Synthesis, characterisation and antimicrobial activity of novel 2-alkoxycarbonylamino-1,3,2-benzodiazaphosphole 2-oxides

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A series of some new class of 2-alkoxycarbonylamino-1,3,2-benzodiazaphosphole 2-oxides **4a–j** were synthesised by reacting 3,4-diaminobenzophenone (**3**) with various dichlorophosphinyl carbamates (**2**) in dry toluene-tetrahydrofuran mixture (1:1) in the presence of triethylamine at 45–50 °C. All the title compounds were evaluated for antimicrobial activity to determine their efficacy and were effective in suppressing the growth of bacteria and fungi. The chemical structures of the title products were characterised by IR, ^{1}H, ^{13}C and ^{31}P NMR and mass spectral studies.

Keywords: 3,4-diaminobenzophenone, spectral analysis, antimicrobial activity

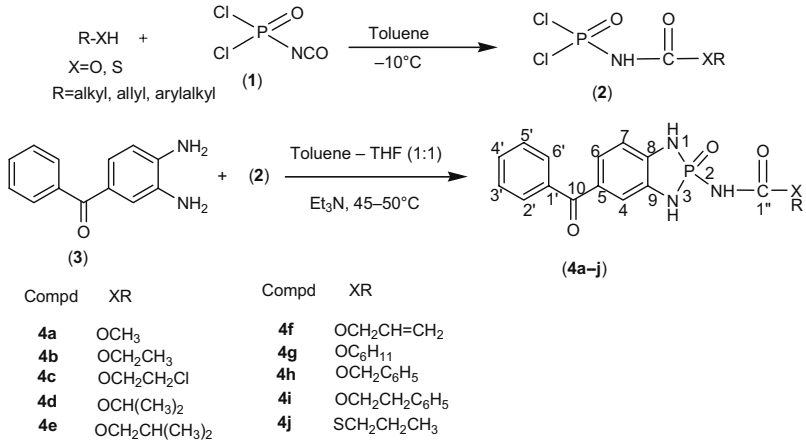
Many organophosphorus (OP) compounds and carbamates are potent inhibitors of esterase's and particularly of cholinesterase. Organophosphorus compounds produce a stable phosphorylated enzyme, and such compounds are therefore extremely valuable tools for the study of biological processes.[1] The most popular pesticides for agriculture purposes are organophosphates, carbamates and pyrethroids. These groups cause neurotoxicity in mammals. Compounds of these three families are spontaneously hydrolysed and undergo enzymatic degradation by hydrolyses.[2] OP compounds being ubiquitous finding multifaceted applications in the field of agriculture, medicine and industry offer potential source of eco-safe pesticides.[3] OP carbamates are one such important class that finds applications as insecticides, herbicides, fungicides, and rodenticides.[4,5] Unlike organochlorine pesticides, OP carbamates are short-lived in the environment and fast-acting on their "target pest" by inhibiting acetylcholinesterase (AChE) enzyme activity and affecting their nervous system.[6] The present generation of OP carbamate pesticide toxicity is not only specific to target "pest," but also lethal to non target organisms.[7]

In our search for eco/bio-friendly pesticides, we have reported synthesis of several exocyclic P–O, P–NH and P–C link dioxaphosphocins[8,9] oxazaphosphorins,[10] benzo-diazaphospholes.[11] In continuation of our attempt to develop potential pesticides, synthesis of novel 2-alkoxy-carbonylamino-1,3,2-benzodiazaphosphole 2-oxides has been accomplished.

