$ requires: C, 35.3; H, 4.4; Cl, 26.1; N, 6.9; P, 7.6%); δ_H (DMSO-d_6) 1.18 (t, $C\underline{H}_3CH_2$, $^3J_{HH}$ 7.1 Hz), 2.53 (s, ring-CH_3), 3.97 (m, $CH_3C\underline{H}_2$), 5.69 (m, $PN\underline{H}C\underline{H}$, J_{PNCH} 11.5 Hz), 6.8 (d, $OCH{=}C\underline{H}$, $^3J_{HH}$ 2.0 Hz), 7.6 (d, $OC\underline{H}{=}CH$, $^3J_{HH}$ 2.0 Hz), 8.27 (d, NHCO, $^3J_{HNCH}$ 8.3 Hz); ν_{max}/cm^{-1} 1642 (C=O), 1240 (P=O).

Diethyl N-[2,2,2-trichloro-1-(5',6'-dihydro-2-methyl-1,4-oxathiin-3'-carboxamido)ethyl]phosphoramidate (**5n**) (1.5 g, 76%) (precipitated product, washed with benzene), m.p. 156–159°C (Found: C, 33.2; H, 4.8; Cl, 23.8; N, 6.1; P, 7.1. $C_{12}H_{20}Cl_3N_2O_5PS$ requires: C, 32.6; H, 4.6; Cl, 24.1; N, 6.3; P, 7.0%); δ_H ($CDCl_3$) 1.31 (m, $C\underline{H}_3CH_2$, $^3J_{HH}$ 6.8 Hz), 2.13 (s, ring-CH_3), 2.95 (t, SCH_2), 4.0 (br m, PNH), 4.12 (m, $CH_3C\underline{H}_2$), 4.35 (t, OCH_2), 5.85 (m, $C\underline{H}CCl_3$), 7.0 (br m, NHCO); ν_{max}/cm^{-1} 3397, 3277 (CON—H), 3180 (PN=H), 1658 (C=O), 1250 (P=O), 1046 (P—OEt).

2,2,2-Trichloro-1,1,-bis(diethoxyphosphorylamino)ethane (**5o**) (0.23 g, 13%), (precipitated product, recrystallized from chloroform/petroleum, b.p. 60–80°C), m.p. 186–189°C (lit.[8] 190–193°C) (Found: C, 27.6; H, 5.4; Cl, 24.5; N, 6.3; P, 14.3. Calc. for $C_{10}H_{23}Cl_3N_2O_6P_2$: C, 27.6; H, 5.3; Cl, 24.4; N, 6.4; P, 14.2%); δ_H ($CDCl_3$) 1.33 (m, $C\underline{H}_3CH_2$, $^3J_{HH}$ 7.1 Hz), 4.0 (br m, PNH), 4.17 (m, $CH_3C\underline{H}_2$, J_{POCH} 7.1 Hz), 5.13 (m, $C\underline{H}CCl_3$ J_{PNCH} 9.5 Hz); ν_{max}/cm^{-1} 3170 (PN—H), 1247 (P=O), 1045 (P—OEt).

2,2,2-Trichloro-1-diethoxyphosphorylamino-1-(N,N,N'N'-tetramethyldiaminophosphorylaminoethane (**5p**) (7.9 g, 83%) (precipitated product, washed with benzene), m.p. 219–221°C (Found: C, 27.6; H, 5.8; N, 12.9. $C_{10}H_{28}Cl_3N_4O_4P_2$ requires: C, 27.7; H, 5.8; N, 12.9%); δ_H ($CDCl_3$) 1.33 (m, $C\underline{H}_3CH_2$, $^3J_{HH}$ 6.9 Hz), 2.65 [m, $(CH_3)_2N$], 4.0 (br m, $PN\underline{H}CHN\underline{H}P$), 4.11 (m, $CH_3C\underline{H}_2$, J_{POCH} 6.9 Hz), 5.18 (m, $C\underline{H}CCl_3$ J_{PNCH} 8.6 Hz, J_{HNCH} 11.3 Hz); ν_{max}/cm^{-1} 3175 (PN—H), 1250 (P=O), 1045 (P—OEt).

