

# Syntheses and Herbicidal Activity of [(Dialkylamino)alkoxymethylene]phosphoramidic Esters

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Twenty [(dialkylamino)alkoxymethylene]phosphoramidic esters were prepared and tested for postemergent herbicide activity. Results of the herbicidal activity at 6000, 2000, and 1000 ppm are given. While many of the compounds showed excellent activity at the higher dose rates, their activity declined markedly at the lower doses. Details of the syntheses and test results are given.

In a 1975 patent (Kosinskaya et al., 1975) and subsequent paper (Kosinskaya et al., 1976) the preparation and some chemistry of [(dialkylamino)alkoxymethylene]phosphoramidic esters are described. These compounds were stated to be physiologically active. During this same period we also prepared a number of these compounds and studied their herbicidal activity. It is the purpose of this paper to describe our work in this area.

We prepared these compounds by one of two methods. In the first method (Scheme I) phosphorus oxychloride was added to dialkylcyanamides by the method of Schindler (1973), and sodium alkoxides were then added to the resulting trichlorides, A. The second method was the same as that used by Kosinskaya et al. (1975) and is shown in Scheme II. This method is more general than the former in that it allows the synthesis of compounds where R, R', and R'' could all be the same or could all be different. Table I lists the compounds prepared for this study along with their yields, boiling points, and analysis. All compounds gave infrared and NMR spectra that were in full agreement with the assigned structures.

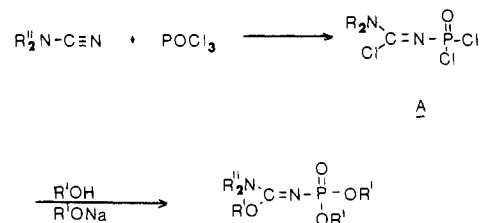
## EXPERIMENTAL SECTION

All boiling points and melting points are uncorrected, Proton NMR spectra were determined in CDCl<sub>3</sub> with Me<sub>4</sub>Si as the internal standard. The following three experiments were chosen as representative of the preparations of compounds in Table I.

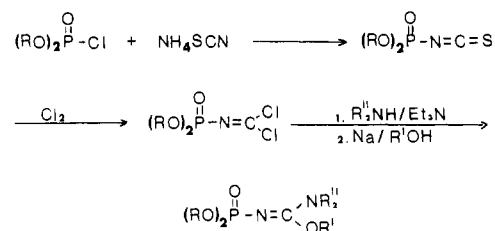
**N'-[Bis(pentyloxy)phosphinyl]-N,N-diethylcarbamimidic Acid Pentyl Ester (17).** The method of Scheme I was followed. N'-(Dichlorophosphinyl)-N,N-diethylcarbamimidic chloride was prepared by the method of Schindler (1973). A solution of this compound (15 g) in dry pentanol (200 mL) was added to a mixture of sodium (4.2 g) in dry pentanol (300 mL). The mixture was stirred for 2 h and then allowed to stand overnight. Water (200 mL) was then added followed by ether (300 mL). The phases were separated, and the aqueous phase was washed once more with ether. The combined organic phases were distilled to remove ether and pentanol, and the residue was then distilled, bp 66–110 °C (0.35 mm). This crude material was redistilled to give the title compound: bp 105–110 °C (0.25 mm); <sup>1</sup>H NMR δ 0.7–2.0 (33 H, m, center peaks of two triplets at 0.9 and 1.18 occur in this multiplet), 3.45 (4 H, q, J = 7 Hz), 3.7–4.25 (4 H, m), (2 H, t, J = 7 Hz).

**N'-(Dibutoxyphosphinyl)-N,N-bis(1-methylethyl)-carbamimidic Acid Propyl Ester (4).** The method of Scheme II was followed. Dibutyl phosphorochloridate was prepared by the method of Poshkus and Herwek (1957)

## Scheme I



## Scheme II



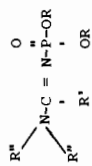
and then converted to the corresponding isothiocyanate by the method of Kulka (1959). This isothiocyanate was then chlorinated with chlorine at -10 °C following the method of Alimov and Levkova (1964). The chlorination was monitored by following the disappearance of the isothiocyanate band at 2000 cm<sup>-1</sup>, and when this had gone, the (dichloromethylene)phosphoramidic acid dibutyl ester was distilled, bp 130–140 °C.

