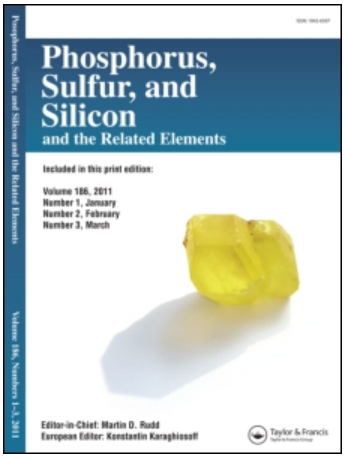

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Synthesis and Plant Growth Regulating Activity of New Triazolo- and Pyrazolopyrimidine Derivatives Of Aminomethyl, Aminoalkyloxymethyl Dimethylphosphine Oxides and (Aminomethane)Phosphonic Acid Esters

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SYNTHESIS AND PLANT GROWTH REGULATING ACTIVITY OF NEW TRIAZOLO- AND PYRAZOLOPYRIMIDINE DERIVATIVES OF AMINOMETHYL-, AMINOALKYLOXYMETHYL DIMETHYLPHOSPHINE OXIDES AND (AMINOMETHANE)PHOSPHONIC ACID ESTERS

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New triazolo[4,5-d]pyrimidine and pyrazolo[3,4-d]pyrimidine derivatives of aminomethyl- and aminomethyloxymethyl dimethylphosphine oxides **8–14** as well as of esters of (aminomethane) phosphonic acid **18–20** were synthesized. The structure of the compounds prepared was confirmed by means of elemental analysis, IR, ^{1}H- and ^{31}P{^{1}H}-NMR spectroscopy. Tertiary phosphine oxides **8, 9** and **12** as well as phosphonate **20** showed herbicidal and plant growth regulating activity.

Keywords: Triazolo[4,5-d]pyrimidines; pyrazolo[3,4-d]pyrimidines; tertiary phosphine oxides; (aminomethane)phosphonates; herbicidal activity; plant growth regulating activity

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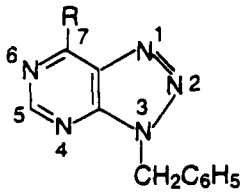
INTRODUCTION

Recently we have published the synthesis and anticytokinine activity data of a series of 7-substituted 3-benzyl-3H-1,2,3-triazolo[4,5-d]pyrimidines of type **1** and 4-substituted 1-benzyl-1H-pyrazolo[3,4-d]pyrimidines of type **2**[1]. Compounds **1** and **2** were easily prepared by a nucleophilic substitution of the chlorine in 7-chloro-3-benzyl-3H-1,2,3-triazolo[4,5-d]pyrimidine (**3**)[2] and 4-chloro-1-benzyl-1H-pyrazolo[3,4-d]pyrimidine (**4**)[3] by means of primary and secondary amines containing additional functionality. According to the phytochemical tests, the anticytokinine activity was better expressed by compounds with piperazino- and morpholino-substituents. The triazolopyrimidines **1** were in general more active than the pyrazolopyrimidines **2**[1] (Scheme 1). In continuation of our investigations on the structure – phytochemical activity relationship in the group of purine analogs, isomers and related compounds[1,4,5], we undertook the synthesis of tertiary phosphine oxides and esters of phosphonic acids, which are derivatives of triazolo[4,5-d]-and pyrazolo[3,4-d]pyrimidines. It is well known that numerous heterocyclic compounds of different types, modified with phosphorous containing substituents exhibit biological activity. Thus, phosphoric, thiophosphoric, phosphonic, thiophosphonic acids, esters and amides thereof, as well as tertiary phosphine oxides including heterocyclic substituents were shown to possess various biological activity: insecticide, fungicide, acaricide and herbicide activity[6–11], antiviral[12], antileucotic[13–15], antihystamine and vasodilator[16], analgesic[17], tranquilizing[18], antihypertensive[19] activity, and they are Ca-antagonists[20].

