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Design, Synthesis, and Herbicidal Activity of Novel Substituted 3-(Pyridin-2-yl)benzenesulfonamide Derivatives

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Supporting Information

ABSTRACT: A series of novel substituted 3-(pyridin-2-yl)benzenesulfonamide derivatives were designed and synthesized using 2-phenylpridines as the lead compound by intermediate derivatization methods in an attempt to obtain novel compound candidates for weed control. The herbicidal activity assay in glasshouse tests showed several compounds (**II6**, **II7**, **II8**, **II9**, **II10**, **II11**, **III2**, **III3**, **III4,** and **III5**) could efficiently control velvet leaf, youth-and-old age, barnyard grass, and foxtail at the 37.5 g/ha active substance. Especially, the activities of **II6**, **II7**, **III2,** and **III4** were proved roughly equivalent to the saflufenacil and better than 95% sulcotrione at the same concentration. The result of the herbicidal activity assay in field tests demonstrated that **II7** at 60 g/ha active substance could give the same effect as bentazon at 1440 g/ha active substance to control dayflower and nightshade, meanwhile **II7** showed better activity than oxyfluorfen to control arrowhead and security to rice. The present work indicates that **II7** may be a novel compound candidate for potential herbicide.

KEYWORDS: *substituted 3-(pyridin-2-yl)benzenesulfonamide compounds, intermediate derivatization methods, herbicide*

INTRODUCTION

Pyridine has been widely used in the fields of medicine[1−3] and pesticide[4−7] as an important intermediate. For instance, neonicotinoid insecticides[8−10] and sulfonylurea herbicides,[11] which are important pesticides in the world, all contain a pyridine ring. According to some statistics, there are more than 30 herbicides containing pyridine ring at present,[12] and more highly active compounds containing pyridine ring were reported in recent years.[13−24]

Substituted 2-phenylpyridines which were disclosed by Schaefer Peter et al. showed good herbicidal activity;[25,26] several compounds could efficiently control velvet leaf (*abutilon thephrasti*), redroot pigweed (*amaranthus retroflexus*), and morningglory (*ipomoea subspecies*) at 250 and 125 g/ha by the postemergence method. T. Konakahara et al.[27] disclosed that fluorinated 2-phenylpyridines could been provided as intermediates for drugs and agrochemicals, such as substituted thiobarbituric acids[28] and 4-[(trifluoromethyl)pyridyl]-phenols.[26,29−32] Yanagi Akihiko et al.[33] discovered 2,6-diarylpyridine derivatives could be used as herbicide and defoliating agent. However, those known compounds which in fact have herbicidal effect are not always completely satisfactory

Accordingly, in order to search for novel compounds which have in particular herbicidal activity and which can be used for the targeted control of unwanted plants, we designed and synthesized substituted 3-(pyridin-2-yl)benzenesulfonamide derivatives (Figure 1 and Table 1) using 2-phenylpyridines as the lead compound by intermediate derivatization methods (IDM)—a practical approach to agrochemical discovery. Intermediate derivatization methods use a three-pronged approach to agrochemical discovery—common intermediate method (CIM), terminal group replacement method (TRM or RM), and active compound derivatization method (ADM or DM).[34−36] Among these three approaches, the terminal group replacement method has been proved as an effective and practical method.[37−44] As shown in Figure 1, according to the terminal group replacement method, modification of the sulfonamide group of 2-phenylpridines by introducing hydrazine derivatives, fatty alcohols, and substituted amines gave compounds **I1**−**I5**, **II1**−**II5**, **II11**−**II12**, **II16**, and **III1**. Meanwhile, carbamic acid ester, which is the important group of the herbicide asulam,[45] was employed to replace the sulfonamide group of 2-phenylpridines to synthesize compounds **II6**−**II10** and **III2**−**III4**. Then, other derivatives were further derived from compounds **II6**−**II10** or **III2**−**III4.** Furthermore, the herbicidal effects of the substituted 3-(pyridin-2-yl)benzenesulfonamide derivatives were investigated in the glasshouse and the field.

