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·研究论文·

对氯苯乙酮肟醚衍生物的合成及生物活性

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摘 要:为寻找高活性的新农药化合物,通过 2-取代氨基-1-对氯苯乙酮-1-肟与卤代烃反应,设计并合成了 35个对氯苯乙酮肟醚衍生物,其结构均经核磁共振氢谱和元素分析确证。初步的生物活性测定结果表明,该类化合物具有一定的杀虫、抑菌及除草活性,其中 C_9、C_{12}在 500 mg/L时对蚜虫 *Aphis craccivaora*的致死率达到 100%; C_{10}、C_{12}、C_{15}和 C_{23}在 1 000 mg/L时对朱砂叶螨 *Tetranychus cinabarinus*的致死率达到 100%; C_{29}、C_{30}和 C_{31}在 500 mg/L时对黄瓜白粉病菌 *Sphaerotheca fuligineas*的抑制率达到 95%以上; C_{29}、C_{30}、C_{33}和 C_{35}在 100 mg/L时对马唐 *Digitaria sanguinalis*的抑制率达到 90%以上。

关键词:苯乙酮肟;合成;肟醚;生物活性
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Synthesis and Bioactivity of 4-Chlorophenyl Methyl Ketone Oxime Ether Derivatives

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Abstract: In search of novel pesticide leading compound with high bioactivity, thirty-five 4-chloro-phenyl methyl ketone oxime ether derivatives were designed and synthesized by the reaction of 2-substituted amino 4-chlorophenyl methyl ketone oxime with halohydrocarbon. The structure of all novel compounds was confirmed by ^1H NMR and elemental analysis. Preliminary bioassays showed that some compounds exhibited certain insecticidal and herbicidal activities. The mortality of C_9, C_{12} to *Aphis craccivaora* reached 100% at the concentration of 500 mg/L. The mortality of C_{10}, C_{12}, C_{15} and C_{23} to *Tetranychus cinabarinus* reached 100% at 1 000 mg/L. The inhibition rate of C_{29}, C_{30} and C_{31} to *Sphaerotheca fuligineas* was over 95% at the concentration of 500 mg/L. The inhibition rate of C_{29}, C_{30}, C_{33} and C_{35} to *Digitaria sanguinalis* was over 90% at the concentration of 100 mg/L.

Key words: phenyl methyl ketone oxime; synthesis; oxime ether; bioactivity

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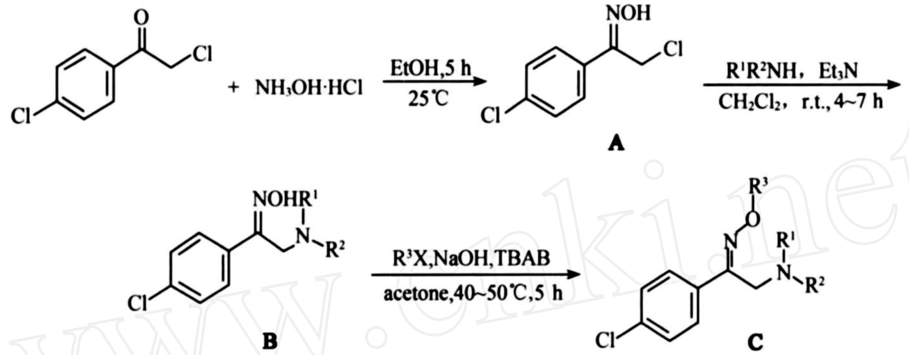
芳基烷基酮肟醚因具有相当的杀虫、杀菌、除草、抗植物病毒活性而令人关注[1]。肟醚结构则已成为新农药研制开发中的常用基团,此类结构化合物大多具有高效、低毒、低残留等优点[2,3]。如20世纪80年代由汽巴-嘉基公司开发的除草剂肟草安(fluxofenim)、杀菌剂啶斑肟(pyrifenox)[1,2]等。

近年来有不少新的苯乙酮肟类衍生物的研究报道[4~6],这一类化合物对作物常见病害如白粉病、炭疽病、菌核病等具有一定的防治效果[5]。笔者设计合成了含对氯苯乙酮肟结构的化合物,并进行了杀虫、杀菌和除草活性筛选,从中发现了一些具有一定活性的化合物。合成路线如下:



