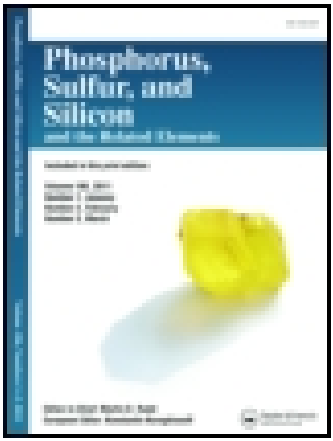

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Biodynamic Organothiophosphates of Pyridine: Synthesis and Bioactivity

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Biodynamic Organothiophosphates of Pyridine: Synthesis and Bioactivity

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The biological importance and practical significance of thiophosphates and pyridine nucleus prompted us to synthesize organothiophosphate of pyridine. In this regard, we have synthesized new series of such derivatives adopting the synthetic methodology, which we have evolved in our laboratory using cycloiminium derivatives of pyridine as starting material and PCl_3 as phosphorylating agent. These representatives were also tested for their insecticidal activity against a notorious polyphagus insect Helicoverpa armigera.

Keywords Insecticide; phosphorylation; thiophosphates

INTRODUCTION

A number of pyridine derivatives occur in nature and some of them play very vital biochemical roles. Pyridine derivatives have been found to be useful as antitumor,[1] antileukemic,[2] antimicrobial,[3] and anthelmintic[4] agents. Due to this versatile behavior of pyridine, we have selected 2-aminopyridine as the starting material for the synthesis of the previously mentioned derivatives. N-alkyl-2-aminopyridinium halides have been prepared with a view to generate new series of aminophosphines, in situ, which led to a variety of amidothiophosphates and trisamidothiophosphates with potential biocidal properties. In an extension to our previous work,[5–8] the new series of thiophosphates have been synthesized using few activating groups at nitrogen atom of the pyridine ring.

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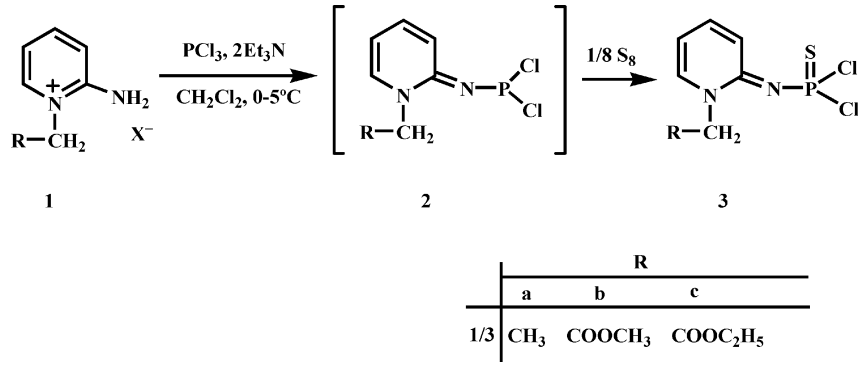
RESULTS AND DISCUSSION

The N-alkyl-2-aminopyridinium halides (**1**) reacted with an equimolar amount of phosphorus trichloride in the presence of two equivalents of triethylamine in methylene chloride, at 0–5°C. After 3–4 h, stirring at ambient temperature in situ, the oxidation of aminodichlorophosphines (**2**) was accomplished with equimolar amount of elemental sulfur, which led to N-alkyl-2-pyridinylidenamidothiophosphoryl dichlorides (**3**) (Scheme 1).



SCHEME 1

3a–c were subsequently subjected to nucleophilic substitution with different secondary amines viz. diethylamine, diphenylamine, and N-methylcyclohexylamine (Scheme 2).

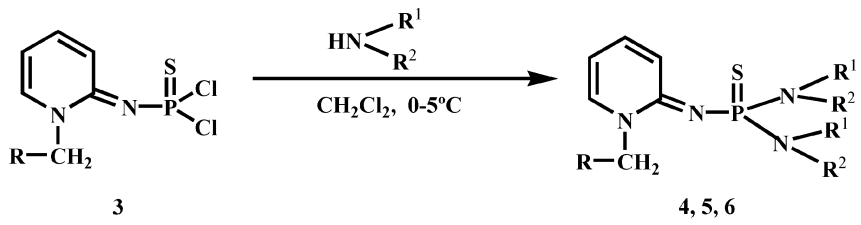
Through this synthetic strategy, two series of alkylidenamidothiophosphoric esters, namely, cycloiminylidenami-dothiophosphoric dichlorides (**3a–c**), and cycloiminylidenamidobis(dialkyl/diaryl/alkylalicyclicamido)thiophosphates (**4–6**) have been obtained in good yield.