MATERIALS AND METHODS

Synthesis. All starting materials and reagents were commercially available and used without further purification except as indicated. Melting points were determined on a Büchi melting point apparatus and are uncorrected. ^{1}H NMR spectra were recorded with a Mercury 300 (Varian, 300 MHz) spectrometer with deuterochloroform as the solvent and tetramethylsilane (TMS) as the internal standard. Elemental analyses were determined on a Yanaco MT-3CHN elemental analyzer.

An overview synthesis of substituted 3-(pyridin-2-yl)-benzenesulfonamide analogues is shown in Scheme 1.

Synthesis of Intermediate a. Substituted 2-dichloro-5-trifluoromethylpyridine (0.18 mol), substituted 4-chlorobezeneboronic (0.18 mol), tetrakis(triphenylphosphine)palladim(0) (0.7 g, 0.61 mmol), and sodium bicarbonate (45.3 g, 0.539 mol) in a mixture of 550 mL of

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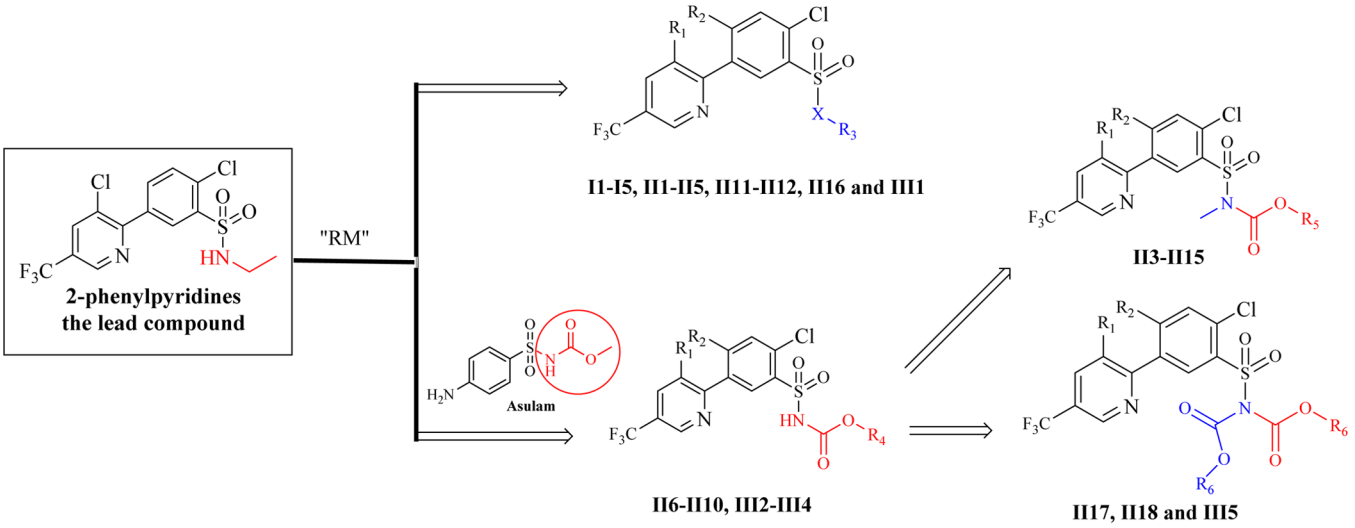

X = O, N; R_1 = H, Cl; R_2 = H, F; R_3 = $NHCH_3$, $NHCH_2CN$, NH_2, $NHNHCH_3$, $OCH_2CH_2C_6H_5$, $OCH_2CH{=}CH_2$, NHCN,  ,  ;

R_4 = H, CH_3, CH_2CH_3, $CH(CH_3)_2$, $CH_3CH_2CH_2CH_3$, $CH_2CH_2OCH_3$; R_5 = CH_3, CH_2CH_3, $CH(CH_3)_2$; R_6 = CH_3, CH_2CH_3

Figure 1. Design of 3-(pyridin-2-yl)benzenesulfonamide derivatives. "RM" means "terminal group replacement method".

dimethoxyethane and 550 mL of water were refluxed for 4 h. The mixture was then acidified to pH 4−5 with dilute hydrochloric acid, and dimethoxyethane was removed by distillation. The remaining aqueous phase was extracted with methylene chloride. The combined methylene chloride phased was washed with water, dried over sodium sulfate, and evaporated. The residue was stirred with a little cold *n*-hexane, filtered off with suction, and dried.