Results and discussion

Dichloroisocyanatophosphine oxide[12,13] (**1**) was prepared by the reaction of phosphorus pentachloride with ureathane in 1,2-dichloroethane at –5 °C under nitrogen atmosphere and then heated at reflux temperature. The mixture was heated very slowly since the reaction is strongly exothermic and much gas is evolved so that explosions may occur if the heating is fast. Addition of dichloroisocynato phosphine oxide to various alkyl-, allyl-, aryl alcohol/thiol at –10 °C under inert atmosphere in dry toluene afforded the corresponding *N*-dichlorophosphinyl carbamates/thiocarbamate **2a–j** which on cyclocondensation *in situ* with 3,4-diaminobenzophenone (**3**) in presence of two equivalents of triethylamine in dry toluene–tetrahydrofuran mixture (1:1) afforded compounds **4a–j** at 45–50 °C. Purification of **4a–j** was achieved by separation of triethylamine hydrochloride by filtration, evaporation of the filtrate and recrystallisation of the residue after washing with water from ethanol. Primary and secondary alcohols/thiols react readily with dichloroisocyanatophosphine oxide (**1**) to give their respective carbamates/thiocarbamates (**2**), but tertiary alcohols/thiols do not undergo any reaction with it due to steric factors. All the chemical structures of the newly synthesised compounds **4a–j** were established by elemental analysis, IR, ^{1}H, ^{13}C and ^{31}P NMR and mass spectral data.

Characteristic IR frequencies were observed at 3363–3327 cm^{-1} (P–NH), 1655–1618 (Ar–C=O–Ar), 1284–1249 (P=O) and 1721–1702 (–C=O–XR) suggested that they are involved in H-bonding.[14-16]



Compd	XR
4a	OCH_3
4b	OCH_2CH_3
4c	OCH_2CH_2Cl
4d	$OCH(CH_3)_2$
4e	$OCH_2CH(CH_3)_2$
4f	$OCH_2CH{=}CH_2$
4g	OC_6H_{11}
4h	$OCH_2C_6H_5$
4i	$OCH_2CH_2C_6H_5$
4j	$SCH_2CH_2CH_3$

Scheme 1

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In ^{1}H NMR spectra of **4a–j**, the endocyclic phosphoramides P–NH hydrogens resonated down field as broad signal at δ 5.72–4.47 due to hydrogen bonding with oxygen of P=O and deshielding effect of carbamatophosphoryl group. The exocyclic P–NH hydrogens of carbamato group gave broad signal at much further downfield at δ 9.23–8.17 obviously due to the strong deshielding effect of O=P–NH–C=O system.

Two signals were present in the ^{31}P NMR spectra of **4a–j** (e.g. **4a** δ –14.62 and 0.72), indicating their existence in two conformers **A** and **B** in solution state (Figs 1 and 2).[17-20] The conformers **A** and **B** almost appear like enantiomers except for the fact that the P=O group points to the aryl ring in **A** and away from the ring in **B**.

The mass spectrum of **4f** exhibited a peak at *m/z* 357(47) corresponding to the molecular ion. Other characteristic fragments were observed in the mass spectrum that unambiguously confirmed the assigned molecular structure.

Conclusion

In our investigation, we have synthesised novel alkoxy carbonylamino-1,3,2-benzodiaza-phosphole 2-oxides to explore their potential bioactivity.

Experimental

The melting points were determined on a Mel-Temp apparatus and were uncorrected. Elemental analyses were performed at the Central Drug Research Institute, Lucknow, India. IR spectra were recorded in KBr pellets on a Perkin–Elmer FT-IR, 1000 unit. ^{1}H, ^{13}C and ^{31}P NMR spectra were taken on a Varian XLAA-400 spectrometer operating at 400 MHz for ^{1}H, 100 MHz for ^{13}C and 161.9 MHz for ^{31}P. The compounds were dissolved in DMSO-d_6 and chemical shifts were referenced to TMS (^{1}H and^{13}C) and 85% H_3PO_4 (^{31}P). Mass spectral data were recorded on FAB-MS instrument at 70 eV with a direct inlet system.

3,4-Diaminobenzophenone was procured from Aldrich Chemical Company Milwaukee, USA and was used without further purification.