All these newly synthesized products **3–6** were white to yellow, sharp melting crystalline solids, and were soluble in slightly polar solvents, e.g., chloroform, methylene chloride, diethylether, etc. The physical and analytical data and bioactivity data of these products have been presented in Tables I and II.

CHARACTERIZATION

^{31}P NMR Spectra

The ^{31}P NMR spectroscopy was found to be quite promising for determining the reaction progress and identification of the products.



R = CH_3, $COOCH_3$, $COOC_2H_5$

	R^1	R^2
4	C_2H_5	C_2H_5
5	CH_3	C_6H_{11}
6	C_6H_5	C_6H_5

SCHEME 2

When phosphorus trichloride and triethylamine were added to a suspension of the quaternary cycloiminium salts in methylene chloride and the mixture was examined for its phosphorus signal, the ^{31}P NMR signal appeared at δ 179.0–191.8 ppm, which was characteristic signal for tri-coordinated phosphines (**2**), which on course of further reaction, was shifted to upfield region, i.e. δ 44.1–50.0 ppm (**3**), and δ 44.2–63.8 ppm (**4–6**). Pure solids also gave signals in the region δ 40.6–63.7 ppm.

^{1}H NMR Spectra

The structures of the products were further confirmed by ^{1}H NMR spectroscopic studies. The methyl protons of diethylamido moiety i.e. $PNCH_2\mathbf{CH_3}$, resonated as a triplet at δ 1.01–1.09 ppm due to three-bond coupling with adjacent methylene protons ($^3J_{HH}$ = 6.9–7.2 Hz). The methylene protons of the same moiety ($PN\mathbf{CH_2}CH_3$), however, showed interesting splitting pattern, a doublet of doublet of quartet was observed due to coupling with geminal and vicinal protons as well as three-bond coupling with phosphorus atom ($^3J_{PH}$ = 13.2–6.9 Hz). The two set of such signals were observed in the range δ 3.07–3.12 and δ 3.25–3.31 ppm. This observation suggested the diastereotopic nature of the methylene protons.

The $N\mathbf{CH_2}$ protons (attached to the pyridine ring) of **3–6b,c** were observed as a singlet in the range δ 4.25–4.32 ppm while the same