*2-(4-Chlorophenyl)-5-(trifluoromethyl)pyridine (**a1**).* Yield: 60% of colorless crystals of melting point 89−90 °C. ^{1}H NMR (300 MHz, $CDCl_3$) δ_H (ppm) = 7.47 (d, *J* = 8.3 Hz, 2H), 7.73 (d, *J* = 8.4 Hz, 2H), 8.04 (d, *J* = 8.5 Hz, 1H), 8.05 (d, *J* = 8.3 Hz, 1H), 8.83 (s, 1H).

*3-Chloro-2-(4-chlorophenyl)-5-(trifluoromethyl)pyridine (**a2**).* Yield: 70% of colorless crystals of melting point 72−74 °C. ^{1}H NMR (300 MHz, $CDCl_3$) δ_H (ppm) = 7.47 (d, *J* = 8.4 Hz, 2H), 7.73 (d, *J* = 8.4 Hz, 2H), 8.04 (s, 1H), 8.83 (s, 1H).

*3-Chloro-2-(4-chloro-2-fluorophenyl)-5-(trifluoromethyl)pyridine (**a3**).* Yield: 76% of colorless crystals of melting point 34−35 °C. ^{1}H NMR (300 MHz, $CDCl_3$) δ_H (ppm) = 7.32 (dd, *J* = 8.3, 2.2 Hz, 2H), 7.43 (d, 1H), 8.05 (s, 1H), 8.86 (s, 1H).

Synthesis of Intermediate b. The intermediate **a** (0.033 mol) was added dropwise to chlorosulfonic acid at 0−5 °C, and the mixture was heated at 130 °C for 8 h.[25] The reaction mixture was then cooled to room temperature and was poured into crushed ice with ethyl acetate (3 × 60 mL). The combined extract was washed with water and saturated brine and dried over anhydrous magnesium sulfate, and then filtered and concentrated under reduced pressure to give a pale yellow liquid.

*2-Chloro-5-(5-(trifluoromethyl)pyridin-2-yl)benzene-1-sulfonyl Chloride (**b1**).* Yield: 90%. ^{1}H NMR (300 MHz, $CDCl_3$) δ_H (ppm) = 7.73 (d, *J* = 8.3 Hz, 1H), 7.92 (d, *J* = 8.4 Hz, 1H), 8.05 (d, *J* = 8.3 Hz, 1H), 8.32 (d, *J* = 8.4 Hz, 1H), 8.80 (s, 1H), 8.99 (s, 1H).

*2-Chloro-5-(3-chloro-5-(trifluoromethyl)pyridin-2-yl)benzene-1-sulfonyl Chloride (**b2**).* Yield: 90%. ^{1}H NMR (300 MHz, $CDCl_3$) δ_H (ppm) = 7.68 (d, *J* = 8.4 Hz, 1H), 7.96 (d, *J* = 8.4 Hz, 1H), 8.08 (s, 1H), 8.52 (s, 1H), 8.87 (s, 1H).

*2-Chloro-5-(3-chloro-5-(trifluoromethyl)pyridin-2-yl)-4-fluorobenzene-1-sulfonyl Chloride (**b3**).* Yield: 91%. ^{1}H NMR (300 MHz, $CDCl_3$) δ_H (ppm) = 7.40 (d, *J* = 8.3 Hz, 1H), 8.05 (s, 1H), 8.25 (d, 1H), 8.86 (s, 1H).