1 合成实验

1.1 仪器及试剂

Bruker AC300型核磁共振仪($CDCl_3$为溶剂,TMS为内标);WRS-1A型数字熔点仪;2W型阿贝折射仪。所用的试剂均为化学纯或者分析纯。

1.2 中间体 A、B的制备

按文献[7]方法合成。

1.3 目标化合物 C的合成[7,8]

以*O*-正丙基-1-(4-氯苯基)-2-(*N*,*N*-二正丁基氨基)-1-乙酮肟(C_9)的合成为例。在100 mL的三口烧瓶中加入0.89 g(3 mmol) 1-(4-氯苯基)-2-(*N*,*N*-二正丁基氨基)-1-乙酮肟,0.61 g(5 mmol)溴代正丙烷,0.20 g(5 mmol)氢氧化钠,0.2 g四丁基溴化胺(TBAB)和50 mL丙酮,40~50℃下搅拌5 h。减压蒸去溶剂,残余物中加入二氯甲烷,有机层经水洗,无水硫酸镁干燥后减压脱溶,得到黄色粘稠液。经柱层析(石油醚-乙酸乙酯=6:1,体积比)分离提纯,得到淡黄色液体0.55 g。

同法合成其他目标化合物,其物理常数及元素分析数据见表1,^1H NMR数据见表2。

Table 1 Physical and elemental analytical data of compounds **C**

Compd.	NR^1R^2	R^3	n_D^{25} or Mp/℃	Yield (%)	Elemental analysis (Calcd, %) C	H	N
C₁	$N(OCH_3)CH_3$	$CH_2=CHCH_2$	1.528 9	57.5	58.31 (58.10)	6.35 (6.38)	10.63 (10.42)
C₂	$N(OCH_3)CH_3$	n-C_3H_7	1.516 5	47.8	57.69 (57.67)	7.12 (7.07)	10.22 (10.35)
C₃	$N(OCH_3)CH_3$	i-C_3H_7	60.1~61.3	76.5	57.75 (57.67)	7.15 (7.07)	10.24 (10.35)
C₄	$N(OCH_3)CH_3$	sec-C_4H_9	1.510 8	63.8	59.16 (59.05)	7.51 (7.43)	9.59 (9.84)
C₅	$N(OCH_3)CH_3$	i-C_4H_9	1.513 8	72.5	59.26 (59.05)	7.35 (7.43)	9.68 (9.84)
C₆	$N(OCH_3)CH_3$	p-Cl$C_6H_4CH_2$	68.3~69.2	50.1	57.87 (57.80)	5.08 (5.14)	7.82 (7.93)
C₇	$N(OCH_3)CH_3$	i-C_5H_{11}	1.510 7	39.2	60.45 (60.29)	7.88 (7.76)	9.27 (9.38)
C₈	$N(n\text{-}C_4H_9)_2$	$CH_2=CHCH_2$	1.515 0	81.6	67.55 (67.74)	8.49 (8.68)	8.14 (8.32)
C₉	$N(n\text{-}C_4H_9)_2$	n-C_3H_7	1.506 5	55.0	67.56 (67.33)	9.36 (9.22)	8.33 (8.27)
C₁₀	$N(n\text{-}C_4H_9)_2$	i-C_3H_7	1.503 2	74.2	67.56 (67.33)	9.25 (9.22)	8.35 (8.27)
C₁₁	$N(n\text{-}C_4H_9)_2$	sec-C_4H_9	1.503 4	75.4	68.21 (68.06)	9.26 (9.42)	7.86 (7.94)
C₁₂	$N(n\text{-}C_4H_9)_2$	i-C_4H_9	1.502 0	60.8	68.26 (68.06)	9.22 (9.42)	7.85 (7.94)
C₁₃	$N(n\text{-}C_4H_9)_2$	i-C_5H_{11}	1.501 9	73.6	68.55 (68.73)	9.53 (9.61)	7.56 (7.63)
C₁₄	$N(n\text{-}C_4H_9)_2$	p-Cl$C_6H_4CH_2$	1.545 9	59.3	65.84 (65.55)	7.29 (7.18)	6.42 (6.65)