TABLE I Physical and Spectral Data of Compounds

Compound	Mol. formula (mol. wt.)	Yield (%)	m.p. (°C)	Elemental analysis %C	%H	%N	^{31}P NMR δ ppm	^{1}H NMR δ ppm (JHz)	^{13}C NMR δ ppm
3a	$C_7H_9N_2PSCl_2$ (255.1)	60	95–97	32.96 (32.93)	3.55 (3.52)	10.98 (10.96)	48.0	1.15 (t, 3H, $^{3}J_{HH}$ = 7.2, NCH_2CH_3); 4.27 (q, $^{3}J_{HH}$ = 7.2, NCH_2CH_3); 6.61 (dt, 1H, $^{3}J_{HH}$ = 6.6, $^{4}J_{HH}$ = 1.5, H-5); 7.3 (t, 1H, $^{3}J_{HH}$ = 7.5, $^{4}J_{HH}$ = 1.5, H-3); 7.57 (dt, 1H, $^{3}J_{HH}$ = 7.2, $^{4}J_{HH}$ = 1.8, H-4); 7.64 (dt, 1H, $^{3}J_{HH}$ = 7.1, $^{4}J_{HH}$ = 1.5, H-6)	
3b	$C_8H_9N_2O_2PSCl_2$ (299.1)	70	110–112	32.12 (32.10)	3.03 (3.04)	9.36 (9.38)	44.1	3.77 (s, 3H, OCH_3), 4.76 (s, 2H, NCH_2); 6.56 (t, 1H, H-5), 7.61-7.70 (m, 3H; H-3, H-4 and H-6)	
3c	$C_9H_{11}N_2O_2PSCl_2$ (313.1)	72	105–107	34.52 (34.48)	3.52 (3.50)	8.95 (8.90)	44.3	1.23 (t, 3H, $^{3}J_{HH}$ = 7.2, OCH_2CH_3); 4.23 (q, 2H, $^{3}J_{HH}$ = 7.2, OCH_2CH_3); 4.74 (s, 2H, NCH_2); 6.73 (dt, 1H, $^{3}J_{HH}$ = 7.2, 6.8, $^{4}J_{HH}$ = 1.3, H-5); 7.54 (dt, $^{3}J_{HH}$ = 7.2, 6.0, $^{4}J_{HH}$ = 1.3, H-3); 7.67 (dt, 1H, $^{3}J_{HH}$ = 7.2, $^{4}J_{HH}$ = 1.3, H-4); 7.69 (dt, 1H, $^{3}J_{HH}$ = 7.2, $^{4}J_{HH}$ = 1.2, H-4) ;	14.1 (OCH_2CH_3); 54.7 (NCH_2); 62.5 (OCH_2CH_3); 112.2 (C-5), 119.3 (C-4); 139.9 (C-3), 141.9 (C-6); 154.9 (C-2); 166.1 (CO)
4a	$C_{15}H_{29}N_4PS$ (328.4)	63	86–88	54.85 (54.82)	8.89 (8.85)	17.06 (17.02)	63.7	1.09 (t, 12H, $^{3}J_{HH}$ = 7.1, $PNCH_2CH_3$); 1.39 (t, 3H, $^{3}J_{HH}$ = 7.1, NCH_2CH_3); 3.11 (ddq, 4H, $^{2}J_{HH}$ = 11.8, $^{3}J_{PH}$ = 13.2, $^{3}J_{HH}$ = 8.6, Ha of $PNCH_2CH_3$); 3.31 (ddq, 4H, $^{3}J_{HH}$ = 15.6, $^{3}J_{HH}$ = 13.2, $^{3}J_{HH}$ = 8.6, Hb of $PNCH_2CH_3$); 4.09 (q, 2H, $^{3}J_{HH}$ = 7.1, NCH_2CH_3); 6.25 (dt, 1H, $^{3}J_{HH}$ = 6.7, $^{3}J_{HH}$ = 1.2, H-5); 7.30 (dd, 2H, $^{3}J_{HH}$ = 6.6, H-3 and H-4); 7.52 (dt, 1H, $^{3}J_{HH}$ = 6.6, $^{4}J_{HH}$ = 1.2, H-6)	
4b	$C_{16}H_{29}N_4O_2PS$ (372.4)	60	82–85	51.59 (51.55)	7.84 (7.82)	15.04 (15.01)	62.7	1.08 (t, 12H, $^{3}J_{HH}$ = 7.2, $PNCH_2CH_3$); 3.10 (ddt, 4H, $^{2}J_{HH}$ = 12.0, $^{3}J_{PH}$ = 10.0, $^{3}J_{HH}$ = 6.9, Ha of $PNCH_2CH_3$); 3.25 (ddt, 4H, $^{2}J_{HH}$ = 11.7, $^{3}J_{PH}$ = 10.0 $^{3}J_{HH}$ = 7.0,Hb of $PNCH_2CH_3$); 3.87 (s, 3H, OCH3); 4.65 (s, 2H, NCH_2); 6.2 (dt, 1H, $^{3}J_{HH}$ = 7.2, $^{4}J_{HH}$ = 1.2, H-5); 7.25 (dt, 2H, $^{3}J_{HH}$ = 6.9, $^{4}J_{HH}$ = 1.2, H-3, H-4); 7.59 (d, $^{3}J_{HH}$ = 7.1, H-6)	14.0 (NCH_2CH_3); 39.6(NCH_2CH_3); 52.1 (OCH_3); 60.2 (NCH_2) 107.5 (C-5); 120.4 (C-4); 138.0 (C-3); 142.0 (C-6); 153.9 (C-2); 167.9 (CO)
4c	$C_{17}H_{31}N_4O_2PS$ (386.5)	64	88–90	52.82 (52.80)	8.08 (8.05)	14.49 (14.46)	44.2	1.04 (t, 12H, $^{3}J_{HH}$ = 6.9, $PNCH_2CH_3$); 1.34 (t, 3H, $^{3}J_{HH}$ = 6.1, OCH_2CH_3); 3.12 (ddt, 4H, $^{2}J_{HH}$ = 13.1, $^{3}J_{PH}$ = 8.2, $^{3}J_{HH}$ = 7.1, Ha of $PNCH_2CH_3$); 3.21 (ddt, 4H, $^{2}J_{HH}$ = 13.1, $^{3}J_{PH}$ = 8.0, $^{3}J_{HH}$ = 7.0, 4H, Hb of $PNCH_2CH_3$); 4.22 (q, 2H, $^{3}J_{PH}$ = 6.1, OCH_2CH_3), 4.25 (s, 2H, NCH_2); 5.28 (t, 1H, $^{3}J_{HH}$ = 7.2, H-5); 7.28 (dd, 2H, $^{3}J_{HH}$ = 7.2, H-3 and H-4); 7.51 (dd, 1H, $^{3}J_{HH}$ = 6.8, H-6)	