A solution of (dichloromethylene)phosphoramidic acid dibutyl ester (15 g) in toluene (100 mL) was cooled to -30 °C, and then a solution of diisopropylamine (6.5 mL) and triethylamine (6.6 mL) in toluene (50 mL) was added dropwise. After complete addition the reaction mixture was allowed to warm to room temperature and was then centrifuged to settle out the precipitated triethylamine hydrochloride. The solution was decanted from this salt and then added dropwise to a solution of sodium (1.1 g) dissolved in 1-propanol (50 mL). The mixture was warmed to 80 °C for 2 h, followed by removal of about half the solvents under reduced pressure. The remainder was extracted with two portions (50 mL) of water, and the toluene layer was then dried. The toluene was removed under reduced pressure, and the residue was distilled: bp 147–151 °C (0.15 mm); <sup>1</sup>H NMR δ 0.7–2.0 (31 H, m, a doublet at 1.25, J = 7 Hz, occurs within this multiplet), 3.7–4.5 (8 H, m).






**N'-(Dibutoxyphosphinyl)-N,N-diethylcarbamimidiothioic Acid Butyl Ester (19).** A solution of (dichloromethylene)phosphoramidic acid dibutyl ester (15 g) in toluene (75 mL) was cooled to -30 °C, and then a solution of diethylamine (5.2 mL) and triethylamine (7.5 mL) in toluene (2.5 mL) was added dropwise. After addition, the mixture was allowed to warm to room temperature and

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TABLE I



HERBICIDAL ACTIVITY AT 6000 ppm

COMPOUND NUMBER	R <sup>n</sup>	R <sup>1</sup>	R	% YIELD	bp. (mm)	EMPIRICAL FORMULA	CALCULATED			FOUND			N	PIG-WEED <sup>c</sup>	BARN-YARD GRASS <sup>d</sup>	JIN-SON WEED <sup>e</sup>	CRAB-GRASS <sup>f</sup>	MORNING GLORY <sup>g</sup>	GIANT FORTALL <sup>h</sup>	ACTIVITY SCORE <sup>i</sup>
							C	H	N	C	H	N								
1	i Pr	O Et	Et	60.4	121 (0.07)	C <sub>13</sub> H <sub>23</sub> N <sub>2</sub> O <sub>4</sub> P	50.63	9.48	9.08	49.18	9.06	8.96	100	95	50	75	95	60	475	
2	i Pr	O i Pr	Et	56.5	120-122 (0.07)	C <sub>14</sub> H <sub>25</sub> N <sub>2</sub> O <sub>4</sub> P	52.16	9.68	8.68	50.69	9.26	8.22	100	95	95	50	95	35	470	
3	i Pr	O n-Bu	Et	56.5	126-131 (0.07)	C <sub>15</sub> H <sub>27</sub> N <sub>2</sub> O <sub>4</sub> P	53.55	9.89	8.32	52.03	9.46	9.30	100	100	100	100	100	95	595	
4	i Pr	O n-Pr	n-Bu	73	147-151 (0.15)	C <sub>16</sub> H <sub>29</sub> N <sub>2</sub> O <sub>4</sub> P	57.12	10.39	7.40	56.69	10.18	7.34	100	95	0	60	100	85	440	
5	i Pr	O n-Pentyl	n-Bu	73	175-182 (0.4)	C <sub>20</sub> H <sub>43</sub> N <sub>2</sub> O <sub>4</sub> P	59.09	10.66	6.89	59.29	10.49	6.65	100	100	100	100	100	100	600	
6	Et	O Me	Et	16.6	104-108 (0.02)	C <sub>10</sub> H <sub>23</sub> N <sub>2</sub> O <sub>4</sub> P	45.10	8.71	10.52	43.00	8.29	10.08	0	15	0	10	10	10	45	
7	Et	O n-hexyl	Et	41.5	149-150 (0.18)	C <sub>15</sub> H <sub>33</sub> N <sub>2</sub> O <sub>4</sub> P	53.55	9.89	8.32	53.64	9.59	8.40	100	100	100	100	100	100	600	
8	Et	O n-Pr	n-Bu	62	153-155 (0.20)	C <sub>16</sub> H <sub>35</sub> N <sub>2</sub> O <sub>4</sub> P	54.89	10.07	7.99	53.86	9.89	7.94	100	100	100	100	100	100	600	
9 <sup>a,b</sup>	Et	O n-Bu	n-Bu	39	155-160 (0.20)	C <sub>17</sub> H <sub>37</sub> N <sub>2</sub> O <sub>4</sub> P	56.02	10.23	7.69	55.61	10.06	8.73	100	100	95	75	100	80	550	
10		O Et	Et	16.5	145 (0.01)	C <sub>11</sub> H <sub>23</sub> N <sub>2</sub> O <sub>5</sub> P	44.89	7.88	9.51	44.20	7.56	9.47	10	15	15	10	5	5	60	
11		O n-Bu	Et	34.2	136-138 (0.01)	C <sub>13</sub> H <sub>27</sub> N <sub>2</sub> O <sub>5</sub> P	48.44	8.44	8.67	45.85	8.13	8.67	15	35	10	10	30	10	110	
12		O n-Pentyl	Et	38.6	157-158 (0.05)	C <sub>14</sub> H <sub>29</sub> N <sub>2</sub> O <sub>5</sub> P	49.99	8.69	8.32	49.38	8.74	8.04	100	100	50	90	95	90	525	
13		O Me	n-Bu	58	163-167 (0.08)	C <sub>14</sub> H <sub>29</sub> N <sub>2</sub> O <sub>5</sub> P	49.98	8.69	8.32	49.06	8.58	8.03	25	65	10	10	70	10	190	
14		O n-Bu	n-Bu	57	182-190 (0.20)	C <sub>17</sub> H <sub>35</sub> N <sub>2</sub> O <sub>5</sub> P	53.95	9.32	7.40	52.87	9.05	7.43	100	100	100	100	100	100	600	
15 <sup>b</sup>	Et	O Me	Me	36	109-110 (0.10)	C <sub>8</sub> H <sub>19</sub> N <sub>2</sub> O <sub>4</sub> P	40.33	8.04	11.76	39.43	8.03	11.32	25	5	5	0	10	5	50	
16 <sup>b</sup>	Et	O n-Pr	n-Pr	46.5	128-132 (0.1)	C <sub>14</sub> H <sub>31</sub> N <sub>2</sub> O <sub>4</sub> P	52.15	9.69	8.69	50.59	9.48	9.08	100	100	95	98	100	98	591	
17 <sup>b</sup>	Et	O n-Pentyl	n-Pentyl	20.5	170-180 (0.15)	C <sub>20</sub> H <sub>43</sub> N <sub>2</sub> O <sub>4</sub> P	59.08	10.66	6.89	58.78	10.75	9.54	100	100	100	95	100	100	595	
18 <sup>b</sup>	Et	O n-Octyl	n-Octyl	21.9	208 (0.12)	C <sub>23</sub> H <sub>49</sub> N <sub>2</sub> O <sub>4</sub> P	65.37	11.54	5.26	65.53	11.43	4.14	0	35	5	20	10	80	160	
19	Et	S n-Bu	n-Bu	78.5	165-170 (0.2)	C <sub>17</sub> H <sub>37</sub> N <sub>2</sub> O <sub>3</sub> PS	53.28	10.42	7.31	53.08	9.57	7.98	100	100	100	100	100	100	600	
20	Et	S n-hexyl	n-Bu	80.6	182-192 (0.2)	C <sub>19</sub> H <sub>41</sub> N <sub>2</sub> O <sub>3</sub> PS	55.84	10.11	6.86	55.38	10.04	7.78	100	100	100	100	100	100	600	