General Procedure for the Preparation of Dithiocarbamate and Xanthate Derivatives (**5q–5s**): Sodium dimethyl- or diethyl-dithiocarbamate, or potassium ethyl xanthate, was added to a solution of an equimolecular quantity of diethyl N-(1,2,2,2-tetrachloroethyl)phosphoramidate (**8**) in benzene (10–20% w/v), and the mixture was heated under reflux for 0.5–1 h (**5q**, **5r**) or stirred at room temperature overnight (**5s**). After filtration to remove sodium or potassium chloride, the filtrate was evaporated under reduced pressure and the residue was recrystallized to give the following:

Diethyl N-[2,2,2-trichloro-1-(dimethylaminothiocarbamylthio)ethyl]phosphoramidate (**5q**) (4.79 g, 80%), m.p. 110–112°C from chloroform/benzene/ petroleum (b.p. 30–40°C) (Found: C, 26.5; H, 4.5; Cl, 26.4; N, 6.9; P, 7.6. $C_9H_{18}Cl_3N_2O_3PS_2$ requires: C, 26.8; H, 4.5; Cl, 26.3; N, 6.9; P, 7.7%); δ_H ($CDCl_3$) 1.30 (m, $C\underline{H}_3CH_2$, $^3J_{HH}$ 7.1 Hz), 3.46 [br s, $(CH_3)_2N$], 4.10 (m, $CH_3C\underline{H}_2$, J_{POCH} 7.1 Hz), 4.5 (br m, PNH), 6.68 (dd, $C\underline{H}CCl_3$ J_{PNCH} 10.7 Hz, J_{HNCH} 12.6 Hz); ν_{max}/cm^{-1} 3130 (PN—H), 1237 (P=O), 1027 (P—OEt).

Diethyl N-[2,2,2-trichloro-1-(diethylaminothiocarbamylthio)ethyl]phosphoramidate (**5r**) (2.08 g, 85%), m.p. 103–104.5°C from chloroform/light petroleum (b.p. 30–40°C) (Found: C, 30.5; H, 5.3; Cl, 24.6; N, 6.4; P, 7.1. $C_{11}H_{23}Cl_3N_2O_3PS_2$ requires: C, 30.5; H, 5.4; Cl, 24.6; N, 6.5; P, 7.2%); δ_H ($CDCl_3$) 1.28 (m, $C\underline{H}_3CH_2O$, $^3J_{HH}$ 6.7 Hz), 1.35 (m, $C\underline{H}_3CH_2N$, $^3J_{HH}$ 5.1 Hz), 4.0 (br m, overlapping PNH and $CH_3C\underline{H}_2N$), 4.13 (m, $CH_3C\underline{H}_2O$, J_{POCH} 6.7 Hz), 6.87 (dd, $C\underline{H}CCl_3$ J_{PNCH} 10.5 Hz, J_{HNCH} 12.7 Hz); ν_{max}/cm^{-1} 3140 (PN—H), 1240 (P=O), 1030 (P—OEt).

Diethyl N-[2,2,2-trichloro-1-(ethoxythiocarbonylthio)ethyl]phosphoramidate (**5s**) (3.94 g, 73%), m.p. 97.5–99°C from benzene/petroleum (b.p. 60–80°C) (Found: C, 26.5; H, 4.4; Cl, 26.3; N, 3.3; P, 7.5. $C_9H_{17}Cl_3NO_4PS_2$ requires: C, 26.7; H, 4.2; Cl, 26.3; N, 3.5; P, 7.6%); δ_H ($CDCl_3$) 1.28 [m, $C\underline{H}_3CH_2OC(S)$, m, $^3J_{HH}$ 7.7 Hz], 1.38 (m, $C\underline{H}_3CH_2OP$, $^3J_{HH}$ 6.8 Hz), 4.10 (m, $CH_3C\underline{H}_2OP$, J_{POCH} 6.9 Hz), 4.5 (br m, PHN), 4.68 [q, $CH_3C\underline{H}_2OC(S)$, $^3J_{HH}$ 7.7 Hz], 6.12 (dd, $C\underline{H}CCl_3$ J_{PNCH} 10.3 Hz, J_{HNCH} 12.5 Hz); ν_{max}/cm^{-1} 3140 (PN—H), 1250 (P=O), 1050 (P—OEt).

Preparation of ethyl N,N-dimethyl-N'-[2,2,2-trichloro-1-(imidazol-1-yl)ethyl]phosphorodiamidate (**13**): Ethyl N,N-dimethylphosphoroamidochloridate[27] (25.7 g), b.p. 96–98°C at 14 mmHg (lit.[27] b.p. 98–100°C at 18 mmHg) was prepared as described and dissolved in benzene (75 cm^3). Anhydrous ammonia was passed through the solution (3 h), after which the precipitate was filtered off, washed with benzene and dried to give ammonium chloride (7.53 g, 96%). The combined filtrate and washings were evaporated under reduced pressure to give crude ethyl N,N-dimethylphosphorodiamidate (**10**) (22.0 g, 43.4%), m.p. 30°C. Condensation of the phosphorodiamidate (**10**) (12.3 g, 81.8 mmol) with

