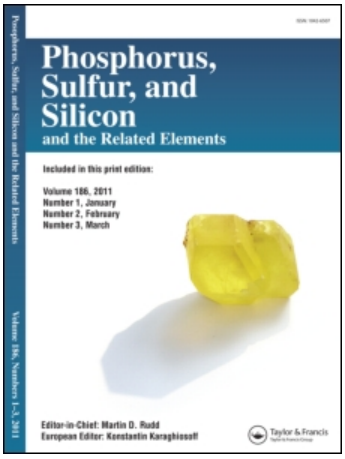

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Synthesis and Biological Activity of Novel Phosphonate Derivatives Containing of Pyridyl and 1,2,3-Triazole Rings

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Synthesis and Biological Activity of Novel Phosphonate Derivatives Containing of Pyridyl and 1,2,3-Triazole Rings

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In order to search for novel agrochemicals with high activity and low toxicity, a series of phosphonate derivatives containing 1,2,3-triazolyl and pyridyl rings were synthesized using 2-chloro-5-(chloromethyl)-pyridine as the starting material. IR, 1 H NMR, 31P NMR, MS, and elemental analyses confirmed their structures. The crystal structure of ***5a*** *was determined by single crystal X-ray diffraction. Preliminary bioassays indicated that some of them possess good herbicidal and moderate fungicidal activities.*

Keywords 1,2,3-triazole; α-hydroxyalkylphosphonate; biological activity; pyridine

INTRODUCTION

It is well known that many triazole-related molecules play an important role in the development of agrochemicals such as insecticides, nematocides, acaricide, and plant-growth regulators.[1–4] In the study of pharmaceuticals and agrochemicals, the introduction of pyridine into the parent compounds may improve the properties and biological activities of the compounds, and many pyridyl containing compounds are known to possess a wide range of biological and pharmacological activities,[5–8] as well as low toxicity toward mammals. Moreover, a variety of the reports regarding synthetic studies of the α-hydroxyalkylphosphonate derivatives have been presented due to the chemical and biological interests such as its strong inhibitory effects against various enzymes.[9–10] As a continuation of our research work—with an attempt to find novel agrochemicals having high activity and low toxicity[11–12]— in this paper,

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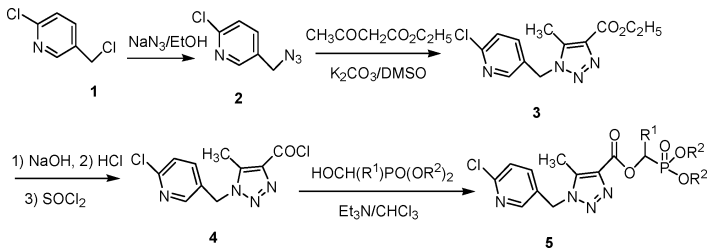
we wish to report the synthesis and biological activities of the target compounds **5**, in which a pyridyl and 1,2,3-triazolyl rings are introduced to α-hydroxyalkylphosphonate moiety.

RESULTS AND DISCUSSION

Synthesis and Structure of the Title Compounds 5

A series of novel phosphonate derivatives containing 1,2,3-triazolyl and pyridyl rings 5a∼h were synthesized as shown in Scheme 1.



$R^1 = C_6H_5$, $R^2 = C_2H_5$ (5a); R^1 = 4-ClC_6H_4, $R^2 = CH_3$ (5b); R^1 = 2,4-$Cl_2C_6H_3$, $R^2 = C_2H_5$ (5c); $R^1 = C_6H_5$, $R^2 = CH_3$ (5d); R^1 = 4-$CH_3OC_6H_4$, $R^2 = C_2H_5$ (5e); R^1 = 2-ClC_6H_4, $R^2 = CH_3$ (5f); R^1 = 4-ClC_6H_4, $R^2 = CH_3$ (5g); $R^1 = CH_3$, $R^2 = CH_3$ (5h)

SCHEME 1

5-(Azidomethyl)-2-chloro-pyridine 2 can be prepared from the corresponding chloride **1** with sodium azide in dry ethanol. 1-[(6-Chloropyridin-3-yl) methyl]-4-ethoxycarbonyl-5-methyl-1*H*-1,2,3-triazole **3** can be conveniently synthesized via the cyclization of compound **2** with ethyl acetylacetate and anhydrous potassium carbonate in DMSO. Carbonyl chloride **4** can be obtained in a moderate yield by the saponification of compound **3** followed by the reaction with thionyl chloride. Carbonyl chloride **4** reacted with various α-hydroxyalkylphosphonates in triethylamine-chloroform system at room temperature to give the target compounds **5** in good yields (78∼93%).