<sup>a</sup> Known compound. <sup>b</sup> Made by the method of Scheme I. <sup>c</sup> *Amaranthus retroflexus* L. <sup>d</sup> *Echinochloa crus-galli* (L.) Beauv. <sup>e</sup> *Datura stramonium* L. <sup>f</sup> *Digitaria ischaemum* (schreb). <sup>g</sup> *Ipomoea purpurea* (L. Roth). <sup>h</sup> *Setaria faberii* Herrm. <sup>i</sup> Activity score is the sum of the activities on each weed species. A perfect score is 600.

was then centrifuged to remove the precipitated triethylamine hydrochloride. This solution was then added dropwise to a solution of the sodium salt of butanethiol suspended in toluene. [This latter was prepared by adding sodium (1.2 g) to methanol (50 mL) and then adding butanethiol (5.4 mL) to this solution. Toluene (50 mL) was then added and the methanol removed by distillation.] The mixture was stirred at 80 °C for 2 h and then at room temperature overnight. About half the solvent was removed under reduced pressure, and the residue was then filtered to remove sodium chloride. The remaining solvent was then removed, and finally the residue was distilled to give 17.3 g of the title compound: bp 165–170 °C (0.2 mm); <sup>1</sup>H NMR δ 0.7–1.9 (27 H, m), 3.18 (2 H, t, *J* = 7 Hz), 3.58 (4 H, q, *J* = 8 Hz), 3.8–4.2 (4 H, m). Anal. Calcd for C<sub>17</sub>H<sub>37</sub>N<sub>2</sub>O<sub>3</sub>PS: C, 53.28; H, 10.42; N, 7.31. Found: C, 53.08; H, 9.57; N, 7.98.