Synthesis of Substituted 3-(pyridin-2-yl)-benzenesulfonamide Compounds. *2-Chloro-5-(5-(trifluoromethyl)pyridin-2-yl)benzenesulfonamide (**I1**).* The intermediate **b1** (0.01 mol) in 20 mL of THF was added dropwise to $NH_3 \cdot H_2O$ at 0−5 °C, and the mixture was stirred at room temperature. Then the mixture was concentrated under reduced pressure to obtain a pale yellow solid. Yield: 85%. Melting point: 163−165 °C. ^{1}H NMR (300 MHz, $CDCl_3$) δ_H (ppm) = 8.97 (s, 1H), 8.76 (d, *J* = 2.3 Hz, 1H), 8.28 (d, *J* = 8.4 Hz, 1H), 8.04 (s, 1H), 7.93 (s, 1H), 7.70 (d, *J* = 8.3 Hz, 1H), 5.17 (s, 2H). Anal. Calcd (%) for $C_{12}H_8ClF_3N_2O_2S$: C, 42.80; H, 2.39; N, 8.32. Found: C, 42.81; H, 2.42; N, 8.35.

*2-((2-Chloro-5-(5-(trifluoromethyl)pyridin-2-yl)phenyl)sulfonyl)-acetonitrile (**I2**).* 2-amino acetonitrile (3 mmol), the intermediate **b1** (1.5 mmol), and triethylamine in 15 mL of THF were stirred at room temperature. Then the mixture was concentrated under reduced pressure to get the target compound. Yield: 40% of yellow solid of melting point 158−160 °C. ^{1}H NMR (300 MHz, $CDCl_3$) δ_H (ppm) = 8.99 (s, 1H), 8.81 (s, 1H), 8.33 (d, *J* = 8.3 Hz, 1H), 8.05 (s, 1H), 7.93 (d, *J* = 7.9 Hz, 1H), 7.74 (d, *J* = 8.5 Hz, 1H), 5.52 (s, 1H), 4.12 (d, *J* = 6.7 Hz, 2H). Anal. Calcd (%) for $C_{14}H_9ClF_3N_3O_2S$: C, 44.75; H, 2.41; N, 11.18. Found: C, 44.76; H, 2.43; N, 11.16.

II1-**II5**, **II11**, **II12**, **II16**, and **III1** were synthesized using the synthetic method of **I2**

*Methyl ((2-Chloro-5-(3-chloro-5-(trifluoromethyl)pyridin-2-yl)-phenyl)sulfonyl)carbamate (**II6**).* Synthesis of 2-chloro-5-(3-chloro-5-(trifluoromethyl)pyridin-2-yl)benzenesulfonamide. The intermediate **b2** (0.01 mol) in 20 mL of THF was added dropwise to $NH_3 \cdot H_2O$ (0.02 mol) at 0−5 °C, and the mixture was stirred at room temperature for 2 h. Then the mixture was concentrated under reduced pressure to obtain a pale yellow solid. Yield: 81%. Melting point: 166−168 °C. ^{1}H NMR (300 MHz, $CDCl_3$) δ_H (ppm) = 5.17(2H, s), 7.69(1H, d), 7.96(1H, d), 8.09(1H, s), 8.57(1H, s), 8.86(1H, s). Synthesis of methyl ((2-chloro-5-(3-chloro-5-(trifluoromethyl)pyridin-2-yl)phenyl)sulfonyl)carbamate. 2-Chloro-5-(3-chloro-5-(trifluoromethyl)pyridin-2-yl)benzenesulfonamide (0.6 g, 1.6 mmol), K_2CO_3 (0.31 g, 2.26 mmol), and methyl chloroformate (0.2 g, 1.67 mmol) in 15 mL of acetone were refluxed for 6 h. The mixture was concentrated under reduced pressure. Then the crude product was purified by column chromatography with a mixture of ethyl acetate and petroleum ether (1:3) to get 0.25 g of target compound. Yield: 31% of yellow solid of melting point 144−146 °C. ^{1}H NMR (300 MHz, $CDCl_3$) δ_H (ppm) = 8.90 (s, 1H), 8.77 (d, *J* = 2.2 Hz, 1H), 8.12 (s, 1H), 8.07 (dd, *J* = 8.3, 2.2 Hz, 1H), 7.89 (s, 1H), 7.72 (d, *J* = 8.3 Hz, 1H), 3.75 (s, 3H). ^{13}C NMR (75 MHz, $CDCl_3$) δ 156.42, 150.51, 144.57, 144.52, 144.47, 135.76, 135.71, 135.63, 134.27, 133.95, 133.44, 131.81, 127.32, 53.87. Anal. Calcd (%) for