RESULTS AND DISCUSSION

The tertiary phosphine oxides **8 – 14** were prepared in analogy to lit.[1] by means of nucleophilic substitution of the chlorine atoms in **3**[2], resp. **4**[3] by the known (aminomethyl)dimethylphosphine oxide **5** ($Y=CH_2$)[21] and (aminoalkyloxymethyl)dimethylphophine oxides **5** [($Y=(CH_2)_2OCH_2$, $(CH_2)_3OCH_2$,$(CH_2)_5OCH_2$][22]. The starting chlorides **3** and **4** were synthesized from the pyrimidinone **6**, resp. **7** by a modification of the reaction conditions utilized in lit.[2] (Scheme 2). The chloride **4** obtained by us



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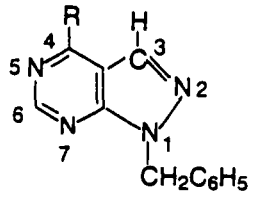
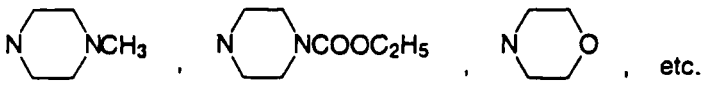


2

R = $NHCH_2CH_2OH$, $NHCH_2CH_2N(C_2H_5)_2$, $NHCH_2CH_2CH_2Cl$



SCHEME I

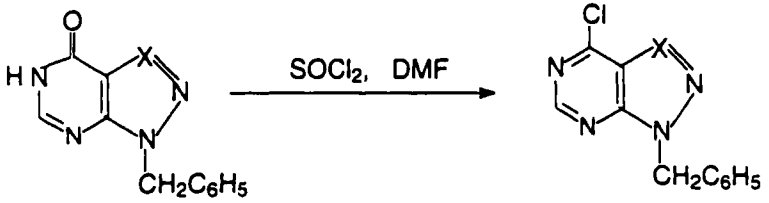
exhibited a substantially different m.p. than that given in the lit.[3]. However, its elemental analysis, IR and ^{1}H-NMR spectral data were in agreement with the structure expected.

The reaction of the chloride **3**, resp. **4** and the selected amines **5** was carried out in the presence of triethylamine using 1:1:1 molar ratio of the reagents in dry tetrahydrofurane (THF) at room temperature (Scheme 3). Thus the following compounds were prepared: 7-[(dimethylphosphinylmethyl)amino]-3-benzyl-3H-1,2,3-triazolo[4,5-d]pyrimidine (**8**); 4-[(dimethylphosphinylmethyl)amino]-1-benzyl-1H-pyrazolo[3,4-d]pyrimidine (**9**); 7-[2-(dimethylphosphinylmethoxy)ethylamino]-3-benzyl-3H-1,2,3-triazolo[4,5-d]pyrimidine (**10**); 4-[2-(dimethyl phosphinylmethoxy)ethylamino]-1-benzyl-1H-pyrazolo[3,4-d]pyrimidine (**11**); 7-[3-(dimethylphosphinylmethoxy)propylamino]-3-benzyl-3H-1,2,3-triazolo[4,5-d]pyrimidine (**12**); 4-[3-(dimethylphosphinyl methoxy)propylamino]-1-benzyl-1H-pyrazolo[3,4-d]pyrimidine (**13**) and 4-[5-(dimethylphosphinylmethoxy)pentylamino]-1-benzyl-1H-pyrazolo[3,4-d]pyrimidine (**14**). The phosphine oxides **8, 9** and **12** were purified by a recrystallization, while **10, 11, 13** and **14** – by means of column chromatography of the crude reaction products, followed by a recrystallization, except for **14**, which was an oily product. Yields, m.ps. and elemental analysis data of **8 – 14** are given in Table I.

TABLE I Preparative and analytical data of tertiary phosphine oxides **8–14** and phosphonates **18–20**

No	*Yield, (%)*	*M.p., °C (Solvent for recr.)*	*General formula (Mol. mass)*	*Elemental analysis*			
				%C		*%H*	
				Calcd.	*Found*	*Calcd.*	*Found*
8	67	199–200 (Ethanol)	$C_{14}H_{17}N_6OP$ (316.3)	53.15	52.88	5.42	5.18
9	82	206–208 (Benzene)	$C_{15}H_{18}N_5OP$ (315.3)	57.13	57.00	5.75	6.06
10	66	114–117 (Ethylacetate)	$C_{16}H_{21}N_6O_2P$ (360.4)	53.32	53.05	5.87	5.87
11	84	115–117 (Benzene-n-Hexane)	$C_{17}H_{22}N_5O_2P$ (359.4)	56.81	57.11	6.17	6.25
12	76	105–106.5 (n-Hexane)	$C_{17}H_{23}N_6O_2P$ (374.4)	54.54	54.24	6.19	6.44
13	47	128–129 (Benzene-n-Hexane)	$C_{18}H_{24}N_5O_2P$ (373.4)	57.89	58.06	6.48	6.44
14	96	Oil	$C_{20}H_{28}N_5O_2P$ (401.4)	–	–	–	–
18	71	139–140 (Ethylacetate)	$C_{14}H_{17}N_6O_3P$ (348.3)	48.27	48.61	4.92	4.80
19	59	151–152 (Ethylacetate)	$C_{16}H_{21}N_6O_3P$ (376.4)	51.00	51.62	5.58	5.56
20	68	163–165 (Benzene-n-Hexane)	$C_{15}H_{18}N_5O_3P$ (347.3)	51.87	52.23	5.22	5.22