Continued

Compd.	NR^1R^2	R^3	n_D^{25} or Mp/℃	Yield (%)	Elemental analysis (Calcd, %) C	H	N
C_{15}	Piperidinyl	$CH_2=CHCH_2$	1.5440	69.5	66.54 (65.63)	7.69 (7.23)	9.27 (9.57)
C_{16}	Piperidinyl	$n-C_3H_7$	1.5335	70.2	65.27 (65.18)	7.64 (7.86)	9.66 (9.50)
C_{17}	Piperidinyl	$i-C_3H_7$	1.5309	62.0	65.39 (65.18)	7.89 (7.86)	9.42 (9.50)
C_{18}	Piperidinyl	$sec-C_4H_9$	1.5280	59.3	66.26 (66.11)	8.33 (8.16)	8.94 (9.07)
C_{19}	Piperidinyl	$i-C_4H_9$	1.5285	71.2	66.32 (66.11)	8.21 (8.16)	9.14 (9.07)
C_{20}	Piperidinyl	$i-C_5H_{11}$	1.5231	60.3	66.98 (66.96)	8.32 (8.43)	8.95 (8.68)
C_{21}	Piperidinyl	$p-ClC_6H_4CH_2$	1.5705	50.9	63.44 (63.67)	5.96 (5.88)	7.38 (7.42)
C_{22}	Morpholinyl	$CH_2=CHCH_2$	53.9～55.1	67.3	61.18 (61.12)	6.30 (6.50)	9.21 (9.50)
C_{23}	Morpholinyl	$n-C_3H_7$	1.5340	73.2	60.85 (60.70)	7.16 (7.13)	9.25 (9.44)
C_{24}	Morpholinyl	$i-C_3H_7$	63.8～64.1	83.4	60.55 (60.70)	7.23 (7.13)	9.51 (9.44)
C_{25}	Morpholinyl	$sec-C_4H_9$	1.5285	71.0	61.72 (61.83)	7.66 (7.46)	9.14 (9.01)
C_{26}	Morpholinyl	$i-C_4H_9$	36.0～37.1	69.8	61.72 (61.83)	7.53 (7.46)	9.20 (9.01)
C_{27}	Morpholinyl	$i-C_5H_{11}$	1.5250	42.4	62.74 (62.86)	7.86 (7.76)	8.91 (8.62)
C_{28}	Morpholinyl	$p-ClC_6H_4CH_2$	41.6～42.3	81.2	60.23 (60.17)	5.16 (5.32)	7.48 (7.39)
C_{29}	Imidazol	$n-C_3H_7$	1.5618	86.3	60.63 (60.54)	5.74 (5.81)	15.36 (15.13)
C_{30}	Imidazol	$i-C_3H_7$	75.0～78.3	76.8	60.36 (60.54)	5.66 (5.81)	15.30 (15.13)
C_{31}	Imidazol	$sec-C_4H_9$	1.5420	50.1	61.65 (61.75)	6.34 (6.22)	14.29 (14.40)
C_{32}	Imidazol	$i-C_4H_9$	85.9～87.5	65.2	61.72 (61.75)	6.35 (6.22)	14.28 (14.40)
C_{33}	$N(CH_3)_2$	$CH_2=CHCH_2$	1.5348	55.4	61.60 (61.78)	6.86 (6.78)	11.15 (11.08)
C_{34}	$N(CH_3)_2$	$n-C_3H_7$	1.5245	64.7	61.37 (61.29)	7.59 (7.52)	11.26 (11.00)
C_{35}	$N(CH_3)_2$	$i-C_3H_7$	51.7～52.4	57.4	61.16 (61.29)	7.64 (7.52)	11.25 (11.00)