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chloral (11.9 g, 81.0 mmol) in benzene (60 cm^3), as described for diethyl phosphoramidate,[8] gave ethyl N,N-dimethyl-N'-(2,2,2-trichloro-1-hydroxyethyl)phosphorodiamidate (**12**) as a colourless oil (11.6 g, 47.8%) (ca. 94% pure by ^{1}H nmr), which was dissolved in a mixture of benzene (50 cm^3) and pyridine (14.7 g) and treated with thionyl chloride (4.62 g, 1 mol equiv.) in benzene (10 cm^3) at 0°C (0.5 h). The upper clear solution was separated by decantation, volatile materials were removed under reduced pressure, and the residue was extracted with carbon tetrachloride to give the crude imine as a brown oil (4.94 g, 45%). The oil was dissolved in chloroform (5 cm^3) and a solution of imidazole (2.0 g, 29.3 mmol) in chloroform (10 cm^3) was added dropwise (5 min). The solution was heated under reflux with decolourising charcoal, filtered, and evaporated to give a residue which was redissolved in chloroform, washed with water, dried, and evaporated to give a product which was recrystallized from carbon tetrachloride (15 cm^3)/chloroform (1.2 cm^3) (with further charcoal treatment) to give the product (**13**) as pale yellow crystals (1.97 g, 14.6%), m.p. 118–120°C (Found: 30.9; H, 4.7; N, 16.0. $C_9H_{16}Cl_3N_4O_2P$ requires: C, 30.9: H, 4.6; N, 16.0%); δ_H ($CDCl_3$) 1.20 (m, $C\underline{H}_3CH_2$, $^3J_{HH}$ 7.3 Hz), 2.55 [m, $(CH_3)_2N$], 3.90 (m, $CH_3C\underline{H}_2$, $^3J_{HH}$ 7.3 Hz), 6.1 (br m, PNH), 5.92 (m, $C\underline{H}CCl_3$ J_{PNCH} 10.0 Hz), 7.03 (s), 7.38 (s), 7.96 (s), (imidazole ring protons); ν_{max}/cm^{-1} 3100 (PN—H), 1242 (P=O), 1048 (P—OEt).

Biological Screening

Fungicidal tests *in vitro* were carried out by standard techniques in nutrient agar. For *Fusarium culmorum, Fusarium oxysporum, Ophiobolus graminis, Helminthosporium sativum*, and *Helminthosporium avenae*, sample concentrations of 500 ppm were used, with incubation for 7 days at 25°C. Results were compared with those of control experiments, either with no added compound present or with phenylmercury acetate as a standard. Sample concentrations of 300 ppm with incubation at 28°C were used for tests against *Piricularia oryzae* (14 days) and *Rhizoctonia solani* (7 days). For these organisms guazatine was used as a reference fungicide.

Tests of fungicidal activity as seed-dressing agents were carried out using seeds of spring barley (Tellus 374) infected with *Pyrenophora teres* (subdivision Ascomycotina) conidial stage *Drechslera teres*, and seeds of winter wheat (Holme 3055) infected with *Leptosphaeria nodorum* (subdivision Ascomycotina) conidial stage *Septoria nodorum*. Seeds were treated with the sample compounds at the rate of 2 cm^3 of 20% w/v solution per kg (400 ppm). For each test, 200 seeds were incubated on moistened filter paper (pH 5.4) for 3 days at 10°C, followed by 4 days at 20°C. The coleoptile and roots were then examined for disease symptoms and the results compared with those of control experiments using untreated seeds, and seeds treated with guazatine.

Germination and early plant development were observed in separate experiments, in which seeds from the above tests were planted in moist sand, and placed in a growing chamber for 4 days at 10°C, followed by 6–7 days at 20°C.

Measurements of anticholinesterase activity were carried out on whole blood samples by the method of Ellman *et al.*,[20] with parathion as the reference compound.

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REFERENCES

1. Part III. D. G. Cameron, H. R. Hudson, M. Pianka and J. F. Volckman, *Phosphorus, Sulfur, and Silicon*, **88**, 15 (1994).
2. M. Pianka and D. J. Polton, *J. Sci. Fd. Agric.*, **16**, 330 (1965).
3. M. Pianka, J. D. Edwards and C. B. F. Smith, *J. Sci. Fd. Agric.*, **17**, 406 (1966).
4. L. A. Summers, *Aust. J. Chem.*, **25**, 671 (1972); L. A. Summers, *J. Heterocyclic Chem.*, **13**, 151 (1976), and cited references.
5. "The Pesticide Manual—A World Compendium—10th Edition, Incorporating the Agrochemicals Handbook," ed. C. Tomlin, British Crop Protection Council, Farnham, Surrey, and The Royal Society of Chemistry, Cambridge, 1991, pp. 1028, 1066.