The starting methyl and ethyl esters of the (aminomethane)phosphonic acid **15** (R = CH_3, C_2H_5) as hydrochlorides were prepared from the known trityl derivatives **17**[23] thereof. The synthesis of **17** was performed by us using the following approach. Thus, dialkyl (trimethylsilyl)phosphite pre-



6, 7 **3, 4**

For **3** and **6** [2]: X = N

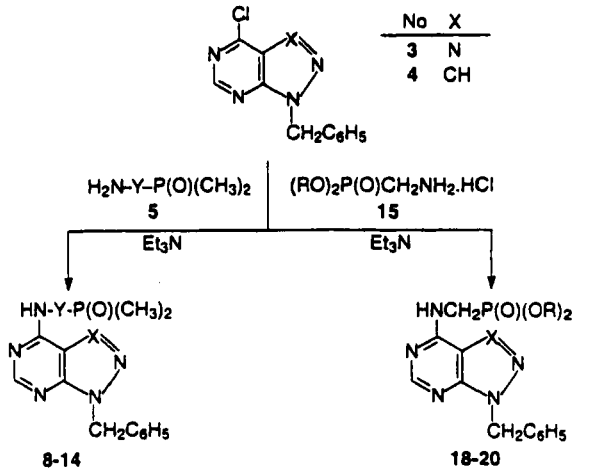
For **4** and **7** [3]: X = CH

SCHEME 2

pared in situ from the corresponding dialkyl phosphite, trimethylchlorosilane and triethylamine according to[24], underwent a smooth addition to N-methylene-N-tritylamine **16**[23] in a refluxing dichloromethane solution to give the known[23] dialkyl N-(tritylaminomethane)phosphonate **17**. In this way, the preparation of **17** was carried out under milder reaction conditions than those utilized in lit.[23]. Its deprotection[23] afforded hydrochlorides **15**. (Scheme 4). The spectral data of **17**, as well as of **15** are in good agreement with those reported in the lit.[23].

The reaction of the chloride **3**, resp. **4** with the hydrochlorides of the phosphonates **15** was carried out in the presence of triethylamine using 1:1:2 reagents ratio in a mixture of dry THF and abs. ethanol at room temperature (Scheme 2). The following compounds were prepared: dimethyl ester of N-[(3-benzyl-3H-1,2,3-triazolo[4,5-d]pyrimidin-7-yl)aminomethane]phosphonic acid (**18**); diethyl ester of N-[(3-benzyl-3H-1,2,3-triazolo[4,5-d]pyrimidin-7-yl)aminomethane]phosphonic acid (**19**) and dimethyl ester of N-[(1-benzyl-1H-pyrazolo[3,4-d]pyrimidin-4-yl)aminomethane]phosphonic acid (**20**). The phosphonates **18–20** were purified by means of recrystallization of the crude reaction products. Yields, m.ps. and elemental analysis data of **18–20** are given in Table I.

The IR, ^{1}H-NMR and ^{31}P{^{1}H}-NMR spectra of the newly prepared tertiary phosphine oxides **8–14** and phosphonates **18–20** were measured and compared with the spectra of the starting amines **5** and **15**, as well as with the previously studied **1** and **2**. The investigation of the spectral data of **8–**



8-14			18-20		
No	X	Y	No	X	R
8	N	CH_2	**18**	N	CH_3
9	CH	CH_2	**19**	N	C_2H_5
10	N	$(CH_2)_2OCH_2$	**20**	CH	CH_3
11	CH	$(CH_2)_2OCH_2$			
12	N	$(CH_2)_3OCH_2$			
13	CH	$(CH_2)_3OCH_2$			
14	CH	$(CH_2)_5OCH_2$			

SCHEME 3

14 and **18–20** shows that they are in agreement with the structures expected.