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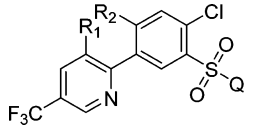
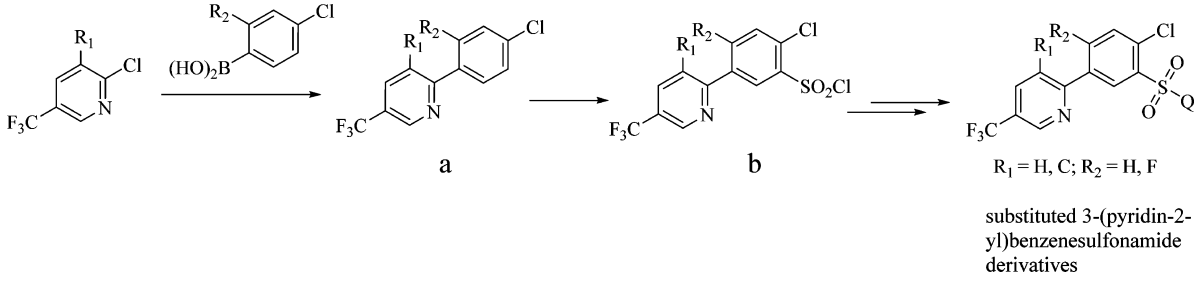
Table 1. Chemical Structures and Herbicidal Activity of Substituted 3-(Pyridin-2-yl)benzenesulfonamide Analogues by Postemergence Treatment in Glasshouse Tests[b]



compounds	R_1	R_2	Q	YOApost- (ga.i./ha)			VELpost- (ga.i./ha)			FOXpost- (ga.i./ha)			BYG post- (ga.i./ha)		
				600	150	37.5	600	150	37.5	600	150	37.5	600	150	37.5
I1	H	H	NH_2	**0**	/[a]	/	**0**	/	/	**0**	/	/	**0**	/	/
I2	H	H	$NHCH_2CN$	0	/	/	0	/	/	0	/	/	0	/	/
I3	H	H	$NCH(CH_3)_2$	0	/	/	0	/	/	0	/	/	0	/	/
I4	H	H	$NHOCH_3$	0	/	/	5	/	/	0	/	/	0	/	/
I5	H	H	$NHCH_3$	0	/	/	0	/	/	0	/	/	0	/	
II1	Cl	H	$OCH_2CH_2C_6H_5$	20	10	5	40	25	20	10	5	5	5	5	0
II2	Cl	H	$OCH_2CH{=}CH_2$	50	15	0	60	10	5	20	15	5	10	0	0
II3	Cl	H		/	/	/	100	/	/	/	/	/	40	/	/
II4	Cl	H	NHCN	100	98	15	100	80	35	35	15	5	35	20	10
II5	Cl	H	$NHCH_2CN$	100	100	100	100	100	100	100	100	100	100	95	95
II6	Cl	H	$NHCO_2CH_3$	100	100	100	100	100	100	100	100	100	100	100	100
II7	Cl	H	$NHCO_2C_2H_5$	100	100	100	100	100	100	100	100	90	100	100	90
II8	Cl	H	$NHCO_2CH(CH_3)_2$	100	100	90	100	100	90	100	100	90	100	100	90
II9	Cl	H	$NHCO_2CH_2CH_2CH_2CH_3$	100	100	100	100	100	100	65	45	10	65	50	15
II10	Cl	H	$NHCO_2CH_2CH_2OCH_3$	100	100	100	100	100	100	85	55	45	98	65	50
II11	Cl	H	$NHN(CH_3)_2$	100	100	100	100	100	100	95	60	50	98	50	45
II12	Cl	H	$NHNHCH_3$	90	80	40	85	15	5	20	0	0	0	0	0
II13	Cl	H	$N(CH_3)CO_2CH_3$	/	/	/	85	/	/	/	/	/	35	/	/
II14	Cl	H	$N(CH_3)CO_2C_2H_5$	/	/	/	0	/	/	/	/	/	0	/	/
II15	Cl	H	$N(CH_3)CO_2CH(CH_3)_2$	25	20	15	95	50	25	10	10	0	15	10	5
II16	Cl	H		35	25	20	98	50	35	10	10	5	10	5	5
II17	Cl	H	$N(CO_2CH_3)_2$	95	90	85	98	85	90	90	40	60	85	40	20
II18	Cl	H	$N(CO_2C_2H_5)_2$	45	30	20	50	45	10	30	20	20	20	10	10
III1	Cl	F	$NHCH_2CN$	5	/	/	0	/	/	0	/	/	0	/	/
III2	Cl	F	$NHCO_2H$	100	100	100	100	100	100	100	100	98	100	100	100
III3	Cl	F	$NHCO_2CH_3$	100	100	100	100	100	100	100	100	65	100	100	60
III4	Cl	F	$NHCO_2CH_2CH_3$	100	100	100	100	100	100	100	100	100	100	100	100
III5	Cl	F	$N(CO_2CH_3)_2$	100	100	95	100	100	100	100	100	80	100	100	50
Lead compound	*Cl*	*H*	*$NHCH_2CH_3$*	*100*	*/*	*20*	*100*	*/*	*15*	*30*	*/*	*10*	*25*	*/*	*10*
			Saflufenacil	*100*	*100*	*100*	*100*	*100*	*100*	*100*	*100*	*100*	*100*	*100*	*90*
	95%		***sulcotrione***	*95*	*90*	*55*	*95*	*80*	*60*	*98*	*90*	*55*	*100*	*98*	*55*