Table 2 ^1H NMR data of compounds **C**

Compd.	^1H NMR ($CDCl_3$/TMS), δ
C_1	2.61 (s, 3H, NCH_3), 3.34 (s, 3H, OCH_3), 3.66 (s, 2H, NCH_2), 4.62 (d, 2H, J = 5.60 Hz, OCH_2), 5.16～5.29 (m, 2H, $=CH_2$), 5.91～6.10 (m, 1H, =CH), 7.37 (d, 2H, J = 8.68 Hz, ArH-2, 6), 7.57 (d, 2H, J = 8.68 Hz, ArH-3, 5)
C_2	0.93 (t, 3H, CH_3), 1.68 (m, 2H, CH_2), 2.59 (s, 3H, NCH_3), 3.35 (s, 3H, OCH_3), 3.65 (s, 2H, NCH_2), 4.06 (t, 2H, OCH_2), 7.35 (d, 2H, J = 8.82 Hz, ArH-2, 6), 7.57 (d, 2H, J = 8.82 Hz, ArH-3, 5)
C_3	1.23 (d, 6H, J = 6.00 Hz, $2CH_3$), 2.60 (s, 3H, NCH_3), 3.35 (s, 3H, OCH_3), 3.66 (s, 2H, NCH_2), 4.35～4.48 (m, 1H, CH), 7.34 (d, 2H, J = 8.44 Hz, ArH-2, 6), 7.62 (d, 2H, J = 8.44 Hz, ArH-3, 5)
C_4	0.93 (t, 3H, CH_3), 1.26 (d, 3H, J = 6.05 Hz, CH_3), 1.49～1.73 (m, 2H, CH_2), 2.62 (s, 3H, NCH_3), 3.39 (s, 3H, OCH_3), 3.69 (s, 2H, NCH_2), 4.19～4.29 (m, 1H, CH), 7.37 (d, 2H, J = 8.45 Hz, ArH-2, 6), 7.64 (d, 2H, J = 8.45 Hz, ArH-3, 5)
C_5	0.90 (d, 6H, J = 6.86 Hz, $2CH_3$), 1.92～2.06 (m, 1H, CH), 2.59 (s, 3H, NCH_3), 3.35 (s, 3H, OCH_3), 3.65 (s, 2H, NCH_2), 3.88 (d, 2H, J = 6.86 Hz, OCH_2), 7.35 (d, 2H, J = 8.50 Hz, ArH-2, 6), 7.57 (d, 2H, J = 8.50 Hz, ArH-3, 5)
C_6	2.57 (s, 3H, NCH_3), 3.30 (s, 3H, OCH_3), 3.64 (s, 2H, NCH_2), 5.10 (s, 2H, OCH_2), 7.30 (d, 2H, J = 8.78 Hz, ArH-2′, 6′), 7.34 (d, 2H, J = 8.60 Hz, ArH-2, 6), 7.37 (d, 2H, J = 8.60 Hz, ArH-3, 5), 7.64 (d, 2H, J = 8.78 Hz, ArH-3′, 5′)
C_7	0.90 (d, 6H, J = 6.34 Hz, $2CH_3$), 1.54 (t, 2H, CH_2), 1.58～1.60 (m, 1H, CH), 2.59 (s, 3H, NCH_3), 3.35 (s, 3H, OCH_3), 3.65 (s, 2H, NCH_2), 3.88 (d, 2H, J = 6.86 Hz, OCH_2), 7.35 (d, 2H, J = 8.54 Hz, ArH-2, 6), 7.57 (d, 2H, J = 8.54 Hz, ArH-3, 5)
C_8	0.86 (t, 6H, $2CH_3$), 1.14～1.28 (m, 4H, $2CH_2$), 1.32～1.41 (m, 4H, $2CH_2$), 2.43 (t, 4H, $2NCH_2$), 3.39 (s, 2H, NCH_2), 4.59 (d, 2H, J = 5.60 Hz, OCH_2), 5.18～5.30 (m, 2H, $=CH_2$), 5.94～6.03 (m, 1H, =CH), 7.34 (d, 2H, J = 8.50 Hz, ArH-2, 6), 7.56 (d, 2H, J = 8.50 Hz, ArH-3, 5)
C_9	0.84～0.95 (m, 9H, $3CH_3$), 1.15～1.27 (m, 4H, $2CH_2$), 1.33～1.44 (m, 4H, $2CH_2$), 1.66～1.73 (m, 2H, CH_2), 2.45 (t, 4H, $2NCH_2$), 3.41 (s, 2H, NCH_2), 4.05 (t, 2H, OCH_2), 7.35 (d, 2H, J = 8.40 Hz, , ArH-2, 6), 7.57 (d, 2H, J = 8.40 Hz, ArH-3, 5)