In the IR spectra of the tertiary phosphine oxides **8–14** measured as KBr pellets (Table II) are present characteristic bands of the phosphoryl group (P=O) at 1150–1177 cm^{-1} and of CH_3-P at 1291–1322 cm^{-1}, which are in accordance with the previously observed values for the starting aminocompounds of type **5**[21,22] as well as for some derivatives of **5**[25]. Additional bands of the P=O-group have been observed in the spectra of compounds **8** and **9**. This phenomenon can be ascribed to two kinds of

phosphoryl groups: the first one bonded, and the second one – nonbonded with hydrogen bonds[26,27]. In the IR spectra of the phosphonates **18–20** (Table II) the P=O-band appears at 1233–1259 cm^{-1} and the ether P-O-R-band is at 1027–1065 cm^{-1}. The IR frequences observed are in accordance with the literature data[27]. Bands of the NH-group of compounds **8–14** and **18–20** are in the region of 1616–1637 cm^{-1}, as well as 3254–3454 cm^{-1}.

TABLE II Characteristic infrared frequences (cm^{-1}) of phosphine oxides **8–14** and phosphonates **18–20**

No	*P=O*	*CH_3P*	*P-O-R*	*NH*	*C_6H_5*
8	1177(s)	1314(vs)	–	1620(vs)	1497(m)
	1150(s)			3435(b)	1589(s)
9	1176(vs)	1305(m)	–	1623(vs)	1487(m)
	1151(m)			3254(b)	1572(m)
10	1160(s)	1316(s)	–	1626(vs)	1498(m)
				3435(b)	1587(m)
11	1166(vs)	1322(s)	–	1637(vs)	1496(m)
				3422(b)	1589(m)
12	1155(vs)	1315(m)	–	1629(vs)	1497(m)
				420(b)	1578(s)
13	1166(s)	1291(m)	–	1616(vs)	1496(m)
				3420(b)	1572(m)
14	1166(s)	1292(m)	–	1617(vs)	1496(m)
				3272(b)	1572(m)
18	1233(s)	–	1027(m)	1615(s)	1497(m)
			1041(m)	3454(b)	1587(m)
19	1236(s)	–	1034(s)	1632(vs)	1493(m)
			1064(s)	3448(b)	1586(m)
20	1259(s)	–	1032(m)	1618(b)	1487(m)
			1052(s)	3262(b)	1569(m)

TABLE III ^1H- and $^{31}P\{^1H\}$-NMR data of phosphine oxides **8–14** (δ in ppm, J in Hz)

	^1H NMR										$^{31}P\{^1H\}$
No	$(CH_3)_2P{=}O$		$CH_2P{=}O$		$C\text{-}CH_2\text{-}C$	CH_2Ph	C_6H_5	$N\text{-}CH{=}N$	$C\text{-}CH{=}N$	NH^a	
	δ	$^2J_{HP}$	δ	$^2J_{HP}$	δ	δ	δ	δ	δ	δ	δ
8	1.63(d)	12.8	4.23(t)	6.2	–	5.72(s)	7.3–7.4(m)	8.46(s)	–	8.33(bs)	+43.79
			4.23(d)[b]	6.3							
9	1.60(d)	12.6	4.13(t)	5.4	–	5.55(s)	7.2–7.4(m)	8.38(s)	8.20(s)	8.44(bs)	+43.64
			4.13(d)[b]	5.4							
10	1.55(d)	13.1	3.84(d)	6.7	3.9(m)	5.79(s)	7.4–7.6(m)	8.52(s)	–	6.97(bs)	+42.84
11	1.40(d)	12.9	3.83(d)	3.8	3.9(m) $^2J_{HP}$=6.8[c]	5.56(s)	7.2–7.4(m)	8.41(s)	8.06(s)	-[e]	+43.08
12	1.57(d)	13.1	3.7–3.9(m)[c]	6.8[d]	1.95(m)	5.76(s)	7.2–7.7(m)	8.47(s)	–	7.09(bs)	+41.81
13	1.54(d)	12.9	3.7–3.8(m)[c]		1.9–2.0(m)	5.76(s)	7.2–7.3(m)	8.36(s)	8.10((s)	2.75(bs)	+41.78
14	1.50(d)	13.1	3.7–3.8(m)[c]		1.6–1.7(m)	5.56(s)	7.3–7.4(m)	8.38(s)	7.99(s)	6 22(bs)	+43.32

Explanations: bs-broad singlet, d-doublet, s-singlet, m – multiplet.

a. The signals of these protons disappeared after D_2O exchange.
b. After D_2O exchange.
c. The signals overlapped with the signals of N-CH_2- and C-CH2O- protons.
d. Identified approximately.
e. Overlapped with the signals of aromCH protons.