[a]Stands for no data. [b]YOApost-, VELpost-, FOXpost-, and BYG post- mean youth-and-old age (*Zinnia elegans Jacq.*), velvet leaf (*Abutilon theophrasti Medic.*), foxtail (*Setaria glauca (L.) Beauv*), and barnyard grass (*Echinochloa crus-galli (L.) Beauv*), respectively.

Scheme 1. Overview Synthetic Methods of Substituted 3-(Pyridin-2-yl)benzenesulfonamide Derivatives



$C_{14}H_9Cl_2F_3N_2O_4S$: C, 39.18; H, 2.11; N, 6.53; Found: C, 39.19; H, 2.15; N, 6.52.

II7–**II10**, **II13**–**II15**, **II17**, **II18**, and **III2**–**III5** were synthesized using the synthetic method of **II6**.

Herbicidal Activity Assay. *Herbicidal Activity Assay in Glasshouse Tests.* All plant materials were obtained from the Agrochemical Discovery Department in Shenyang Research Institute of Chemical Industry. Plants were grown in plastic flowerpots containing loamy sand with about 3.0% humus as substrate. The seeds of the test plants were sown separately according to species.

The test plants were grown to a height of 3–15 cm, depending on the species, and only then treated with the active ingredients

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Table 2. Herbicidal Activity of II5, II6, II7, II10, III2, and III4 by Postemergence Treatment in Glasshouse Tests Employing a Parallel Experiment[a]

	YOApost-				VELpost-				FOXpost-				BYGpost-			
compd	300	150	37.5	18.75	300	150	37.5	18.75	300	150	37.5	18.75	300	150	37.5	18.75
II5	100	100	100	100	100	100	100	100	100	100	70	55	100	100	100	75
II6	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
II7	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
II10	100	100	100	100	100	100	100	100	85	55	45	40	100	98	50	45
III2	100	100	100	100	100	100	100	100	100	100	65	50	100	100	60	50
III4	100	100	100	100	100	100	100	90	100	100	80	50	100	100	50	25

[a]YOApost-, VELpost-, FOXpost- and BYG post- mean youth-and-old age (*Zinnia elegans Jacq.*), velvet leaf (*Abutilon theophrasti Medic.*), foxtail (*Setaria glauca (L.) Beauv*), and barnyard grass (*Echinochloa crus-galli (L.) Beauv*), respectively.

suspended or emulsified in water. For this purpose, the test plants were either sown directly or grown in the same vessels or they were germinated separately and transplanted into the test vessels a few days before the treatment. The application rate for postemergence treatment was 600, 150, and 37.5 g/ha active substance.