The addition of a base (triethylamine or pyridine) was essential to the condensation reaction. Without triethylamine or pyridine, the reaction was greatly slowed and the yields were very low even at refluxing temperature. Moreover, the reactions are significantly affected by the electronic and stereo-hindered effects of α-hydroxyalkylphosphonates. When the electron-withdrawing substituents are attached to α-hydroxyalkylphosphonates, the reactions undergo much faster than that of electron-donating one.

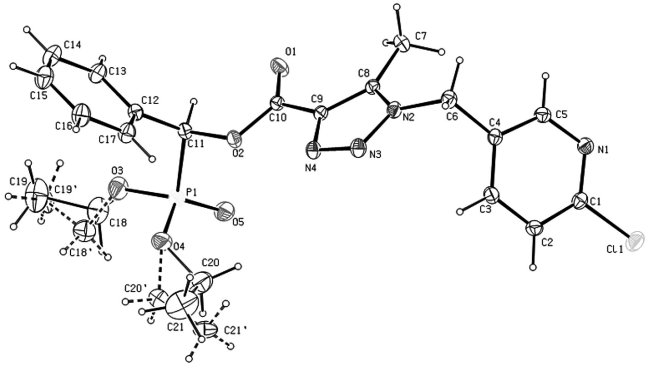


FIGURE 1 The molecular structure of 5a, showing 50 % probability displacement ellipsoids and the atom-numbering scheme. Both disorder components are shown.

Their structures of compounds **5** were confirmed by IR, ^{1}H NMR, ^{31}P NMR, EI-MS, and elemental analyses, all spectra data were consistent with the assigned structures, which were listed in the experimental part.

Moreover, in order to confirm its structure and investigate its stereochemistry, a single crystal of **5a** was obtained from acetone and petroleum ether (1:1 v/v) solvent system. X-ray diffraction analysis indicated that the single crystal of **5a** is triclinic, space group P-1, cell parameters A = 8.530 (1), B = 9.621 (1), C = 14.639 (1) Å, α = 95.865 (2), β = 92.955 (2), γ = 90.536 (2)°, V = 1193.4 (2) Å^3, Z = 2, Dx = 1.333 g/cm^3, F (000) = 500, μ = 0.266 mm,$^{-1}$ and final R = 0.0656, wR = 0.1720 for 4282 reflections (I > 2σ(I)). Figures 1 and 2 are the molecular structure of compound **5a** and packing of the molecules in the unit cell, respectively.

The selected bond distances and angles are listed in Table I. The C9-N4 and C8-N2 bonds are significantly shorter than a normal single C—N bond[13] and are close to the value for a C=N bond,[14] this indicates significant electron delocalization in the triazolyl system. The O5-P1-O4,

TABLE I Selected Geometric Parameters (Å, °)

C8-N2	1342 (3)	C9-N4	1.364 (3)
O5-P1-O4	116.88 (15)	O5-P1-C11	113.10 (13)
O5-P1-O3	117.06 (16)	O4-P1-C11	105.50 (13)
O4-P1-O3	102.06 (17)	O3-P1-C11	100.20 (13)

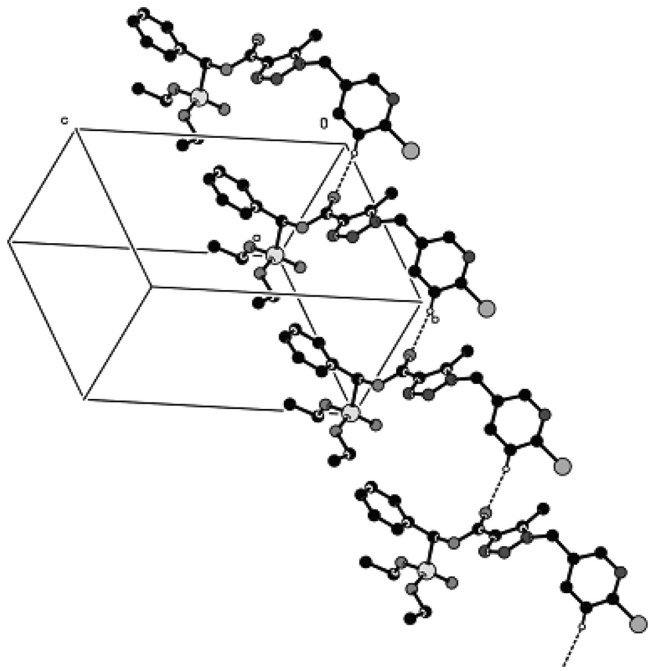


FIGURE 2 Packing of the molecules in the unit cell, showing the formation of C-H. . . O hydrogen bonds (dashed lines).