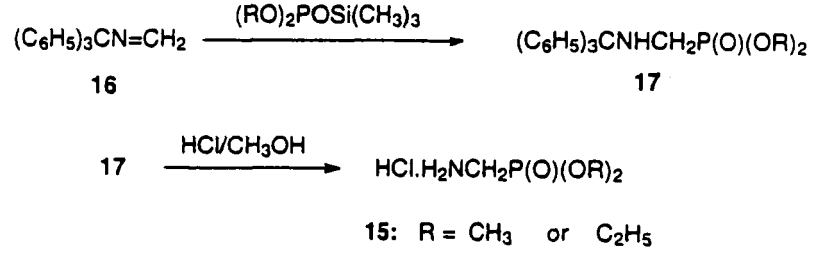
TABLE IV ^{1}H- and $^{31}P\{^{1}H\}$-NMR data of phosphonates **18–20** (δ in ppm, J in Hz)

No	^{1}H-NMR									$^{31}P\{^{1}H\}$
	$CH_2P=O$		$(CH_3O)_2P=O^a$ or $(CH_3CH_2O)P=O^b$		CH_2Ph	C_6H_5	N-CH=N	C-CH=N	NH[c]	
	δ	$^{2}J_{HP}/^{3}J_{HH}$	δ	$^{3}J_{HP}$	δ	δ	δ	δ	δ	δ
18	4.26(dd)	11.6/6.2	3.84(d)	10.8	5.80(s)	7.3–7.5(m)	8.56(s)	–	6.64(bs)	+25.49
	4.26(d)[d]	11.6[d]								
19	4.1–4.3(m)[e]	[e]	1.34(t, $^{3}J_{HH}$7.0)	[e]	5.80(s)	7.3–7.5(m)	8.55(s)	–	6.60(bs)	+22.88
20	4.20(dd)	11.6/5.1	3.81(d)	10.9	5.56(s)	7.3–7.4(m)	8.45(s)	8.05	6.73(bs)	+26.44

Explanations: d – doublet, dd – doublet of doublet, m – multiplet, s – singlet, t – triplet.

a. In compounds **18** and **20**.
b. In compound **19**.
c. The signals of these protons disappeared after D_2O exchange.
d. After D_2O exchange.
e. Overlapped with the signals of $P(O)OCH_2CH_3$ protons; $^{2}J_{HP}$ and $^{3}J_{PH}$ cannot be measured.

The ^{1}H-NMR spectra of the tertiary phosphine oxides **8–14** (Table III) and phosphonates **18–20** (Table IV) exhibit signals of protons of the heterocyclic moiety as well as of the phosphorous – containing side chain at the pyrimidine ring. Thus, the singlets of the benzylic CH_2-protons are at 5.55–5.80 ppm, while the phenyl multiplets are in the region of 7.2–7.5 ppm. The pyrimidine ring protons (-N-C**H**=N-) exhibit singlets at 8.36–8.56 ppm and the pyrazole ring protons (-C-C**H**=N-) of the pyrazolopyrimidines **9, 11, 13, 14** and **20** are singlets in the stronger field at 7.99–8.20 ppm. Similar chemical shifts of the heterocyclic moiety protons are observed in the spectra of the previously studied compounds **1** and **2**[1].



SCHEME 4

In the ^{1}H-NMR spectra of **8–14**, the CH_3-protons at P=O (Table III) appear as doublets at 1.40–1.63 ppm with $^2J_{PH}$ 12.6–13.1 Hz. The methylene group protons CH_2P=O are at 3.70–4.23 ppm. Except for compounds **13** and **14** having a longer side chain, $^2J_{PH}$ of CH_2P=O can be measured and it is in the region of 3.6–6.8 Hz. Similar values of the chemical shifts of $(CH_3)_2$P=O and CH_2P=O, as well as of $^2J_{PH}$have been observed previously for the starting amines **5**[21,22]. The signals of ^{31}P{^{1}H} of **8–14** are singlets and appear in the range of +41.78 to +43.79 ppm, which is typical for tertiary phosphine oxides containing methyl and methylene groups at the phosphorous atom[25].