The plants were kept at 10−25 °C or 20−35 °C depending on the species. The test lasted 2−4 weeks during which the plants were tended and their reaction to the individual treatments was evaluated.

Evaluation was on a scale from 0 to 100, where 100 means no emergence of the plants or complete destruction of at least the above-ground parts and 0 means no damage or normal growth.

The plants used in the glasshouse tests comprised the following species: velvet leaf (*Abutilon Theophrasti Medic.*), youth-and-old age (*Zinnia Elegans Jacq.*), barnyard grass (*Echinochloa crus-galli(L.) Beauv.*), and foxtail (*Setaria Glauca(L.) Beauv.*).

Herbicidal Activity Assay in Field Tests. The experiment of the field tests was operated on the basis of field efficacy trials of Chinese pesticide standards (a) GB/T17980.40-2000. The test weeds in rice field were at 2−4 leaf stage. The controlling weeds comprised the following species: dayflower (*commelina tuberosa*) and nightshade (*disambiguation*) in Liaoning and arrowhead (*sagittarian trifolia*) in Heilongjiang. The application rate for treatment was 30 and 60 g/ha active substance. The application rate for treatment of bentazon[46]-(48%, water dispersible granule) which was used as the control in Liaoning was 1440 g/ha active substance, while 24% oxyfluorfen EC was used as the control in Herlongjiang.

Formulas used in these tests are as follows: Control effect (%) = (the number of live weeds in the control area − the number of live weeds in the treated area)/the number of live weeds in the control area × 100%.

RESULTS AND DISCUSSION

Chemistry. The designed substituted 3-(pyridin-2-yl)-benzenesulfonamide compounds were synthesized through critical intermediates (**b**) as shown in Scheme 1. The reactions of the intermediates **b1**, **b2**, and **b3** via the amino compounds and triethylamine using THF as the solvent afforded series I, series II, and series III in considerable yield, respectively. The 28 target compounds and intermediates were characterized by ^{1}H NMR and elemental analyses. All spectral and analytical data were consistent with the assigned structures.

Herbicidal Activity. The 28 target compounds were evaluated for their herbicidal ability to control the unwanted plants using postemergence treatment in the glasshouse and the field tests. For postemergence treatment in the glasshouse, the designed substituted 3-(pyridin-2-yl)benzenesulfonamide compounds were compared to the lead compounds which were disclosed by researchers at BASF Aktiengesellschaft,[26] saflufenacil[47] and sulcotrione.[48] As shown in Table 1, series **I** compounds which were synthesized through intermediates **b1** could not control unwanted plants at the 600 g/ha active substance, and most compounds of series II and III could efficiently control velvet leaf, youth-and-old age, barnyard grass, and foxtail. Especially, **II6**, **II7**, **II8**, **II9**, **II10**, **II11**, **III2**, **III3**, **III4**, and **III5** showed higher activity than the lead compound which showed detective values of 20, 15, 10, and 10 for velvet leaf, youth-and-old age, barnyard grass, and foxtail at the 37.5 g/ha active substance, respectively. The activity of **II6**, **II7**, **III2**, and **III4** proved roughly equivalent to the saflufenacil and better than 95% sulcotrione at the same concentration. Meanwhile, the other compounds of series **II** and **III** did not show exciting activity.