General procedure for synthesis of 2-alkoxycarbonylamino-1,3,2-benzodiazaphosphole 2-oxides **(4a–j)**: Synthesis of 2-methoxy-carbonylamino-5-benzoyl-2,3-dihydro-1*H*-1,3,2-diazaphosphole 2-oxide (**4a**). A solution of methyl alcohol (0.064 g, 2 mmol) in dry toluene (10 ml) was added drop-wise over a period of 20 min to a cold and stirred solution (–10 °C) of dichloroisocynatophosphine oxide (**1**, 0.36 g, 2 mmol) in dry toluene (25 ml). After addition, the temperature of the reaction mixture was slowly raised to room temperature and stirring was continued for another 2 h. This mixture was added dropwise to a stirred solution (0 °C) of 3, 4-diaminobenzophenone (**3**, 0.414 g, 2 mmol) and triethylamine (0.404 g, 4 mmol) in 40 ml of dry toluene–tetrahydrofuran mixture (1:1). After the addition, the temperature of the reaction mixture was brought to 45–50 °C and stirring was continued for additional 8 h. Progress of the reaction was monitored by TLC analysis. The precipitated triethylamine hydrochloride was filtered off and the solvent was evaporated under reduced pressure.

The residue obtained was washed with water and recrystallised from ethanol to get the pure compound of **4a**. Yield (0.40 g, 61%), m.p. 152–154 °C.

The other compounds of this series **4b–j** were prepared adopting the above procedure.

The physical and spectral data of the compounds **4a–j**.

2-Methoxycarbonylamino-5-benzoyl-2,3-dihydro-1H-1,3,2-diazaphosphole 2-oxide **(4a)**: IR (KBr) cm^{-1}: 3354 (P–NH), 1718 (–COXR), 1621 (Ar–CO–Ar), 1254 (P=O); ^{31}P NMR (DMSO-d_6, δ ppm): –14.62, 0.72; ^{1}H NMR (DMSO-d_6, δ ppm): 7.28 (s, 1H, 4-H), 6.57 (d, *J* = 8.2 Hz, 1H, 6-H), 7.09 (d, *J* = 8.0 Hz, 1H, 7-H), 7.74–7.52 (m, 5H, C(O)C_6H_5, ArH), 4.92 (s, 2H, P–NH), 8.31 (s, 1H, NH–CO), 3.64 (s,1H, OCH_3); Anal. Calcd for $C_{15}H_{14}N_3O_4P$: C, 54.39; H, 4.26; N, 12.68; Found: C, 54.56; H, 4.47; N, 12.77%.

2-Ethoxycarbonylamino-5-benzoyl-2,3-dihydro-1H-1,3,2-diazaphosphole 2-oxide **(4b)**: Yield 56%; m.p. 139–142 °C; IR (KBr) cm^{-1}: 3341 (P–NH), 1721 (–COXR), 1639 (Ar–CO–Ar), 1261 (P=O); ^{31}P NMR (DMSO-d_6, δ ppm): –13.70, 0.96; ^{1}H NMR (DMSO-d_6, δ ppm): 7.28 (s, 1H, 4-H), 6.62 (d, *J* = 8.2 Hz, 1H 6-H), 7.03 (d, *J* = 7.8 Hz, 1H, 7-H), 7.73–7.44 (m, 5H, C(O)C_6H_5, ArH), 5.87 (s, 2H, P–NH), 8.34 (brs, 1H, NH–CO), 3.97 (q, 2H, OCH_2), 1.19 (t, 3H, CH_3); ^{13}C NMR (DMSO-d_6, δ ppm): 115.0 (s, 1C, C-4), 139.7 (s, 1C, C-5), 127.3 (s,1C, C-6), 121.0 (s, 1C, C-7) 136.7 (s, 1C, C-8), 139.7 (s, 1C, C-9), 194.6 (s, 1C, C-10), 139.7 (s, 1C, C-1'), 129.4 (s, 2C, C-2' and 6'), 128.8 (s, 2C, C-3' and 5'), 132.0 (s, 1C, C-4'), 146.9 (s, 1C, C-1"), 59.2 (s, 1C, C-2"), 14.6 (s, 1C, C-3"); FAB-MS *m/z* (%): 345 [16.6, (M$^+$)], 329 (8.3), 307 (52), 299 (25), 281 (16.6), 273 (8.3), 212 (43.6), 154 (100), 136 (52), 105 (35.3); Anal. Calcd for $C_{16}H_{16}N_3O_4P$: C, 55.65; H, 4.67; N, 12.17; Found: C, 55.53; H, 4.51; N, 11.98%.