The ^{1}H- and ^{31}P{^{1}H}-NMR data of the phosphonates **18–20** are given in Table IV. In the ^{1}H-NMR spectra of dimethyl phosphonates **18** and **20** the doublets of the methoxy groups protons are at 3.84, resp. 3.81 ppm with $^3J_{PH}$ 10.8, resp. 10.9 Hz. The signals of CH_2P=O in the compounds **18** and **20** are doublets of doublets centered at 4.26, resp. 4.20 ppm, due to additional spin-spin coupling. The signals of ^{31}P{^{1}H} of **18–20** are singlets and appear in the range of +22.88 to +26.44 ppm similarly to other esters of (aminoalkane)phosphonic acids[26,27].

Phytochemical experiments

Compounds **8, 9, 12** and **20** were tested for plant growth regulating activity. They strongly inhibited the growth of both cucumber and wheat seedlings at preemergence application. The effect was better expressed in relation to the dicotyledonous plant object (Table V). Thus, ΔpI_{50} value of the pyrazolopyrimidines **9** and **20** showing the selectivity of herbicide action, was 1.15 and 1.09, respectively. In comparison to glyphosate, the preemergent herbicidal activity of compounds **9** and **12** is much higher. Both triazolopyrimidines studied – **8** and **12**, possessed lower activity and selectivity.

TABLE V Effect of the compounds tested on the growth of cucumber and wheat seedlings grown in the dark

Compound	*Herbicidal activity* pI_{50}[a] *[M]*				
	Cucumber		*Wheat*		ΔpI_{50}[b]
	Shoot, mm	*Root, mm*	*Shoot, mm*	*Root, mm*	
Glyphosate	4.09	3.94	3.93	3.79	0.16
8	2.53	2.42	2.15	1.81	0.38
9	4.35	4.20	3.20	2.16	1.15
12	2.98	2.72	2.65	2.61	0.33
20	4.18	4.21	3.09	3.59	1.09

a. pI_{50} value was defined under Experimental.
b. ΔpI_{50} was calculated as a difference between pI_{50} of the shoots.

The data obtained from preemergence test system were confirmed using intact pea plants at postemergence treatment (Table VI). Application of the compounds tested at 1 and 2 mM concentrations provoked typical herbicide effects – inhibition of the growth of the whole plants. The growth suppression was accompanied with a decrease of leaf pigments and soluble protein content (Table VII). The tertiary phosphine oxide **9** showed similar activity as the standard glyphosate, while the phosphonosubstituted pyrazolopyrimidine **20** exceeded the activity of the standard. Compared to them, both triazolopyrimidines studied – **8** and **12**, were found to be less active.

TABLE VI Effect of **8, 9, 12** and **20** and glyphosate on the growth of young pea plants

Compounds	*Conc.*	*Length of the seedlings*				*Fresh weight of the seedlings*				*Dry weight of the seedlings*			
		Roots		*Above ground part*		*Roots*		*Above ground part*		*Roots*		*Above ground part*	
	[mM]	*mm*	*%*	*mm*	*%*	*mg*	*%*	*mg*	*%*	*mg*	*%*	*mg*	*%*
Control	–	91	*100.0*	106	*100.0*	218	*100.0*	656	*100.0*	16.3	*100.0*	46.2	*100.0*
Glyphosate	2	75	*82.4*	70	*66.0*	133	*61.0*	388	*59.1*	8.9	*54.6*	25. 1	*54.3*
8	1	92	*101.1*	110	*103.7*	191	*87.6*	560	*85.4*	13.6	*83.4*	40.2	*87.0*
	2	80	*87.9*	98	*92.4*	142	*65.1*	422	*64.3*	10.8	*66.2*	39.6	*85.7*
9	1	73	*80.2*	79	*74.5*	178	*81.6*	486	*74.1*	10.1	*62.0*	29.8	*64.5*
	2	71	*78.0*	68	*64.2*	170	*78.0*	402	*61.3*	8.8	*54.0*	27.8	*60.2*
12	1	88	*92.3*	103	*97.2*	183	*83.9*	494	*75.3*	14.3	*87.7*	39. 1	*84.6*
	2	84	*92.3*	94	*88.7*	147	*67.4*	387	*59.0*	11.2	*68.7*	37.3	*80.7*
20	1	62	*68.1*	65	*61.3*	136	*62.4*	411	*62.6*	9.2	*56.4*	31.5	*68.2*
	2	76	*83.5*	69	*65.1*	111	*50.9*	365	*55.6*	8.1	*49.7*	24.2	*52.4*
LSD[a] %		6		9		14		29		0.8		8.1	

a. LSD: lowest significant difference

TABLE VII Effect of glyphosate and compounds tested on leaf pigment content and soluble protein in pea seedlings. The data are presented as a % to the relative control[a]