6. "Agrochemicals: Preparation and Mode of Action," R. J. Cremlyn, Wiley, Chichester, 1991.
7. D. Woodcock, *Chem. in Brit.*, **4,** 294 (1968).
8. B. S. Drach, A. D. Sinitsa and A. V. Kirsanov, *Zhur. Obshchei Khim.* **39,** 1940 (1969); *Chem. Abstr.*, **72,** 31337f (1970).
9. A. Maeder, U.S. Patent 2 894 019 (1959); P. I. Alimov, *Izvest. Akad. Nauk SSSR, Ser. Khim.*, 61 (1961); *Chem. Abstr.*, **55,** 18577 (1961).
10. B. S. Drach and A. D. Sinitsa, *Zhur. Obshch. Khim.*, **38,** 2778 (1968); *Chem. Abstr.*, **70,** 77232e (1969).
11. A. F. Grapov and N. N. Melnikov, *Russ. Chem. Rev.*, **42,** 772 (1973); R. J. W. Cremlyn, *Internat. Pest Control*, **20,** 12 (1978).
12. B. G. Van den Bos, M. J. Koopman and H. O. Huisman, *Rec. Trav. Chim. Pays-Bas Belg.*, **79,** 807 (1960).
13. J. Drabek, I. Pastorek and V. Konecny, *J. Sci. Fd. Agric.*, **20,** 152 (1969).
14. P. J. Eccles, H. R. Hudson, C. Mavrommatis, M. Pianka and A. R. Qureshi, Proc. Internat. Conf. Phosphorus Chem., Nice, France, September 1983, ed. J. G. Riess, F. Mathey, D. Robert and R. Wolf, *Phosphorus Sulfur*, **18,** 439 (1983).
15. "Atlas IK-Spektrov Fosfororganicheskikh Soedinenii," R. R. Shagidullin, F. S. Mukhametov, R. B. Nigmatullina, V. S. Vinogradova and A. V. M. Chernova, ed. A. N. Pudovik, Nauka, Moscow, 1977.
16. "The Infrared Spectra of Complex Molecules," 2nd Edition, L. J. Bellamy, Methuen, London, 1958.
17. C. D. Hall, R. Ardrey, R. Dyer, and P. G. LeGras, *J. Chem. Soc., Perkin Trans.*, **2,** 1232 (1977).
18. T. H. Siddall and C. A. Prohaska, *J. Am. Chem. Soc.*, **84,** 2502 (1962); H. Finegold, *J. Am. Chem. Soc.*, **82,** 2641 (1960); A. H. Cowley, M. J. S. Dewar, W. R. Jackson and W. B. Jennings, *J. Am. Chem. Soc.*, **92,** 5206 (1970); W. B. Jennings, *Chem. Comm.*, 867 (1971); W. B. Jennings, *Chem. Rev.*, **75,** 307 (1975).
19. H. R. Hudson, M. McPartlin, R. W. Matthews, H. Powell, R. O. Yusuf, Z. M. Jászay, G. Keglevich, I. Petneházy and L. Töke, *Phosphorus, Sulfur, and Silicon*, **79,** 239 (1993).
20. G. L. Ellman, K. D. Courtney, V. Andres, Jr. and R. M. Featherstone, *Biochemical Pharmacology*, **7,** 88–95 (1961).
21. A. I. Vogel, "Textbook of Quantitative Inorganic Analysis," 4th ed., Longman, London, pp. 498–499, 1978.
22. F. R. Atherton, H. T. Openshaw and A. R. Todd, *J. Chem. Soc.*, 660 (1945).
23. R. Keat and R. A. Shaw, *J. Am. Chem. Soc.*, **87,** 4802 (1965).
24. K. Fuji *et al.*, *J. Pharm. Soc. Japan*, **74,** 1049 (1954).
25. A. E. Dukker, Neth. Appln. 6,605,525; *Chem. Abstr.*, **66,** 95055 (1967).
26. F. Garcia Gonzales, *Anales Soc. Españ. Fis. Quim.*, **32,** 815 (1934).
27. "Organic Phosphorus Compounds," eds. G. M. Kosolapoff and L. Maier, Ch. 16, Vol. 6, Wiley Interscience, New York, p. 708, 1973.

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