2-[2-Chloroethoxycarbonylamino-5-benzoyl-2,3-dihydro-1H-1,3,2-diazaphosphole 2-oxide **(4c)**: Yield 58%; m.p. 160–162 °C; IR (KBr) cm^{-1}: 3346 (P–NH), 1709 (–COXR), 1626 (Ar–CO–Ar), 1256 (P=O); ^{31}P NMR (DMSO-d_6, δ ppm): –14.06, 0.84 ppm; ^{1}H NMR (DMSO-d_6, δ ppm): 7.17 (s, 1H, 4-H), 6.58 (d, *J* = 8.2 Hz, 1H 6-H), 7.01 (d, *J* = 8.3 Hz, 1H, 7-H), 7.83–7.48 (m, 5H, C(O)C_6H_5, ArH), 4.67 (brs, 2H, P–NH), 8.17 (brs, 1H, NH–CO), 3.70 (t, 2H, OCH_2), 3.97 (t, 2H, CH_2Cl); Anal. Calcd for $C_{16}H_{15}N_3O_4PCl$: C, 50.61; H, 3.98; N, 11.07; Found: C, 50.52; H, 4.12; N, 11.20%.

2-Isopropoxycarbonylamino-5-benzoyl-2,3-dihydro-1H-1,3,2-diazaphosphole 2-oxide **(4d)**: Yield 52%; m.p. 158–160 °C; IR (KBr) cm^{-1}: 3360 (P–NH), 1706 (–COXR), 1618 (Ar–CO–Ar), 1284 (P=O); ^{31}P NMR (DMSO-d_6, δ ppm): –13.82, 0.91 ppm; ^{1}H NMR (DMSO-d_6) δ: 7.16 (s, 1H, 4-H), 6.56 (d, *J* = 8.5 Hz, 1H 6-H), 6.98 (d, *J* = 8.8 Hz, 1H, 7-H), 7.73–7.40 (m, 5H, C(O)C_6H_5, ArH), 5.53 (s, 2H, P–NH), 8.30 (brs, 1H, NH–CO), 4.78–4.70 (m, 1H, OCH), 1.24–1.11 (m, 6H, $2CH_3$); ^{13}C NMR (DMSO-d_6 δ ppm): 114.2 (s, 1C, C-4), 140.0 (s, 1C, C-5), 127.4 (s,1C, C-6), 121.5 (s, 1C, C-7) 136.5 (s, 1C, C-8), 140.0 (s, 1C, C-9), 195.2 (s, 1C, C-10), 140.0 (s, 1C, C-1'), 130.3 (s, 2C, C-2' and 6'), 129.4 (s, 2C, C-3' and 5'), 131.7 (s, 1C, C-4'), 145.3 (s, 1C, C-1"), 52.4 (s, 1C, C-2"); Anal. Calcd for $C_{17}H_{18}N_3O_4P$: C, 56.83; H, 5.05; N, 11.69; Found: C, 56.75; H, 4.93; N, 11.61%.

2-Isobutoxycarbonylamino-5-benzoyl-2,3-dihydro-1H-1,3,2-diazaphosphole 2-oxide **(4e)**: Yield 46%; m.p. 226–228 °C; IR (KBr) cm^{-1}: 3342 (P–NH), 1716 (–COXR), 1623 (Ar–CO–Ar), 1252 (P=O); ^{31}P NMR (DMSO-d_6, δ ppm): –15.11, 0.78; ^{1}H NMR (DMSO-d_6, δ ppm): 7.08 (s, 1H, 4-H), 6.55 (d, *J* = 8.2 Hz, 1H 6-H), 6.98 (d, *J* = 8.2 Hz, 1H, 7-H), 7.69–7.48 (m, 5H, C(O)C_6H_5, ArH), 5.48 (s, 1H, P–NH), 8.45 (brs, 1H, NH–CO), 3.30 (t, 2H, OCH_2), 2.54–2.50 (m, 2H, CH_2), 1.95–1.23 (m, 1H, CH), 0.83 (d, *J* = 7.2 Hz, 6H, $2CH_3$); Anal. Calcd for $C_{18}H_{20}N_3O_4P$: C, 57.91; H, 5.40; N, 11.26; Found: C, 58.12; H, 5.49; N, 11.18%.