Compound	*Conc. [mM]*	*Chl. a*	*Chl. B*	*Carotenoides*	*Soluble protein*
Glyphosate	2	65.6	59.2	63.7	75.4
8	1	86.4	78.1	81.1	89.2
	2	76.9	69.5	72.8	75.8
9	1	73.5	63.8	76.5	62.2
	2	59.2	52.2	61.3	51.3
12	1	82.7	77.8	83.5	90.3
	2	74.9	73.6	70.8	83.1
20	1	69.4	62.8	65.3	67.5
	2	49.1	41.1	44.8	49.5

[a]Fresh weight values of the controls: Chl. a (chlorophyll a) – 1.761 mg/g; Chl. b (chlorophyll b) – 0.640 mg/g; carotenoides – 1.293 mg/g; soluble protein – 14.32 mg/g.

The results obtained are in an agreement with the data of other authors about the herbicidal and plant growth regulating activity of the pentavalent derivatives of phosphorous – phosphoric and phosphonic acid derivatives[28–31].

EXPERIMENTAL

Melting points (m.p. uncorrected): microhot stage Boetius PHMK 05. IR spectra: Bruker IFC 25 (KBr pellets). ^{1}H-NMR spectra: Bruker Spectrospin WM-250 (250 MHz), ^{31}P{^{1}H}-NMR spectra: Bruker Avance (81 MHz). $CDCl_3$ as a solvent. Chemical shifts are measured towards TMS as internal standard (^{1}H-NMR spectra) or 85% H_3PO_4 (^{31}P{^{1}H}-NMR spectra). TLC: "Merck" Silicagel $60F_{254}$ on aluminium sheets, layer thickness 0.2 mm. Mobile phase: ethylacetate:hexane=1:2. Column chromatography: "Acros Chimica" Silicagel, particle size 0.2–0.06 mm using 1:50 product:silicagel ratio. The eluents are used in the following order: 1. Ethylacetate:light petroleum (b.p. 40–60°): aq. NH_3 = 4:1:0.1; 2. Ethylacetate; 3. Methanol.

Phytochemical experiments

Preemergent Herbicidal Activity

Seedlings of wheat (*Triticum aestivum* L., cv. Sadovo-1) and cucumber (*Cucumis sativus* L., cv. Levina) were used in this type of experiment. The seeds were put on two layers filter paper moistened with test compound solutions. After 96 h incubation in the dark (25°C) shoot and root lengths of the test-objects were measured. The inhibitory action of the compounds was calculated as a % to the relative control. The herbicidal activity was expressed by pI_{50} value (logarithm of the reciprocal of molar concentration at which 50% inhibition of the growth is obtained).

Postemergent Herbicidal Activity

Pea (*Pisum sativum* L., cv. Citrina) seedlings with a fully developped second leaf grown in a climatic chamber at 25°C under daylight conditions (25°C, 12 h photoperiod, light intensity approximately 70 $\mu mol.cm^{-2}.sec^{-1}$) were sprayed with an emulsified solution of a test compound containing an emulsifier (0.5%, v/v), prepared with Tween 80. The growth parameters (length, fresh and dry weight, chlorophyll and soluble protein content) were determined 7 days after the treatment. Glyphosate (N-phosphonomethylglycine) was used as a standard.

All biological experiments were performed 3 times, each in 3 replications at least. The data were evaluated statistically by Fisher *t*-criteria.

Preparation of 7-chloro-3-benzyl-3H-1,2,3-triazolo[4, 5-d]pyrimidine (3) and 4-chloro-1-benzyl-1H-pyrazolo[3,4-d]pyrimidine (4) (General Procedure)

To a stirred and boiled suspension of 10 mmol triazolopyrimidinone **6**[2], resp. **7**[3] in thionylchloride (11.5 ml, 160 mmol) is added dropwise dimethylformamide (1.2 ml, 16 mmol). The reaction mixture is heated under reflux until clear, and then additionally 1 h more, after that it is stirred at room temperature for 1 h. The volatile components are removed in vacuo at 30°. The residue, cooled to 0°C, is treated with ice and neutralized to pH 7 by slow addition of 10 % $NaHCO_3$. The solid product is filtered, air dried and recrystallized from light petroleum (b.p. 40–60°C).