Continued

Compd.	^{1}HNMR ($CDCl_3$/TMS), δ
C_{10}	0.86 (t, 6H, $2CH_3$), 1.14～1.22 (m, 4H, $2CH_2$), 1.29 (d, 6H, J = 6.30 Hz, $2CH_3$), 1.34～1.44 (m, 4H, $2CH_2$), 2.45 (t, 4H, $2NCH_2$), 3.41 (s, 2H, NCH_2), 4.34～4.42 (m, 1H, OCH), 7.33 (d, 2H, J = 8.70 Hz, ArH-2, 6), 7.61 (d, 2H, J = 8.70 Hz, ArH-3, 5)
C_{11}	0.85～0.97 (m, 9H, $3CH_3$), 1.18～1.25 (m, 4H, $2CH_2$), 1.23 (d, 3H, J = 8.40 Hz, CH_3), 1.34～1.44 (m, 4H, $2CH_2$), 1.53～1.68 (m, 2H, CH_2), 2.44 (t, 4H, $2NCH_2$), 3.41 (s, 2H, NCH_2), 4.17～4.19 (m, 1H, OCH), 7.34 (d, 2H, J = 8.40 Hz, ArH-2, 6), 7.62 (d, 2H, J = 8.40 Hz, ArH-3, 5)
C_{12}	0.84～0.92 (m, 12H, $4CH_3$), 1.16～1.19 (m, 4H, $2CH_2$), 1.21～1.26 (m, 4H, $2CH_2$), 1.98～2.03 (m, 1H, CH), 2.43 (t, 4H, $2NCH_2$), 3.38 (s, 2H, NCH_2), 3.85 (d, 2H, J = 7.20 Hz, OCH_2), 7.33 (d, 2H, J = 8.70 Hz, ArH-2, 6), 7.57 (d, 2H, J = 8.70 Hz, ArH-3, 5)
C_{13}	0.84～0.94 (m, 12H, $4CH_3$), 1.15～1.27 (m, 4H, $2CH_2$), 1.33～1.44 (m, 4H, $2CH_2$), 1.55 (t, 2H, CH_2), 1.64～1.71 (m, 1H, CH), 2.43 (t, 4H, $2NCH_2$), 3.38 (s, 2H, NCH_2), 4.13 (t, 2H, OCH_2), 7.33 (d, 2H, J = 8.70 Hz, ArH-2, 6), 7.56 (d, 2H, J = 8.70 Hz, ArH-3, 5)
C_{14}	0.87 (t, 6H, $2CH_3$), 1.12～1.24 (m, 4H, $2CH_2$), 1.30～1.40 (m, 4H, $2CH_2$), 2.41 (t, 4H, $2NCH_2$), 3.41 (s, 2H, NCH_2), 5.10 (s, 2H, OCH_2), 7.26～7.38 (m, 6H, ArH-2, 6, 2′, 6′, 3, 5), 7.55 (d, 2H, J = 8.40 Hz, ArH-3′, 5′)
C_{15}	1.39～1.52 (m, 6H, $3CH_2$), 2.41 (t, 4H, $2NCH_2$), 3.28 (s, 2H, NCH_2), 4.57 (d, 2H, J = 5.40 Hz, OCH_2), 5.16～5.28 (m, 2H, =CH_2), 5.89～6.05 (m, 1H, =CH), 7.30 (d, 2H, J = 8.80 Hz, ArH2, 6), 7.57 (d, 2H, J = 8.80 Hz, ArH-3, 5)
C_{16}	0.92 (t, 3H, CH_3), 1.37～1.57 (m, 6H, $3CH_2$), 1.62～1.74 (m, 2H, CH_2), 2.43 (t, 4H, $2NCH_2$), 3.30 (s, 2H, NCH_2), 4.05 (t, 2H, OCH_2), 7.35 (d, 2H, J = 8.70 Hz, ArH-2, 6), 7.61 (d, 2H, J = 8.70 Hz, ArH-3, 5)
C_{17}	1.24 (d, 6H, J = 6.30 Hz, $2CH_3$), 1.41～1.57 (m, 6H, $3CH_2$), 2.44 (t, 4H, $2NCH_2$), 3.32 (s, 2H, NCH_2), 4.36～4.41 (m, 1H, OCH), 7.33 (d, 2H, J = 8.70 Hz, ArH～2, 6), 7.65 (d, 2H, J = 8.70 Hz, ArH-3, 5)
C_{18}	0.91 (t, 3H, CH_3), 1.21 (d, 3H, J = 6.00 Hz, CH_3), 1.41～1.58 (m, 6H, $3CH_2$), 1.62～1.67 (m, 2H, CH_2), 2.44 (t, 4H, $2NCH_2$), 3.33 (s, 2H, NCH_2), 4.15～4.21 (m, 1H, OCH), 7.35 (d, 2H, J = 8.70 Hz, ArH-2, 6), 7.65 (d, 2H, J = 8.70 Hz, ArH-3, 5)