2-(Prop-2-enyloxy)carbonylamino-5-benzoyl-2,3-dihydro-1H-1,3,2-diazaphosphole 2-oxide **(4f)**: Yield 49%; m.p. 165–167 °C; IR (KBr) cm^{-1}: 3363 (P–NH), 1712 (–COXR), 1618 (Ar–CO–Ar), 1284 (P=O); ^{31}P NMR (DMSO-d_6, δ ppm): –14.33, 0.98; ^{1}H NMR (DMSO-d_6, δ ppm): 7.16 (s, 1H, 4-H), 6.60 (d, *J* = 8.2 Hz, 1H 6-H), 7.00 (d, *J* = 8.2 Hz, 1H, 7-H), 7.90–7.47 (m, 5H, C(O)C_6H_5, ArH), 5.80 (s, 2H, P–NH), 8.70 (d, *J* = 8.6 Hz, 1H, NH–CO), 4.41 (d, *J* = 1.5 Hz, 1H, OCH_2), 5.98–5.80 (m, 1H, CH), 5.14 (d, J_{trans} = 11.3 Hz, CH_2), 5.17 (d, J_{cis} = 9.9 Hz, CH_2); FAB-MS *m/z* (%): 357 [(40, M$^+$)], 355 [100, (M$^+$–2H)], 329 (8), 289 (6), 243 (11), 176 (10), 154 (48), 137 (27), 107 (14); Anal. Calcd for $C_{17}H_{16}N_3O_4P$: C, 57.15; H, 4.51; N, 11.76; Found: C, 57.02; H, 4.61; N, 11.65%.

2-Cyclohexyloxycarbonylamino-5-benzoyl-2,3-dihydro-1H-1,3,2-diazaphosphole 2-oxide **(4g)**: Yield 51%; m.p.148–150 °C; IR (KBr) cm^{-1}: 3348 (P–NH), 1712 (–COXR), 1613 (Ar–CO–Ar), 1239 (P=O); ^{31}P NMR (DMSO-d_6, δ ppm): –15.33, 0.54; ^{1}H NMR (DMSO-d_6, δ ppm): 7.28 (s, 1H, 4-H), 6.82 (d, *J* = 8.2 Hz, 1H 6-H), 7.10 (d, *J* = 7.2 Hz, 1H, 7-H), 7.67–7.28 (m, 5H, C(O)C_6H_5, ArH), 4.47 (brs, 2H, P–NH), 8.30 (brs, 1H, NH–CO), 3.55 (s,1H, OCH), 1.70–1.22 (m, 10H, cyclohexyl-H); ^{13}C NMR (DMSO-d_6, δ ppm): 113.3 (s, 1C, C-4), 138.1 (s, 1C, C-5), 126.6 (s,1C, C-6), 120.0 (s, 1C, C-7) 136.8 (s, 1C, C-8), 138.1 (s, 1C, C-9), 195.1 (s, 1C, C-10), 138.1 (s, 1C, C-1'), 129.5 (s, 2C, C-2' and 6'), 128.8 (s, 2C, C-3' and 5'), 132.6 (s, 1C, C-4'), 143.0 (s, 1C, C-1"), 59.8 (s, 1C, C-2"), 46.0 (s, 1C, C-3"); 31.3 (s, 1C, C-4"), 29.2 (s, 1C, C-5"), 31.3 (s, 1C, C-6"); 46.0 (s, 1C, C-7"); FAB-MS *m/z* (%): 399 [13.6, (M$^+$)], 385 (15), 355 (12.2), 325 (12.2), 281 (23), 267 (9.5), 221 (22), 207 (35), 191 (12), 147 (100); Anal. Calcd for $C_{20}H_{22}N_3O_4P$: C, 60.15; H, 5.55; N, 10.52; Found: C, 60.02; H, 5.44; N, 10.63%.