5a	$C_{21}H_{37}N_4PS$ (408.6)	60	73–75	61.73 (61.72)	9.13 (8.90)	13.71 (14.15)	61.6	0.89-1.61 (m, 22H, $^2J_{AB} = 11.5$, $^3J_{ax-ax} = 9.2$, $^2J_{eq-ax} = 3.0$, $PN(C_6H_{11})CH_3$); 2.51 (d, 6H, $^3J_{PH} = 12.0$, $PN(C_6H_{11})CH_3$); 1.39 (t, 3H, $^3J_{HH} = 7.1$, NCH_2CH_3);5.25 (m, 2H, NCH_2CH_3); 6.16 (dt, 1H, $^3J_{HH} = 6.7$, $^4J_{HH} = 1.4$, H-5); 7.22 (dt, 2H, $^3J_{HH} = 7.0$, $^4J_{HH} = 1.4$, H-3 & H-4); 7.52 (dd, 1H, $^3J_{HH} = 7.0$,$^4J_{HH} = 1.4$, H-6)
5b	$C_{22}H_{37}N_4O_2PS$ (582.7)	62	75–77	58.38 (74.19)	8.24 (5.32)	12.38 (9.65)	59.8	0.86–1.45 (m, 22H, $^2J_{AB} = 12.5$, $^3J_{ax-ax} = 9.4$, $^2J_{eq-ax} = 3.0$, $PN(C_6H_{11})CH_3$); 2.51 (d, 6H, $^3J_{PH} = 12.0$, $PN(C_6H_{11})CH_3$); 3.87 (s, 3H, OCH3); 4.65 (s, 2H, NCH_2); 6.16 (dt, 1H, $^3J_{HH} = 6.5$, $^4J_{HH}$ =1.4, H-5); 7.20 (dt, 2H, $^3J_{HH} = 7.0$, $^4J_{HH} = 2.0$, H-3 & H-4); 7.62 (dd, 1H, $^3J_{HH} = 6.8$,$^4J_{HH} = 2.0$, H-6)
5c	$C_{23}H_{39}N_4O_2PS$	70	80–82	59.20 (58.95)	8.42 (8.42)	12.01 (11.97)	60.5	0.78–1.40 (m, 22H, $^2J_{AB} = 11.35$, $^3J_{ax-ax} = 9.4$, $^2J_{eq-ax} = 2.8$, $PN(C_6H_{11})CH_3$); 1.34 (t, 3H, $^3J_{HH} = 6.1$, OCH_2CH_3); 2.51 (d, 6H, $^3J_{PH} = 12.0$, $PN(C_6H_{11})CH_3$); 4.22 (q, 2H, $^3J_{PH} = 6.1$, OCH_2CH_3), 4.25 (s, 2H, NCH_2); 6.16 (dt, 1H, $^3J_{HH} = 6.7$, $^4J_{HH}$ =1.4, H-5); 7.22 (dt, 2H, $^3J_{HH} = 7.0$, $^4J_{HH} = 1.4$, H-3 & H-4); 7.52 (dd, 1H, $^3J_{HH} = 7.0$,$^4J_{HH} =$ 1.4, H-6)
6a	$C_{31}H_{29}N_4PS$	54	77–80	71.52 (71.50)	5.62 (5.60)	10.76 (10.72)	40.6	1.39 (t, 3H, $^3J_{HH} = 7.1$, NCH_2CH_3); 5.32 (q, 3H, NCH_2CH); 6.69 (dt, 1H, $^3J_{HH} = 6.4$, $^4J_{HH} = 2.4$, H-5); 7.15-7.19 (m, 20H, PNC_6H_5); 7.32 (dt, 1H, $^3J_{HH} = 4.7$, $^4J_{HH} = 1.8$, H-3); 7.61 (dt, 2H, $^3J_{HH} = 4.6$, $^4J_{HH} = 1.8$, H-4 & H-6)
6b	$C_{32}H_{29}N_4O_2PS$	60	68–72	68.07 (68.02)	5.18 (5.12)	9.92 (9.95)	43.2	3.87 (s, 3H, OCH3); 4.65 (s, 2H, NCH_2); 6.58 (dt, 1H, $^3J_{HH} = 6.4$, $^4J_{HH} = 2.4$, H-5); 7.29-7.32 (m, 20H, PNC_6H_5); 7.34 (dt, 2H, $^3J_{HH} = 6.1$, $^4J_{HH} = 2.9$, H-3 & H-4); 7.62 (dd, 1H, $^3J_{HH} = 6.0$, $^4J_{HH} = 2.9$, H-6)
6c	$C_{33}H_{31}N_4O_2PS$	62	72–74	68.49 (68.44)	5.39 (5.33)	9.68 (9.62)	42.4	1.34 (t, 3H, $^3J_{HH} = 6.1$, OCH_2CH_3); 4.22 (q, 2H, $^3J_{PH} = 6.1$, OCH_2CH_3), 4.25 (s, 2H, NCH_2); 6.67 (dt, 1H, $^3J_{HH} = 6.4$, $^4J_{HH} = 2.4$, H-5); 7.30-7.36 (m, 20H, PNC_6H_5); 7.38 (dt, 2H, $^3J_{HH} = 6.0$, $^4J_{HH} = 2.2$, H-3 & H-4); 7.62 (dd, 1H, $^3J_{HH} = 6.0$, $^4J_{HH} = 2.2$, H-6)