C_{19}	0.90 (d, 6H, J = 6.60 Hz, $2CH_3$), 1.41～1.57 (m, 6H, $3CH_2$), 1.96～2.01 (m, 1H, CH), 2.44 (t, 4H, $2NCH_2$), 3.33 (s, 2H, NCH_2), 3.86 (d, 2H, J = 6.60 Hz, OCH_2), 7.35 (d, 2H, J = 8.40 Hz, ArH-2, 6), 7.59 (d, 2H, J = 8.40 Hz, ArH-3, 5)
C_{20}	0.91 (d, 6H, J = 6.30 Hz, $2CH_3$), 1.38～1.45 (m, 2H, CH_2), 1.51～1.58 (m, 6H, $3CH_2$), 1.60～1.69 (m, 1H, CH), 2.44 (t, 4H, $2NCH_2$), 3.31 (s, 2H, NCH_2), 4.12 (t, 2H, OCH_2), 7.34 (d, 2H, J = 8.60 Hz, ArH-2, 6), 7.59 (d, 2H, J = 8.60 Hz, ArH-3, 5)
C_{21}	1.41～1.56 (m, 6H, $3CH_2$), 2.39 (t, 4H, $2NCH_2$), 3.29 (s, 2H, NCH_2), 5.09 (s, 2H, OCH_2), 7.23～7.37 (m, 6H, ArH-2, 6, 2′, 6′, 3, 5), 7.55 (d, 2H, J = 8.40 Hz, ArH-3′, 5′)
C_{22}	2.50 (t, 4H, $2NCH_2$), 3.33 (s, 2H, NCH_2), 3.66 (t, 4H, $2OCH_2$), 4.59 (d, 2H, J = 5.40 Hz, OCH_2), 5.15～5.30 (m, 2H, =CH_2), 5.87～6.03 (m, 1H, =CH), 7.35 (d, 2H, J = 8.77 Hz, ArH-2, 6), 7.59 (d, 2H, J = 8.77 Hz, ArH-3, 5)
C_{23}	0.91 (t, 3H, CH_3), 1.61～1.72 (m, 2H, CH_2), 2.49 (t, 4H, $2NCH_2$), 3.32 (s, 2H, NCH_2), 3.66 (t, 4H, $2OCH_2$), 4.04 (t, 2H, OCH_2), 7.35 (d, 2H, J = 8.54 Hz, ArH～2, 6), 7.60 (d, 2H, J = 8.54 Hz, ArH-3, 5)
C_{24}	1.28 (d, 6H, J = 6.20 Hz, $2CH_3$), 2.55 (t, 4H, $2NCH_2$), 3.38 (s, 2H, NCH_2), 3.72 (t, 4H, $2OCH_2$), 4.39～4.46 (m, 1H, CH), 7.39 (d, 2H, J = 8.60 Hz, ArH-2, 6), 7.69 (d, 2H, J = 8.60 Hz, ArH-3, 5)
C_{25}	0.89 (t, 3H, CH_3), 1.20 (d, 3H, J = 6.20 Hz, CH_3), 1.43～1.70 (m, 2H, CH_2), 2.49 (t, 4H, $2NCH_2$), 3.33 (s, 2H, NCH_2), 3.66 (t, 4H, $2OCH_2$), 3.87 (d, 2H, J = 6.40 Hz, OCH_2), 4.13～4.22 (m, 1H, CH), 7.33 (d, 2H, J = 8.57 Hz, ArH-2, 6), 7.65 (d, 2H, J = 8.57 Hz, ArH-3, 5)
C_{26}	0.90 (d, 6H, J = 6.80 Hz, $2CH_3$), 1.95～2.01 (m, 1H, CH), 2.51 (t, 4H, $2NCH_2$), 3.35 (s, 2H, NCH_2), 3.68 (t, 4H, $2OCH_2$), 3.87 (d, 2H, J = 6.40 Hz, OCH_2), 7.36 (d, 2H, J = 8.26 Hz, ArH-2, 6), 7.60 (d, 2H, J = 8.26 Hz, ArH-3, 5)
C_{27}	0.90 (d, 6H, J = 6.20 Hz, $2CH_3$), 1.53 (t, 2H, CH_2), 1.55～1.59 (m, 1H, CH), 2.49 (t, 4H, $2NCH_2$), 3.32 (s, 2H, NCH_2), 3.66 (t, 4H, $2OCH_2$), 4.12 (t, 2H, OCH_2), 7.34 (d, 2H, J = 8.52 Hz, ArH-2, 6), 7.59 (d, 2H, J = 8.52 Hz, ArH-3, 5)
C_{28}	2.51 (t, 4H, $2NCH_2$), 3.38 (s, 2H, NCH_2), 3.70 (t, 4H, $2OCH_2$), 5.13 (s, 2H, OCH_2), 7.25～7.33 (m, 4H, ArH-2, 6, 2′, 6′), 7.40 (d, 2H, J = 8.70 Hz, ArH-3, 5), 7.59 (d, 2H, J = 8.63 Hz, ArH-3′, 5′)