O5-P1-O3, and O5-P1-C11 bond angles are larger than the O4-P1-O3, O4-P1-C11, and O3-P1-C11, indicating a distorted tetrahedral configuration for the P atom. Intra- and intermolecular C-H. . . O hydrogen bonds contribute strongly to the stability of the molecular configuration (Figure 2 and Table II). In addition, short intermolecular distances between the centroids of the N1-C1/C2/C3-C4-C5 rings (centroid Cg1) and the parallel pyridine rings of adjacent molecules indicate the presence of $\pi - \pi$ stacking interactions in the crystal structure,[15] with a centroid-to-centroid distance of 3.841 (2) Å, dihedral angle of 0.00 (1)°, and a shortest interplanar distance of 3.478 (1) Å; symmetry code: (i) -1-x, 2-y, -z.

Biological Activities

Herbicidal Activity

The herbicidal activity of the title compounds **5** against *Brassica napus* (oil rape) and *Echinochloa crus-galli* (barnyard grass) were measured according to the method described in the experimental section.

The preliminary results of bioassay showed that some of compounds **5** possess potent and selective herbicidal activities against dicotyledonous weeds such as oil rape at the dosage of 100 mg/L. For example, compounds **5c**, **5d,** and **5g** exhibit 77.6%, 76.5%, and 62.4% inhibitory activity against root of rape, respectively. It is also found that compounds 5 exhibit a stronger inhibitory effect against root of rape than that of stem (see Table III).

Fungicidal Activities

The preliminary fungicidal activities of the target compounds **5** were evaluated by the classic plate method at a concentration of 100 mg/L. The six fungi used, *Fusarium oxysporium, Rhizoctonia solani, Botrytis cinereapers, Gibberella zeae, Dothiorella gregaria,* and *Colletotrichum gossypi*, belong to the group of field fungi and were isolated from corresponding crops. The activity data were listed in Table III. The results indicated that most of compounds **5** exhibit moderate to weak inhibitory activities against the above six fungi.

EXPERIMENTAL

Melting points were determined with a WRS-1B digital melting point apparatus, and uncorrected. ^{1}H NMR and ^{31}P NMR spectra were recorded with a VARIAN MERCURY-PLUS400 spectrometer with TMS and 85% H_3PO_4 as the internal and external references, respectively, and $CDCl_3$ as the solvent; while mass spectra were obtained with a Finnigan TRACEMS2000 spectrometer using the EI method. IR spectra were measured by a NICOLET NEXUS470 spectrometer. Elemental analyses were performed with an ELEMENTAR Vario EL III CHNSO elementary analyzer. X-ray diffraction analysis was carried out with a BRUKER SMART APEX CCD X-ray diffraction instrument. All of the solvents and materials were reagent grade and purified as required. α-hydroxyalkylphosphonate was prepared according to the literature procedure.[15–16]

TABLE II Hydrogen-bond Geometry (Å, °)

D-H...A	D-H	H...A	D...A	D-H...A
C7-H7B...O1	0.96	2.59	3.158 (3)	118
C2-H2...O1^{i}	0.93	2.44	3.333 (3)	162

Symmetry code: (i) x, y+1, z.