TABLE II Total Percent Mortality of Third Instar *H. armigera* Pest after 1,3,7, and 14 Days

S. No.	Treatment	Total percent mortality (concentration)							
		1 day		3 day		7 day		14 day	
		a	b	a	b	a	b	a	b
5b	(N-(O-methoxy-2-oxoethyl)-2-pyridinylidenamido) bis(N-methyl cyclohexyl amido)thiophosphate	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	180 (168.21)	100 (199.77)	400 (360.00)	300 (240.23)
5c	(N-ethoxy-2-oxoethyl)-2-pyridinylidenamido) bis(diethylamido) thiophosphates.	20 (51.68)	0.00 (0.00)	20 (51.68)	0.00 (0.00)	160 (156.67)	80 (105.1)	320 (254.65)	240 (203.23)
4b	(N-(O-ethoxy-2-oxoethyl)-2-pyridinylidenamido)bis(diethylamidol) thiophosphate	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	80 (105.91)	80 (105.91)	80 (240.46)	280 (227.31)
4c	N-(O-ethoxy-2-oxoethyl)-2-pyrimidenylidenamido (diethylamido) (phenyl) thiophosphonate	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	100 (119.77)	40 (73.76)	300 (240.23)	240 (203.14)
	Endosulfan	60 (90.58)		120 (132.5)		220 ((191.54)		340 (269.42)	
	Control	0.00 (0.00)		0.00 (0.00)		0.00 (0.00)		0.00 (0.00)	

a: 0.05% concentration; and b: 0.025% concentration terms in parentheses are the angular transformed values.

protons in **3–6a** resonated as a quartet at δ 4.09 ppm ($^3J_{HH} = 7.1$ Hz) due to coupling with three-bond apart methyl protons (δ 1.39 ppm).

The O**C**$\mathbf{H_3}$ protons of **3–6b** resonated as a singlet at δ 3.87 ppm while the OCH_2**C**$\mathbf{H_3}$ protons resonated as a characteristic set of triplet at δ 1.34 ppm ($^3J_{HH} = 6.1$ Hz) and quartet at 4.22 ppm ($^3J_{HH} = 6.1$ Hz).