2-Phenylmethoxycarbonylamino-5-benzoyl-2,3-dihydro-1H-1,3,2-diazaphosphole 2-oxide **(4h)**: Yield 51%; m.p. 83–85 °C; IR (KBr) cm^{-1}: 3361 (P–NH), 1719 (–COXR), 1630 (Ar–CO–Ar), 1261 (P=O); ^{31}P NMR (DMSO-d_6, δ ppm): 15.33, 0.54; ^{1}H NMR (DMSO-d_6, δ ppm): 7.17 (s, 1H, 4-H), 6.62 (d, *J* = 8.2 Hz, 1H 6-H), 7.10 (d, *J* = 8.4 Hz, 1H, 7-H), 7.70–7.38 (m, 5H C(O)C_6H_5, ArH), 5.66 (s, 2H,

Table 1 Antibacterial activity of **4a–j**

Compd	Zone of inhibition/mm			
	Staphylococcus aureus		*Escherichia coli*	
	25 (μg/disc)	75 (μg/disc)	25 (μg/disc)	75 (μg/disc)
4a	5	7	5	6
4b	4	6	6	8
4c	5	9	5	8
4d	6	7	6	7
4e	7	8	5	6
4f	5	6	7	8
4g	6	7	6	7
4h	5	8	5	9
4i	6	8	4	6
4j	5	6	5	7
Vancomycin	10	–	–	–
Gentamycin	–	–	8	–

Table 2 Antifungal activity of compounds

Compd	Zone of inhibition/mm			
	Aspergillus niger		*Fusarium solani*	
	25 (μg/disc)	75 (μg/disc)	25 (μg/disc)	75 (μg/disc)
4a	5	7	5	6
4b	4	6	6	8
4c	5	9	5	8
4d	6	7	5	7
4e	7	8	7	6
4f	5	6	6	8
4g	6	7	5	7
4h	5	8	4	9
4i	6	8	5	6
4j	5	6	6	7
Nystatin	10	–	–	–

P-NH), 8.30 (brs 1H, NH–CO), 4.37 (s, 2H, OCH_2), 8.03–7.98 (m, 5H, ArH); ^{13}C NMR (DMSO-d_6, δ ppm): 114.2 (s, 1C, C-4), 139.9 (s, 1C, C-5), 127.5 (s,1C, C-6), 121.6 (s, 1C, C-7) 137.2 (s, 1C, C-8), 139.9 (s, 1C, C-9), 194.5 (s, 1C, C-10), 139.9 (s, 1C, C-1'), 129.8 (s, 2C, C-2' and 6'), 128.9 (s, 2C, C-3' and 5'), 131.4 (s, 1C, C-4'), 144.2 (s, 1C, C-1"), 65.4 (s, 1C, C-2"), 136.5 (s, 1C, C-3"); 127.6 (s, 1C, C-4"), 128.5 (s, 1C, C-5"), 127.9 (s, 1C, C-6"); 128.5 (s, 1C, C-7"), 127.6 (s, 1C, C-8"); Anal. Calcd for $C_{21}H_{18}N_3O_4P$: C, 61.92; H, 4.45; N, 10.32; Found: C, 62.10; H, 4.61; N, 10.44%.