**Postemergence Herbicide Tests.** The foregoing compounds were tested as postemergence (foliage applied) herbicides against six weed species including redroot pigweed (*Amaranthus retroflexus* L.), jimsonweed (*Datura stramonium* L.), tall morning glory [*Ipomoea purpurea* (L. Roth)], barnyard grass [*Echinochloa crus-galli* (L.) Beauv.], smooth crabgrass [*Digitaria ischaemum* (Schreb.) Muhl.], and giant foxtail (*Setaria faberi* Herrm.).

In preparation for application to the plant foliage, 0.6 g of each compound was dissolved in 10 mL of acetone. One hundred milligrams of ethoxylated sorbitan monolaurate Tween 20 was added to the mixture, which was agitated vigorously with an ultrasonic probe. Distilled water was then added to each mixture, making 100 mL of each 6000-ppm solution. The solutions were applied to the drip point on the plant foliage 7 days after emergence by using a No. 152 DeVilbiss atomizer.

At the time of treatment, the dicotyledonous species were in the cotyledon stage and the monocots were in the one and one-half leaf stage. The heights of the plants measured from the tip of the tallest leaves to the soil line were as follows: redroot pigweed 2.5 cm, jimsonweed 3 cm, tall morning glory 8 cm, barnyard grass 14 cm, smooth crabgrass 5 cm, and giant foxtail 7 cm. Although none of the seed employed in this test was capable of 100% germination, care was taken to be sure that each species had germinated to its expected percentage level (from previous germination tests) prior to treatment of the plants. Tests involving dosage rates lower than 6000 ppm were conducted by dilution of the 6000-ppm solutions with distilled water prior to application onto plant foliage.

The effects of uptake from the soil were assessed by drenching (11.2 kg/ha) 46 mL of 250-ppm solutions onto the soil surface in 11.4-cm pots containing the aforementioned seeds. Since none of the compounds tested were active via soil uptake, all additional testing was confined to foliant application.

In all tests, the percent control of each species was estimated by visual comparison with untreated controls 2 weeks after treatment. Within a species, the amount of necrotic tissue determined the percent control rating. Small differences in remaining live tissue were indicated by small differences in percent control, i.e., 90% vs. 95%. A maximum herbicide activity score of 600 was achieved when each of the six weed species in the test was 100% controlled.

## RESULTS AND DISCUSSION

The percent weed control results from postemergence application at 6000 ppm are indicated in Table I. As may be seen in Table I the postemergence herbicide activity

Table II. Herbicidal Activity at 2000 and 1000 ppm

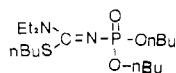
compound no.	activity <sup>a</sup> score at 2000 ppm	activity score at 1000 ppm
1	60	60
2	110	110
3	220	150
4	405	175
5	340	150
6	0	0
7	390	160
8	355	230
9	595	585
10	0	0
11	0	0
12	100	60
13	0	0
14	330	260
15	0	0
16	230	90
17	380	320
18	0	0
19	330	330
20	310	240

<sup>a</sup> Activity score is the sum of activities on each weed species.

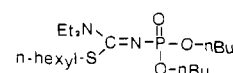
of compounds having a given R'' was lowest when R and R' were lower alkyl groups but increased as the chain lengths of R and R' substituents increased up to butyl or pentyl. Following this optimum chain length for R and R' substituents, the postemergence herbicide activity decreased as the chain length of R and R' increased. The substituent present in the R'' position appeared not to influence the activity of the compounds as much as the substituents in the R and R' positions. When R'' varied and R and R' were constant or changed only slightly, the activity of comparable compounds was similar.

The postemergence herbicide activity of the compounds, with the exception of 9, decreased markedly as the dosages were decreased to 2000 and 1000 ppm. The herbicide activity score for each of the compounds at 2000 and 1000 ppm is summarized in Table II. Once applied in a herbicidally effective amount, the compounds had a striking ability to kill the weeds very quickly.

In view of the herbicidal activity of these compounds, a few compounds in which the alkoxy group on the carbon was replaced by the corresponding alkylthio group were also synthesized. Thus, compounds 19 and 20 were pre-



19



20

pared. As shown in Tables I and II, these compounds also showed good herbicidal activity at 6000 ppm, but this again decreased markedly as the dosage was lowered.

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