TABLE III The Herbicidal and Fungicidal Activities of Compounds 5 (Inhibitory Rate %)

	Herbicidal activity				Fungicidal activity (100 mg/L)					
	oil rape (root/stem)		barnyard (root/stem)							
Compound	100 (mg/L)	10 (mg/L)	100 (mg/L)	10 (mg/L)	*Fusarium oxysporium*	*Rhizoctonia solani*	*Botrytis cinereapers*	*Gibberella zeae*	*Dothiorella gregaria*	*Colletotrichum gossypii*
5a	49.4/52.0	48.2/52.0	30.0/37.8	26.0/26.7	30.4	40.2	19.4	40.6	11.5	37.0
5b	56.5/60.0	38.8/48.0	44.0/44.4	32.0/28.9	30.4	46.4	25.0	37.5	15.4	33.3
5c	77.6/68.0	38.8/64.0	40.0/28.9	36.0/26.7	34.8	60.8	47.2	53.1	30.8	37.0
5d	50.6/60.0	29.4/60.0	42.0/31.1	28.0/24.4	26.09	30.9	11.1	31.3	38.5	14.8
5e	55.3/60.0	34.1/60.0	30.0/33.3	16.0/22.2	30.4	36.1	5.6	15.6	11.5	25.9
5f	41.2/60.0	20.0/60.0	20.0/31.1	12.0/33.3	26.1	30.9	44.4	15.6	0.0	25.9
5g	76.5/60.0	60.0/20.0	40.0/11.1	38.0/4.4	30.4	41.2	22.2	43.8	15.4	29.6
5h	62.4/28.0	23.5/24.0	36.0/22.2	30.0/11.1	34.8	38.1	5.6	34.4	0.0	25.9

Synthesis of 5-(Azidomethyl)-2-chloro-pyridine 2

Sodium azide (7.8 g, 0.12 mol) was added to a solution of 2-chloro-5-(chloromethyl)-pyridine (16.1 g, 0.1 mol) in dry ethanol (80 mL) and refluxed for 6 hours (monitored by thin-layer chromatography). The workup involved stripping of the solvent followed by addition of water and extraction of the product mixture into CH_2Cl_2, after phase separation, drying over anhydrous sodium sulfate, filtration and evaporation, compound **2** was obtained as an amber oil (yield: 95%), which can be used without further purification.^{1}H NMR ($CDCl_3$, 400 MHz) δ: 4.45 (s, 2H, CH_2), 7.53 (d, $J = 8.0$ Hz, 1H, Py-H), 7.66 (d, $J = 8.0$ Hz, 1H, Py-H), 8.38 (s, 1H, Py-H).

Synthesis of 1-[(6-chloro-pyridin-3-yl)methyl]-4-ethoxycarbonyl-5-methyl-1H-1,2,3-triazole 3

5-(azidomethyl)-2-chloro-pyridine **2** (8.4 g, 50 mmol) and ethyl acetylacetate (6.5 g, 50 mmol) were added to a suspension of milled potassium carbonate (3.45 g, 25 mmol) in DMSO (50 mL). The mixture was stirred at room temperature for 6 h (monitored by thin-layer chromatography) and poured to water (500 mL). The solid was collected by filtration, washed with water and diethyl ether, respectively, and dried to give **3** as a light yellow solid (yield: 95%, m.p. 88–90°C). ^{1}H NMR ($CDCl_3$, 400 MHz) δ: 1.42 (t, 3H, $OCH_2\underline{CH_3}$), 2.52 (s, 3H, CH_3), 4.42 (q, 2H, $O\underline{CH_2}CH_3$), 5.54 (s, 2H, CH_2), 7.35 (d, $J = 8.4$ Hz, 1H, Py-H), 7.45 (d, $J = 8$ Hz, 1H, Py-H), 8.34 (s, 1H, Py-H).

Synthesis of 1-[(6-chloro-pyridin-3-yl)methyl]-5-methyl-1H-1,2,3-triazole-4-carbonyl chloride 4

A mixture of **3** (8.4 g, 30 mmol), NaOH powder (1.8 g, 45 mmol) and water (50 mL) was refluxed for 2 h; after cooling, the solution was acidified with 10% HCl to pH 4, The solid was collected by filtration and dried to give carboxylic acid as a light yellow solid, yield: 96%, m.p. 159∼161°C. ^{1}H NMR (DMSO-d_6, 400 MHz) δ: 2.51 (s, 3H, CH_3), 5.69 (s, 2H, CH_2), 7.53 (d, $J = 8$ Hz, 1H, Py-H), 7.69 (d, $J = 8$ Hz, 1H, Py-H), 8.41 (s, 1H, Py-H), 13.06 (s, br, 1H, OH).

A mixture of carboxylic acid (2.52 g, 10 mmol) and thionyl chloride (3.54 g, 30 mmol) in chloroform (30 mL) was refluxed for 5–6 h. After the removal of solvent and excess thionyl chloride under vacuum, chloroform (30 mL) was added, filtered and evaporated to get **4** as a light yellow solid (yield: 85%, m.p. 105–107°C), which can be used without further purification.