Continued

Compd.	^1HNMR ($CDCl_3$/TMS), δ
C_{29}	0.97(t, 3H, CH_3), 1.71～1.83(m, 2H, CH_2), 4.23(t, 2H, OCH_2), 5.15(s, 2H, NCH_2), 6.88 (s, 1H, imidazolyl-4), 6.99 (s, 1H, imidazolyl-5), 7.32 (d, 2H, J = 8.70 Hz, ArH-3, 5), 7.48(d, 2H, J = 8.70 Hz, ArH-2, 6), 7.51 (s, 1H, imidazolyl-2)
C_{30}	1.23(d, 6H, J = 6.00 Hz, $2CH_3$), 4.36～4.45(m, 1H, OCH), 4.89 (s, 2H, NCH_2), 6.86(s, 1H, imidazolyl-4), 7.00(s, 1H, imidazolyl-5), 7.22(d, 2H, J = 8.70 Hz, ArH-3, 5), 7.32(d, 2H, J = 8.70 Hz, ArH-2, 6), 7.40(s, 1H, imidazolyl-2)
C_{31}	0.94(t, 3H, CH_3), 1.29(d, 3H, J = 6.30 Hz, CH_3), 1.53～1.80(m, 2H, CH_2), 4.31～4.37(m, 1H, OCH), 5.15(s, 2H, NCH_2), 6.87 (s, 1H, imidazolyl-4), 6.98 (s, 1H, imidazolyl-5), 7.31 (d, 2H, J = 8.40 Hz, ArH-3, 5), 7.52(d, 2H, J = 8.40 Hz, ArH-2, 6), 7.56(s, 1H, imidazolyl-2)
C_{32}	0.97(d, 6H, J = 6.60 Hz, $2CH_3$), 2.06～2.10(m, 1H, CH), 4.07(d, 2H, J = 6.90 Hz, OCH_2), 5.21(s, 2H, NCH_2), 6.91 (s, 1H, imidazolyl-4), 7.03 (s, 1H, imidazolyl-5), 7.33 (d, 2H, J = 8.40 Hz, ArH-3, 5), 7.52(d, 2H, J = 8.40 Hz, ArH-2, 6), 7.68(s, 1H, imidazolyl-2)
C_{33}	2.24(s, 6H, $2CH_3$), 3.29(s, 2H, NCH_2), 4.60 (d, 2H, J = 5.40 Hz, OCH_2), 5.20～5.28(m, 2H, =CH_2), 5.91～6.10 (m, 1H, =CH), 7.35(d, 2H, J = 8.55 Hz, ArH-2, 6), 7.55(d, 2H, J = 8.55 Hz, ArH-3, 5)
C_{34}	0.91(t, 3H, CH_3), 1.62～1.73(m, 2H, CH_2), 2.24(s, 6H, $2CH_3$), 3.29(s, 2H, NCH_2), 4.05 (t, 2H, OCH_2), 7.35(d, 2H, J = 8.47 Hz, ArH-2, 6), 7.55(d, 2H, J = 8.47 Hz, ArH-3, 5)
C_{35}	1.23(d, 6H, J = 6.20 Hz, $2CH_3$), 2.24(s, 6H, $2NCH_3$), 3.29(s, 2H, NCH_2), 4.32～4.45(m, 1H, CH), 7.35(d, 2H, J = 8.55 Hz, ArH-2, 6), 7.60(d, 2H, J = 8.55 Hz, ArH-3, 5)

2 生物活性测定

按《国家南方农药创制中心生测标准程序》进行。称取一定量药物,加入 2%DMF使药物溶解,用无菌水稀释成 1 000 mg/L母液。然后再用无菌水稀释成 500、250、125、100 mg/L系列浓度药液备用。