2-Phenylethoxycarbonylamino-5-benzoyl-2,3-dihydro-1H-1,3,2-diazaphosphole 2-oxide **(4i)**: Yield 54%; m.p.132–134 °C; IR (KBr) cm^{-1}: 3341 (P–NH), 1702 (–COXR), 1621 (Ar–CO–Ar), 1261 (P=O); ^{31}P NMR (DMSO-d_6, δ ppm): -15.54, 0.53; ^1H NMR (DMSO-d_6, δ ppm): 7.14 (s, 1H, 4-H), 6.65 (d, J = 7.8 Hz, 1H 6-H), 6.88 (d, J = 8.6 Hz, 1H, 7-H), 7.52–7.46 (m, 5H, $C(O)C_6H_5$, ArH), 4.95 (s, 2H, P–NH), 8.35 (s, 1H, NH–CO), 4.01 (t, 2H, OCH_2), 2.75 (t, 2H, CH_2 Ar), 7.21–7.12 (m, 5H, ArH); ^{13}C NMR (DMSO-d_6, δ ppm): 114.0 (s, 1C, C-4), 138.3 (s, 1C, C-5), 127.6 (s,1C, C-6), 121.4 (s, 1C, C-7) 137.4 (s, 1C, C-8), 138.3 (s, 1C, C-9), 194.1 (s, 1C, C-10), 138.3 (s, 1C, C-1'), 130.9 (s, 2C, C-2' and 6'), 129.4 (s, 2C, C-3' and 5'), 131.6 (s, 1C, C-4'), 143.1 (s, 1C, C-1"), 65.2 (s, 1C, C-2"), 34.5 (s, 1C, C-3"); 131.6 (s, 1C, C-4"), 127.9 (s, 1C, C-5"), 125.9 (s, 1C, C-6"), 128.4 (s, 1C, C-7"), 125.9 (s, 1C, C-8"), 127.9 (s, 1C, C-9"); Anal. Calcd for $C_{22}H_{20}N_3O_4P$: C, 62.71; H, 4.78; N, 9.97; Found: C, 62.58; H, 4.67; N, 10.09%.

2-Propylthiocarbonylamino-5-benzoyl-2,3-dihydro-1H-1,3,2-diazaphosphole 2-oxide **(4j)**: Yield 58%; m.p.159–161 °C; IR (KBr) cm^{-1}: 3361 (P–NH), 1712 (–COXR), 1618 (Ar–CO–Ar), 1249 (P=O); ^{31}P NMR (DMSO-d_6, δ ppm): –17.11, 0.48; ^1H NMR (DMSO-d_6, δ ppm): 7.21 (s, 1H, 4-H), 6.62 (d, J = 7.9 Hz, 1H, 6-H), 7.33 (d, J = 8.6 Hz, 1H, 7-H), 7.77–7.55 (m, 5H $C(O)C_6H_5$, ArH), 5.72 (s, 2H, P–NH), 9.23 (d, J = 10.8 Hz, 1H, NH–CO), 2.70 (t, 2H, SCH_2), 1.54-1.46 (m, 2H, CH_2), 0.89 (t, 3H, CH_3); Anal. Calcd for $C_{17}H_{18}N_3O_3PS$: C, 54.39; H, 4.83, N, 11.19; Found: C, 54.26; H, 4.69; N, 11.32%.

Biological activity

It has been found that benzodiazaphospholes and their phosphorus carbamates are expected to possess broad spectrum of biological activity with less toxicity.[21]

Antibacterial activity

All the compounds (**4a–j**) were tested for their antibacterial activity against *Staphylococcus aureus* and *Escherichia coli*.

Various concentrations of synthesised compounds (25, 75 μg/disc) dissolved in dimethyl formamide (DMF) were added to each filter paper disc and DMF was used as control. Plates were incubated at 37 °C and examined for zone of inhibition around each disc after 24 h (Table 1). The antibacterial activity was evaluated by measuring zone of inhibition against test organisms. The results were compared with commercial standard antibiotics like vancomycin and gentamycin (25 μg/disc). Three replicates were used for each observation.

Antifungal activity

The antifungal bioassay for all the title compounds (**4a–j**), were tested against *Aspergillus niger* and *Fusarium solani* by the disc method in potato-dextrose-agar (PDA) medium with various concentrations (25, 75 μg/disc). The fungi test plates were incubated for 72 h at 28 °C. The antifungal activity was evaluated by measuring the zone of inhibition against test organisms. Nystatin was used as commercial standard. Most of the tested compounds showed moderate antifungal activity.

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