Other aromatic protons have resonated in the expected regions, δ 7.01–7.62 ppm. The H-5 proton resonated as a doublet of triplet in the range δ 5.28–6.25 ppm ($^3J_{HH} = 6.0$–7.2, $^4J_{HH} = 1.2$ Hz) due to three and four-bond coupling with H-3, H-4 and H-6. The H-3 proton resonated as a doublet of doublet or merged triplet in the range of δ 7.25-7.61 ppm due to vicinal coupling with H-4 and four-bond coupling with H-5 with coupling constants $^3J_{HH} = 6.9$–7.2 Hz, $^4J_{HH} = 1.2$ Hz, respectively. The H-4 proton also showed a doublet of doublet in the range δ 7.25–7.61 ppm due to three-bond coupling with H-3 proton ($^3J_{HH} = 6.1$–7.0 Hz). Since there is very less difference in the chemical shift values of the H-4 and H-6 protons, a merged multiplet was observed for these protons in few cases. The ring protons of PN(CH_3)*c*-**C**$_6$**H**$_{11}$ were shielded and appeared as a multiplet in the region δ 0.82–1.65 ppm, suggesting the nonequivalent nature of these protons. The equatorial protons have been found more deshielded in comparison to axial protons with a difference of δ 0.1–0.7 ppm.[9] The methyl protons of PN(**C**$\mathbf{H_3}$)*c*-C_6H_{11}moiety resonated as a doublet in the range δ 2.43–2.51 ppm due to three-bond coupling with phosphorus ($^3J_{PH} = 12.0$–12.5 Hz).

^{13}C NMR Spectra

The NCH_2**C**$\mathbf{H_3}$ carbon is highly shielded and appeared at δ 14.0 ppm, while the N**C**$\mathbf{H_2}CH_3$ carbon resonated at δ 39.6 ppm. The NCH_2 carbon absorbed at δ 60.2 ppm. The aromatic carbons, C-3, C-4, C-5, and C-6, resonated at δ 138.0, 120.4, 107.5, and 142.0 ppm, respectively. The C-2 carbon being quaternary gave a very low intensity peak at δ 153.9 ppm. The highly deshielded CO appeared at δ 167.9 ppm. The ^{13}C NMR data were also helpful in establishing the proposed structure. The C_α $C_{\beta,\beta'}$, $C_{\gamma,\gamma'}$, and C_δ of PN(CH_3)*c*-**C**$_6$**H**$_{11}$, appeared at δ 25.8–30.9 ppm. The PN(**C**$\mathbf{H_3}$)*c*-C_6H_{11} showed signal at δ 54.0 ppm. The N**C**$\mathbf{H_2}C_6H_5$ carbon resonated at δ 54.8 ppm. The *meta* carbon of NCH_2**C**$_6$**H**$_5$moiety gave a doublet at δ 127.4 and δ 127.7 ppm. Similarly, *ortho* carbons also gave a doublet at δ 136.3 and δ 137.4 ppm. The *para* carbon showed a singlet at δ 128.8 ppm.

BIOLOGICAL ACTIVITY

The protection of agricultural crops and boosting up of their products through the wise and considerate use of appropriate agrochemicals,

e.g. pesticides, fertilizers, growth promoters etc., have played a very crucial and needful role in ensuring sufficient food supply to an ever exploding world population. Historically, highly chlorinated insecticides have been predominantly used and the most important and classical examples were undoubtedly, DDT, 2,2-bis(p-chlorophenyl)-1,1,1-trichloroethane, which were now regarded as hard insecticides,[10–13] i.e., stable in environment and exist as such for many years, not only in soil and water, but in plants and animal tissues as well.[14–15] Since, pests develop resistance against the commonly used pesticides in due course of time, we need to continually design and synthesize new organophosphorus pesticides with potential broad spectrum of bioactivity and less toxicity to higher animals.

In this light, four synthesized novel organothiophophates (**4–5bc**) have been screened for their insecticidal activity against *Helicoverpa armigera*, a polyphagus insect that severely damages almost all the crops throughout the year in India. The study has been conducted on the second and third instar larval stages of the said insect. Two concentrations, viz., 0.025% and 0.05% of the test compounds were selected along with the standard check, the endosulfan 35, together with an untreated control. The mortality counts of the insect pests were recorded daily up to fourteen days. All the test compounds initially were found to exhibit low bioactivity up to 3 days but after 7 and 14 days time interval their activity were increased to be at par with the check compound (Figure 1, Table II). This observation has indicated that the metabolites of the test compounds may be even more potent than the original compound themselves. It has been already reported in literature[11] that under natural conditions, these compounds suffers a P═S → P═O bond change in due course of time, that is, the thiophosphates is oxidized to phosphates by the air in soil. Furthermore, nitrogen of the diethylamido substitutent (**4b**,**c**) is converted into nitrogen oxide in the similar conditions, i.e., in air and soil. Hence, it is just possible that the enhanced insecticidal behavior of all the test compounds after 7 days onwards arises due to the above mentioned chemical changes in the molecules and due to electron withdrawing chlorine and ester moieties.[11] This property also seems to be a plus point for test compounds which on longer stay on the crops, ensures killing of all the stages (I, II, III, and also the pupal stages) of this insect. This study thus confirmed the potential insecticidal nature of the compounds.