General Procedure for the Preparation of O,O-dialkyl 1-[(6-Chloro-pyridin-3-yl)methyl]-5-methyl-1H-1,2,3-triazol-4-yl carbonyloxy substituted methyl phosphonate 5a–h.

A solution of 4 (0.59 g, 2.2 mmol) in anhydrous chloroform (10 mL) was added dropwise to a stirred mixture of α-hydroxyalkylphosphonate (2 mmol) and triethylamine (0.22 g, 2.2 mmol) in chloroform (25 mL) at 0∼5°C. After the addition complete, the mixture was stirred at room temperature for 6 h until the reaction was complete (monitored by thin-layer chromatography). The workup involved washing with dilute hydrochloride acid, saturated sodium bicarbonate and brine, respectively. After phase separation, drying over anhydrous sodium sulfate, filtration, and evaporation, the residue was purified by flash column chromatography on silica gel using acetone and petroleum ether (1:1 v/v) as eluent, giving the target compound **5a-h** in 85∼93% yields.

O,O-Diethyl 1-[(6-chloropyridin-3-yl) methyl]-5-methyl-1H-1, 2,3-triazol-4–ylcarbonyloxy-phenylmethyl phosphonate (5a)

White solid, m.p. 145–147°C, yield: 85%; ^{1}H NMR ($CDCl_3$, 400 MHz) δ: 1.22–1.26 (m, 6H, $2OCH_2\underline{CH_3}$), 2.55 (s, 3H, CH_3), 4.06–4.10 (m, 4H, $2OCH_2\underline{CH_3}$), 5.52 (s, 2H, CH_2), 6.38 (d, $J = 13.2$ Hz, 1H, CH), 7.27–7.58 (m, 7H, Ar-H, Py-H), 8.37 (s, 1H, Py-H); ^{31}P NMR ($CDCl_3$, 162 MHz) δ: 15.24; IR (KBr) υ:1717 (C=O), 1469, 1234 (P=O), 1188 (C-O-C), 1034 (P-O-C), 976 (P-C); MS (70 eV) m/z (%): 478 (M^+, 8.7), 341 (26.3), 236 (27.3), 234 (80.0), 137 (15.6), 126 (100), 110 (5.7), 91 (56.1), 81 (24.8), 77 (16.7); Anal. Calcd. for $C_{21}H_{24}ClN_4O_5P$: C 52.67, H 5.05, N 11.70; found: C 52.49, H 5.31, N 11.99.

O,O-Diethyl 1-[(6-chloropyridin-3-yl) methyl]-5-methyl-1H-1,2,3-triazol-4-ylcarbonyloxy-4-chlorophenylmethyl phosphonate (5b)

Yellow oil, yield: 88%; ^{1}H NMR ($CDCl_3$, 400 MHz) δ: 1.27–1.31 (m, 6H, $2OCH_2\underline{CH_3}$), 2.17 (s, 3H, CH_3), 4.14–4.18 (m, 4H, $2O\underline{CH_2}CH_3$), 5.51 (s, 2H, CH_2), 6.77 (d, $J = 14.0$ Hz, 1H, CH), 7.30–7.51 (m, 5H, Ar-H, Py-H), 7.69 (d, $J = 8.4$ Hz, 1H, Py-H), 8.36 (s, 1H, Py-H); IR (KBr, cm^{-1})υ: 1732 (C=O), 1462, 1259 (P=O), 1163 (C-O-C), 1024 (P-O-C), 974 (P-C); MS (70 eV) m/z (%): 512 (M^+, 7.0), 276 (58.9), 236 (42.7), 137 (58.3), 126 (100), 110 (14.4), 91 (12.7), 81 (32.4), 77 (10.6); Anal. Calcd. for $C_{21}H_{23}Cl_2N_4O_5P$: C 49.14, H 4.52, N 10.91; found: C 49.39, H 4.34, N 10.63.