2.1 杀虫活性

2.1.1 杀蚜虫 *Aphis craccivaora*活性 测试浓度为 500 mg/L,重复 3次,设空白对照。

2.1.2 杀螨 *Tetranychus cinabarinus*活性 测试浓度 1 000 mg/L,重复 3次,设空白对照。

2.2 杀菌活性

采用活体盆栽法测试,测试对象为稻瘟病菌 *Piricularia oryzae*、水稻纹枯病菌 *Rhizoctonia solani*、黄瓜灰霉病菌 *Botrytis cinerea*、黄瓜白粉病菌 *Sphaerotheca fuliginea*、小麦赤霉病菌 *Gibberella zeae*、玉米小斑病菌 *Helminthosporium maydis*,测试浓度分别为 500、250和 125 mg/L,重复 4次。设空白对照。

2.3 除草活性

采用平皿法,测试对象为稗草 *Echinochloa crusgalli* Link、高粱 *Sorghum vulgare* Pers.、马唐 *Digitaria sanguinalis*、苋菜 *Ambrosia tricolor* Linn.、黄瓜 *Cucumis sativus*、油菜 *Brassica alboglabra*,测试浓度为 100 mg/L,重复 3次。设空白对照。

3 结果与讨论

生物活性测定结果(表 3)表明,所合成的部分化合物具有一定的杀虫活性。在 500 mg/L时,化合物 C_8、C_9、C_{11}、C_{12}、C_{13}对蚜虫的致死率达到 80%～100%; C_{10}、C_{12}、C_{15}和 C_{23}在 1 000 mg/L时对螨的致死率达到 100%。

Table 3 Insecticidal activity of compounds **C**

Compd.	Mortality (%)	
	A. craccivaora (500 mg/L)	T. cinabarinus (1 000 mg/L)
C_8	89.0	0
C_9	100	0
C_{10}	0	100.0
C_{11}	86.2	0
C_{12}	100	100.0
C_{13}	89.4	0
C_{15}	0	100.0
C_{23}	0	100.0
C_{29}	0	78.4
C_{33}	0	61.9
C_{35}	11.8	98.0

Note: No insecticidal activity for the compounds which were not listed in the table.

杀菌活性测定结果(表 4)显示, C_{29}、C_{30}和 C_{31}在 500 mg/L时对黄瓜白粉病菌的抑制率均在 95%以上。

Table 4 Inhibition rate (%) to *S. fuliginea* of compounds **C** in different concentration

Compd.	500 mg/L	250 mg/L	125 mg/L
C_{29}	99.4	94.3	92.5
C_{30}	100.0	98.9	95.4
C_{31}	95.1	56.1	33.5

Note: No fungicidal activity for the compounds which were not listed in the table.

除草活性测定结果 (表 5)表明, C_{29}、C_{30}、C_{31}、C_{33}、C_{34}和 C_{35}在 100 mg/L时对马唐的抑制率为85%～95%。

可以看出,当 NR^1R^2为甲基甲氧基氨基时,均无杀虫、杀菌、除草活性;当 NR^1R^2为二正丁基氨基时,化合物具有较好的杀蚜虫活性;当 NR^1R^2为咪唑基团时,对白粉病菌具有较好的抑制作用;除草活性主要表现为对马唐的抑制作用,其中以NR^1R^2为二甲基氨基、咪唑基时活性较好。对此将进一步通过 QSAR进行分析和优化。

Table 5 Herbicidal activity of compounds **C** (100 mg/L)

Compd.	Inhibition rate (shoot/root, %)					
	E. crusgalli	S. vulgare	D. sanguinalis	A. tricolor	C. sativus	B. alboglabra
C_1	0	45/10	60/0	0	0	0
C_{15}	0	0	89/68	52/35	0	0
C_{17}	53/20	25/0	90/50	60/50	50/13	60/60
C_{22}	0	0	81/11	45/32	0	0
C_{23}	0	0	78/24	57/70	0	0
C_{25}	0	0	61/19	70/87	0	0
C_{27}	0	0	78/85	70/78	0	0
C_{29}	88/83	63/83	95/95	88.3/90	62/83	60/70
C_{30}	82/85	72/82	95/95	82/75	65/85	65/60
C_{31}	75/60	50/75	90/75	95/97	60/75	65/60
C_{32}	40/57	6.7/28	65/80	58.3/58.3	38/40	48/30
C_{33}	42/0	0	94/90	59/58	0	0
C_{34}	66/41	41/8	94/88	52/36	0	0
C_{35}	50/15	0	94/90	60/33	0	0

Note: No herbicidal activity for the compounds which were not listed in the table.

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