EXPERIMENTAL

All the glassware used was washed first with alkali, followed by dilute acid solution then plenty of water, and further rinsed with acetone or

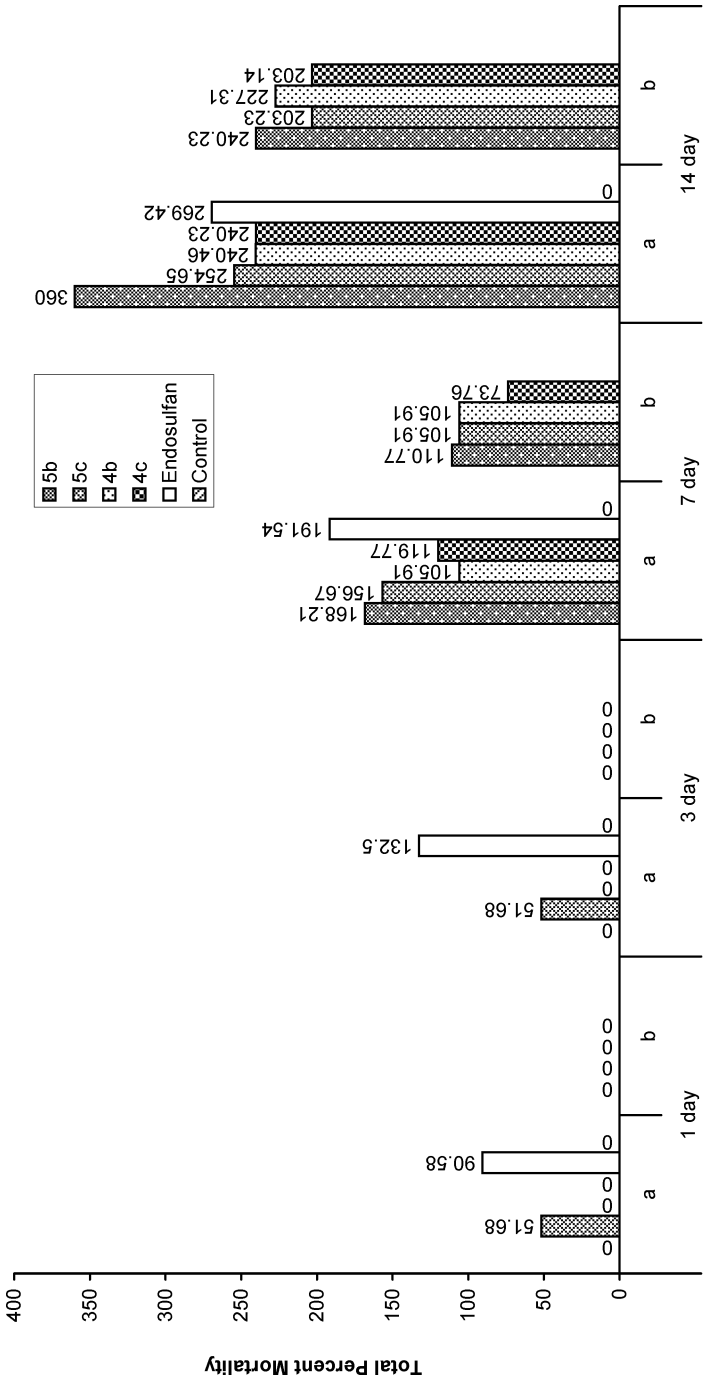


FIGURE 1 Total percent mortality of third instar *H. armigera* pest after 1, 3, 7 and 14 days.

alcohol, dried in an electric oven. Good quality dry needles and syringes were used for adding reactants during the course of reactions. All the solvents used in this work were carefully purified prior to use while fine chemicals were used as obtained from Aldrich, Lancaster, and Merck. Elemental analyses were carried out on Heraeus Carlo Erba 1108 analyzer. ^{31}P NMR spectra were recorded on Jeol AL300 at 121.50 MHz (obset 156 KHz) using 85% H_3PO_4 as an internal standard. ^{1}H NMR spectra were recorded in $CDCl_3$ solution also on Jeol AL300 at 300.4 MHz (obset 130 KHz) using TMS as the internal reference. ^{13}C NMR spectra were similarly recorded in deuterated solvent on Jeol AL300 at 75.45 MHz (Obset 124 KHz) using TMS as the internal standard.