O,O-Diethyl 1-[(6-chloropyridin-3-yl)methyl]-5-methyl-1H-1,2, 3-triazol-4-ylcarbonyloxy-2,4-dichlorophenylmethyl phosphonate (5c)

Yellow oil, yield: 92%; ^{1}H NMR ($CDCl_3$, 400 MHz) δ: 1.23–1.26 (m, 6H, $2OCH_2\underline{CH_3}$), 2.54 (s, 3H, CH_3), 4.04–4.07 (m, 4H, $2O\underline{CH_2}CH_3$), 5.53 (s, 2H, CH_2), 6.32 (d, $J = 13.6$ Hz, 1H, CH), 7.33–7.54 (m, 5H, Ar-H, Py-H), 8.37 (s, 1H, Py-H); MS (70 eV) *m/z* (%): 546 (M^+, 5.8), 409 (9.4), 310 (14.5), 236 (51.0), 137 (14.4), 126 (100), 110 (16.0), 91 (17.9), 81 (32.8), 77 (4.6); Anal. Calcd. for $C_{21}H_{22}Cl_3N_4O_5P$: C 46.05, H 4.05, N 10.23; found: C 46.31, H 4.17, N 9.97.

O,O-Dimethyl 1-[(6-chloropyridin-3-yl)methyl]-5-methyl-1H-1, 2,3-triazol-4-ylcarbonyloxy-phenylmethyl phosphonate (5d)

Yellow oil, yield: 93%; ^{1}H NMR ($CDCl_3$, 400 MHz) δ: 2.55 (s, 3H, CH_3), 3.69–3.72 (m, 6H, $2OCH_3$), 5.52 (s, 2H, CH_2), 6.40 (d, $J = 13.6$ Hz, 1H, CH), 7.33–7.59 (m, 6H, Ar-H, Py-H), 8.37 (s, 1H, Py-H); Anal. Calcd. for $C_{19}H_{20}ClN_4O_5P$: C 50.62, H 4.47, N 12.43; found: C 50.49, H 4.63, N 12.58.

O,O-Diethyl 1-[(6-chloropyridin-3-yl)methyl]-5-methyl-1H-1,2, 3-triazol-4-ylcarboxyloxy-4-methoxyphenylmethyl phosphonate (5e)

Yellow oil, yield: 89%; ^{1}H NMR ($CDCl_3$, 400 MHz) δ: 1.21–1.25 (m, 6H, $2OCH_2\underline{CH_3}$), 2.54 (s, 3H, CH_3), 3.80 (s, 3H, OCH_3), 4.04–4.08 (m, 4H, $2O\underline{CH_2}CH_3$), 5.52 (s, 2H, CH_2), 6.31 (d, $J = 12.8$ Hz, 1H, CH), 7.33–7.53 (m, 6H, Ar-H, Py-H), 8.36 (s, 1H, Py-H); MS (70 eV) *m/z* (%): 508 (M^+, 16.9), 371 (10.4), 272 (61.3), 236 (4.58), 137 (10.1), 135 (100), 126 (50.7), 110 (4.1), 91 (8.4), 81 (9.9), 77 (12.4); Anal. Calcd. for $C_{22}H_{26}ClN_4O_6P$: C 51.92, H 5.15, N 11.01; found: C 52.17, H 5.18, N 11.36.

O,O-Dimethyl 1-[(6-chloropyridin-3-yl)methyl]-5-methyl-1H-1, 2,3-triazol-4-ylcarboxyloxy-2-chlorophenylmethyl phosphonate (5f)

Yellow oil, yield: 90%; ^{1}H NMR ($CDCl_3$, 400 MHz) δ: 2.53 (s, 3H, CH_3), 3.78-3.82 (m, 6H, $2OCH_3$), 5.52 (s, 2H, CH_2), 6.90 (d, $J = 13.2$ Hz, 1H, CH), 7.28-7.40 (m, 4H, Ar-H), 7.50 (d, $J = 8.4$ Hz, 1H, Py-H), 7.53 (d, $J = 7.6$ Hz, 1H, Py-H), 8.36 (s, 1H, Py-H); ^{31}P NMR ($CDCl_3$, 162 MHz) δ: 16.75; MS (70 eV) *m/z* (%): 484 (M^+, 8.7), 375 (64.6), 248 (13.0), 236 (4.58), 139 (100), 126 (77.1), 110 (18.8), 109 (60.4), 91 (18.8), 81 (7.7), 77 (33.2); Anal. Calcd. for $C_{19}H_{19}Cl_2N_4O_5P$: C 47.03, H 3.95, N 11.55; found: C 47.28, H 4.08, N 11.17.