Chloride **3**: Yield 60 %, m.p. 94–95°C. Lit.[2]: m.p. 92°C (from light petroleum, b.p. 60–80°C).

Chloride **4**: Yield 80 %, m.p. 75°C. Lit.[3]: m.p. 245°C (from methanol). Calcd. for $C_{12}H_9ClN_4$ (244.5): C, 58.90 %; H, 3.71 %. Found: C, 58.65 %; H, 4.01 %.

IR (nujol): no bands for C=O and NH.

^{1}H-NMR (80 MHz, $CDCl_3$): 5.50 (s, 2H, $CH_2C_6H_5$); 7.16 (s, 5H, CHarom), 7.88 (s, 1H, -C-CH=N-); 8.10 (s, 1H, -N-CH=N-).

Synthesis of phosphine oxides 8–14 (General procedure)

A solution of (aminoalkyl)dimethylphosphine oxide of type **5**[21,22] (2 mmol) in dry THF (5 ml) is added dropwise to a stirred solution containing chloride **3**, resp. **4** (2 mmol) and triethylamine (0.28 ml, 2 mmol) in dry THF (5 ml) at room temperature. The reaction mixture is stirred until the starting chloride is consumed completely according to TLC (ca. 48 hrs). The mixture is evaporated under reduced pressure, water (10 ml) is added to the residue and it is extracted with dichloromethane. The extract is dried (Na_2SO_4) and the solvent is removed. Compounds **8, 9** and **12** are recrystallized. Compounds **10, 11, 13** and **14** are purified by means of column chromatography. They are eluted from the column with eluent 3. The eluate is evaporated to dryness, the residue is dissolved in dichloromethane and filtered. After evaporation of the filtrate, the residue is recrystallized, with the exception of **14**, which is an uncrystallizable oil.

Synthesis of phosphonates 18–20 (General procedure)

1. Preparation of dimethyl-, resp. diethyl ester of N-(tritylaminomethane)phosphonic acid **17** (R = CH_3, C_2H_5).

A solution of dimethyl, resp. diethyl phosphite (2 mmol) and triethylamine (0.35 ml, 2.5 mmol) in dry dichloromethane (50 ml) is treated with trimethylchlorosilane (0.32 ml, 2.5 mmol) at 0°C under argon as it is described in the lit.[24]. To this mixture a solution of N-methylene-N-tritylamine (**16**)[23] (0.542 g, 2 mmol) in dry dichloromethane (5 ml) is added dropwise at 0°C. The solution is brought to room temperature, after which it is refluxed for 1 h. After cooling, it is poured into water (50 ml) and the organic products are extracted with dichloromethane. The combined organic extracts are dried (Na_2SO_4) and evaporated to afford dimethyl, resp. diethyl N-(tritylaminomethane)phosphonate of type **17** (R = CH_3, C_2H_5), which is purified by recrystallization.

17 ($R = CH_3$): Yield 87 %; m.p. 214–217°C (from ethylacetate). Acc. to lit.[23], m.p. 210–211°C (from methanol-chloroform).

17 ($R = C_2H_5$): Yield 88 %; m.p. 115–117°C (from methanol-chloroform). Acc. to lit.[23], m.p. 115–117°C (from methanol-chloroform).

2. Deprotection of **17** to **15**, and reaction of the latter with **3**, resp. **4**.

A mixture of dialkyl N-(tritylaminomethane)phosphonate **17** (2 mmol) and a 1M solution of HCl in methanol (8 ml) is refluxed for 15 min. acc. to the lit.[23]to give the hydrochloride of dialkyl N-(aminomethane)phosphonate of type **15** ($R = CH_3$, resp. C_2H_5), identical in ^{1}H-NMR data with those cited in the lit.[23]. The phosphonate hydrochloride **15**, thus prepared is dissolved in abs. ethanol (5 ml) and the solution is added dropwise to a stirred solution containing chloride **3**, resp. **4** (2 mmol) and triethylamine (0.56 ml, 4 mmol) in dry THF (5 ml) at room temperature. The reaction mixture is stirred until the staring chloride is consumed completely according to TLC (ca. 48 hrs). The mixture is worked up as in the synthesis of componds **8–14**. The compounds **18–20** are purified by means of recrystallization.

Yields, m.p. and elemental analysis data of compounds **8–14** and **18–20** are given in Table I.

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