General Procedure for the Synthesis of N-alkyl-2-pyridinylidenamido-dichlorothiophosphates (3a–c)

To a well-stirred suspension of N-alkyl-2-aminopyridinium halide (0.01 mol) in methylene chloride, was added phosphorus trichloride (0.01 mol) followed by dropwise addition of triethylamine (0.02 mol) in methylene chloride at 0–5°C. After 3–4 h stirring, powdered sulfur (0.01 mol) was added to reaction mixture and stirring was continued. After 15–16 h, the reaction mixture was then filtered off. The solvent of filtrate was removed under vacuo and the crude was extracted with diethyl ether and was left in refrigerator whereupon a white to yellow colored solid was obtained.

General procedure for the Synthesis of (N-alkyl-2-aminopyridinyli-denamido)bis(diethylamido)thiophosphates (4a–c)

2-aminopyridinium halide (0.01 mol), was stirred in methylene chloride. Phosphorus trichloride (0.01 mol) was added to this suspension in the presence of triethylamine (0.02 mol) in methylene chloride at 0–5°C. After 2–4 hrs. sulfur powder (0.01 mol) was added at room temperature after 24 hrs., four equivalents of diethylamine (0.04 mol) mixed in methylene chloride at 0–5°C was further added and stirring was continued for another 20–24 hrs. The reaction mixture was then filtered off and dried under *vacuo*, extracted with ether and left in refrigerator whereupon a white to yellow solid was deposited.

General Procedure for the Synthesis of N-alkyl-2-pyridinylidenamido) bis(N-methylcyclohexylamido)thiophosphates (5a–c)

To a well-stirred suspension of salt in methylene chloride was added phosphorus trichloride (0.01 mol) directly and triethylamine (0.02 mol) at 0–5°C. After 3–4 h stirring, sulfur (0.01 mol) was added at ambient temperature. A solution of N-methylcyclohexylamine (0.02 mol) in methylene chloride was added dropwise at 0–5°C, after 24–30 h. stirring. The stirring was continued for 24–30 h at room temperature. Then it was filtered off and solvent of the filtrate was removed in vacuo. The solid was extracted with diethyl ether and kept in refrigerator, whereupon white to cream crystals were obtained.

General Procedure for the Synthesis of (N-alkyl-2-pyridinylidenamido)bis (diphenylamido)thiophosphates (6a–c)

To a suspension of N-alkyl-2-aminopyridinium halide (0.01 mol) in methylene chloride, was added phosphorus trichloride (0.01 mol) in presence of dropwise addition of triethylamine (0.02 mol) in methylene chloride at 0–5°C. After 3–4 h, sulfur (0.01 mol) was added to the reaction mixture. Triethylamine (0.02 mol) was added directly and diphenylamine (0.02 mol) in methylene chloride then added dropwise after 20–24 hrs. stirring at 0–5°C. After 20–24 h stirring, reaction mixture was filtered off and the solvent was removed in vacuo. Residue was extracted with diethyl ether and left in refrigerator whereupon a cream to yellow solid was obtained.

Insecticidal Activity on *H. armigera*

Two concentrations 50 ppm and 25 ppm of four test compounds were made. For this purpose 250 mg of compound was dissolved in 1–2 ml of acetone and the solution was made up to 500 ml by adding distilled water. Thus, a solution of 0.05% was obtained 250 ml of this solution was taken in a flat bottom flask and further diluted to 500 ml to obtain the solution of 0.025% concentration.

The third instar larvae were selected for the study. For this 2–3 g of gram shoots were soaked in the test solution that was made earlier and were dried, then introduced in plastic container with larvae. Twenty such containers were prepared for each replication and there were four replicates for each treatment. A parallel set of four replicates of twenty insects each, representing the standard check (endosulfan 35 ec, 0.05)

and untreated control was also run. All the insects were placed at room temperature and percent mortality was checked every day.

CONCLUSION

A series of novel thiophosphates incorporating pyridine ring have been synthesized through one-pot method. The insecticidal study of these compounds confirmed their potential insecticidal nature.

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