O,O-Dimethyl 1-[(6-chloropyridin-3-yl)methyl]-5-methyl-1H-1,2,3-triazol-4-ylcarboxyloxy-4-chlorophenylmethyl) phosphonate (5g)

Yellow oil, yield: 92 %; ^{1}H NMR ($CDCl_3$, 400 MHz) δ: 2.54 (s, 3H, CH_3), 3.73-3.78 (m, 6H, $2OCH_3$), 5.53 (s, 2H, CH_2), 6.35 (d, $J = 13.2$ Hz, 1H, CH), 7.34-7.54 (m, 6H, Ar-H, Py-H), 8.36 (s, 1H, Py-H); ^{31}P NMR ($CDCl_3$, 162 MHz) δ: 16.81; Anal. Calcd. for $C_{19}H_{19}Cl_2N_4O_5P$: C 47.03, H 3.95, N 11.55; found: C 46.91, H 3.70, N 11.82.

O,O-Dimethyl 1-[(6-chloropyridin-3-yl)methyl]-5-methyl-1H-1, 2,3 -triazol-4-yl carboxyloxy-2-ethyl phosphonate (5h)

Yellow oil, yield: 87%; ^{1}H NMR ($CDCl_3$, 400 MHz) δ: 1.58 (q, $J = 6.8$ Hz, 3H, $CH\underline{CH_3}$), 2.53 (s, 3H, CH_3), 3.81–3.92 (m, 6H, $2OCH_3$), 5.53 (q, $J = 7.6$ Hz, 1H, CH), 5.59 (s, 2H, CH_2), 7.34 (d, $J = 8.4$ Hz, 1H, Py-H), 7.52 (d, $J = 8$ Hz, 1H, Py-H), 8.37 (s, 1H, Py-H); ^{31}P NMR ($CDCl_3$, 162 MHz) δ: 21.08; IR (KBr) υ:1736 (C=O), 1460, 1244 (P=O), 1186 (C-O-C), 1044 (P-O-C), 831 (P-C); Anal. Calcd. for $C_{14}H_{18}ClN_4O_5P$: C 43.25, H 4.67, N 14.41; found: C 43.38, H 4.30, N 14.18.

Bioassay Methods

Herbicidal Activities Testing

Herbicidal testing of the newly synthesized compounds **5** was carried out in a greenhouse, with temperature 23 ± 1°C, RH 60 ± 5%, light intensity 10 Klux, photoperiod 8 h/day. Twenty seeds of each weed species including rape and barnyard grass were chosen for testing. Seedlings were grown in the test plate of 9 cm diameter containing two pieces of filter paper and 9 mL solution of the tested compound (100 mg/L and 10 mg/L, respectively). Distilled water was used as a comparison compound. The herbicidal activity was assessed as the inhibitory rate in comparison with the distilled water. The herbicidal rating score based on visual observation. Range from 0–100 %; 0 means no effect; 100% means complete killing. The test was run three times, and the results were averaged and given as activity in Table III.

Fungicidal Activity Testing

The fungicidal activity measurement method was adapted from the one described by Molina Torres et al.[17] The synthesized target compounds were dissolved in 0.5–1.0 mL of DMF to the concentration of 1000 mg/L. The solutions (1 mL) were mixed rapidly with thawed potato glucose agar culture medium (9 mL) under 50°C. The mixtures were poured into Petri dishes. After the dished were cooled, the solidified plates were incubated with 4 mm mycelium disk, inverted, and

incubated at 28°C for 48 h. Water was used as the blank control. Three replicates of each test were carried out. The mycelial elongation radius (mm) of fungi settlements was measured after 48 h of culture. The growth inhibitory rates were calculated with the following equation: $I = [(C - T)/C] * 100\%$. Here, I is the growth inhibitory rate (%), and T is the treatment group fungi settlement radius (mm). The results are also given in Table III.

The bioassays also indicated that most of the **5** compounds did not display inhibitory effect against *aphides* and *Tetranychus urticae* at the dosage of 250 mg/L, further structure-activity relationships are under investigation.

CONCLUSIONS

In conclusion, we have synthesized a series of phosphonate derivatives containing 1,2,3-triazolyl and pyridyl rings using 2-chloro-5-(chloromethyl)-pyridine as the starting material. Preliminary bioassays indicated that some of them possess good herbicidal and moderate fungicidal activities.

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