By comparison of activity of series **I**, series **II**, and series **III**, it may be seen that substituent site R_1 is a critical active group, and it could clearly improve the activities once R_1 is chlorine. Hydrogen and fluorine were designed to infer the preliminary structure−activity relationship of substituent site R_2; **II6** and **III3** which have the same structure except R_2 showed similar excellent activity for velvet leaf, youth-and-old age, barnyard grass, and foxtail. However, the activities of **II5** and **III1** differ significantly. **II5** of which R_2 is hydrogen could obviously control target weeds, while **III1** of which R_2 is fluorine loses the ability to control weeds. Therefore, more compounds should be synthesized to get the structure−activity relationship at site R_2. Moreover, it is evident that introduction at substituent position Q of methyl carbamate (**II6**), ethyl carbamate (**II7**), isopropyl carbamate (**II8**), buty carbamate (**II9**) and 2-methoxyethyl carbamate (**II10**) could improve the herbicidal activity, and it seems that the ability to control barnyard grass and foxtail may decrease with the increase in number of carbon of carbamic acid ester.

In order to compare activity of these highly reactive compounds (**II5**, **II6**, **II7**, **II10**, **III2,** and **III4**), a parallel experiment was executed in glasshouse. As shown in Table 2, **II6** and **II7** could excellently control youth-and-old age, velvet leaf, foxtail, and barnyard grass at 18.5 g/ha active substance. **II5**, **II10**, **III2**, and **III4** showed detective values of 100 for youth-and-old age and velvet leaf at 18.5 g/ha active substance and not good enough for foxtail and barnyard grass at low concentration.

Herbicidal activity results in field test (Table 3) showed that **II7** at 60 g/ha active substance showed roughly the same activity with bentazon (48%, water dispersible granule) at 1440 g/ha active substance. The detective value of control effect of **II7** at 60 g/ha active substance is 70% after 7 days treatment and 60% after 15 days treatment. Especially, 10% **II7** OF (oil miscible flowable concentrate) could excellently control arrowhead and showed better activity than 24% oxyfluorfen EC (emulsifiable concentrate). As shown in Table 4, the control effect of 10% **II7** OF showed 95, 100, and 100 at 150

Table 3. Herbicidal Activity of II7 in Field Tests (Liaoning, China)

compd	concn g(a.i./ha)	control effect to dayflower and nightshade (%)	
		7 days	15 days
II7	30	40	40
	60	70	60
bentazon	1440	70	70

Table 4. Herbicidal Activity of II7 in Field Tests (Heilongjiang, China)

compd	concn g(a.i./ha)	control effect to arrowhead (%)			control effect to rice (%)		
		15 days	30 days	45 days	15 days	30 days	45 days
10% II7 OF	100	95	97	95	0	0	0
	150	95	100	100	0	0	0
24% oxyfluorfen EC	180	31	68	69	0	0	0

g(a.i./ha) after 15 days, 30 days, and 45 days treatment, respectively, while 24% oxyfluorfen EC showed detective values of 31, 68, and 69 for arrowhead at 180 g(a.i./ha) after 15 days, 30 days, and 45 days treatment, respectively. Meanwhile, **II7** and oxyfluorfen could not control rice and showed high security to rice.

In summary, a series of novel substituted 3-(pyridin-2-yl)benzenesulfonamide compounds were designed and synthesized by intermediate derivatization methods. The compounds (**II6**, **II7**, **II8**, **II9**, **II10**, **II11**, **III2**, **III3**, **III4**, and **III5**) showed higher activity than the lead compound at the 37.5 g/ha active substance using herbicidal activity assay in glasshouse tests, and the activity of **II6**, **II7**, **III2**, and **III4** proved roughly equivalent to the saflufenacil and better than 95% sulcotrione at the same concentration. The result of the herbicidal activity assay in field tests in Liaoning showed that **II7** could effectively control dayflower and nightshade. The activity of **II7** at 60 g/ha active substance proved roughly equivalent to bentazon at 1440 g/ha active substance. Meanwhile, the herbicidal assay in field tests in Heilongjiang showed 10% **II7** OF could excellently control arrowhead. Compound **II7** excited better activity than oxyfluorfen and security to rice. Our results suggest that **II7** may be a novel compound candidate for potential herbicide. This study will be useful for the design of new herbicides for weed control.

■ ASSOCIATED CONTENT

Supporting Information

^{1}H NMR, melting point data, and elemental analyses data for compounds **I3, I5, II1−II5, II7−II18, and III1−III5.** This material is available free of charge via the Internet at http://pubs.acs.org.

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Notes

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