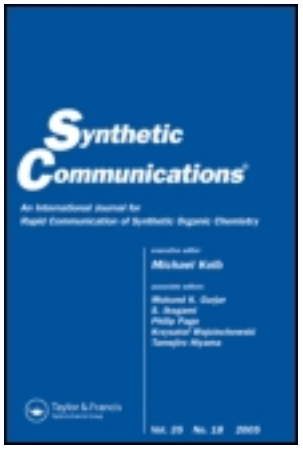

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New Efficient Synthesis of 5,6-Disubstituted-3-phenyl-1,2,3-triazolo[4,5-d]pyrimidin-7-ones via a Tandem Aza-Wittig Reaction

Tao Wang [a], Xi Xian Ke [a], Shui Tao Zhou [a] & Hui Zong Chen [a]

[a] Key Laboratory of Functional Organic Small Molecules, Ministry of Education, College of Chemistry and Chemical Engineering, Jiangxi Normal University, Nanchang, China

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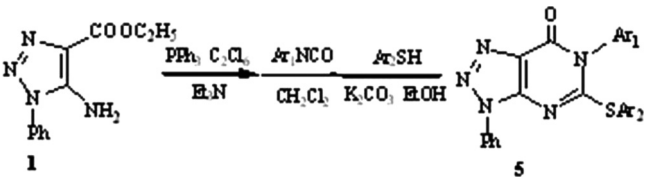
NEW EFFICIENT SYNTHESIS OF 5,6-DISUBSTITUTED-3-PHENYL-1,2,3-TRIAZOLO[4,5-*d*]PYRIMIDIN-7-ONES VIA A TANDEM AZA-WITTIG REACTION

Tao Wang, Xi Xian Ke, Shui Tao Zhou, and Hui Zong Chen
Key Laboratory of Functional Organic Small Molecules, Ministry of Education, College of Chemistry and Chemical Engineering, Jiangxi Normal University, Nanchang, China

GRAPHICAL ABSTRACT



Abstract *Twelve novel 5,6-disubstituted-3-phenyl-1,2,3-triazolo[4,5-*d*]pyrimidine-7-ones* ***5a–5l*** *were designed and successfully synthesized via tandem aza-Wittig and annulation reactions of the corresponding iminophosphorances* ***2****, aromatic isocyanate, and substituted thiophenols in satisfactory yields. The results from the preliminary bioassay indicated that some of these compounds possess inhibitory activities against the root and stalk of* Brassica napus *(rape) as well as* Echinochloa crusgalli *(barnyard grass) at the dosages of 100 mg/L and 10 mg/L, respectively.*

Keywords Aza-Wittig reaction; herbicidal activity; synthesis; 1,2,3-triazolo[4,5-*d*]-pyrimidine-7-ones

INTRODUCTION

The synthesis of triazolopyrimidine derivatives has become a topic of particular interest recently because of the broad spectrum of biological properties of these compounds. Some of these derivatives have shown remarkable biological properties such as antitumor, antiviral, adenosine A_{2A} receptor antibacterial, and anti-HIV activities,[1–6] whereas others exhibited good insecticidal, growth regulatory, herbicidal, fungicidal, and anti-inflammatory activities.[7–15] However, so far few reports are available on the herbicidal activities of 1,2,3-triazolo [4,5-*d*]pyrimidine derivatives.

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Address correspondence to Tao Wang, Key Laboratory of Functional Organic Small Molecules, Ministry of Education, College of Chemistry and Chemical Engineering, Jiangxi Normal University, Nanchang 330022, China. E-mail: wangtao1962@sohu.com

The aza-Wittig reactions of iminophosphoranes have received increasing attention in view of their wide utilities in the synthesis of N-heterocyclic compounds.[16–22] Recently, we have become interested in the synthesis of new bioactive heterocycles such as triazolo[4,5-*d*]pyrimidine-7-ones using various iminophosphoranes, with the aim of discovering bioactive compounds by evaluating their biological activities. Herein, we present the facile synthesis of a class of 5,6-disubstituted-3-phenyl-1,2,3-triazolo[4,5-*d*]pyrimidine-7-ones via the tandem aza-Wittig and cyclization reaction. The results of the bioassay indicated that these compounds possess herbicidal activity against the root and stalk of *brassica napus* (rape) and *echinochloa crusgalli* (barnyard grass).

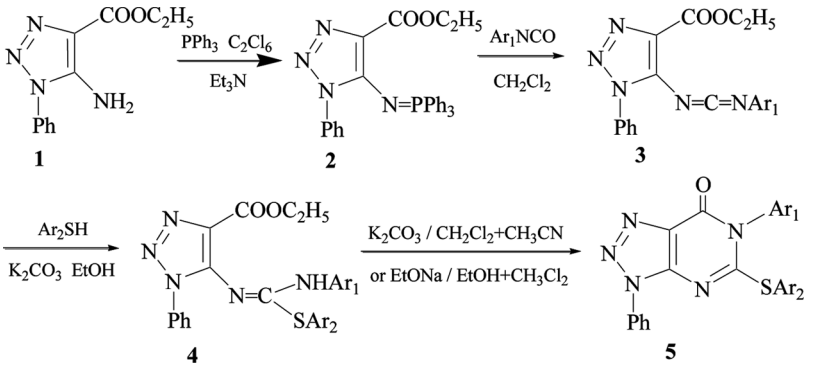
RESULTS AND DISCUSSION

Synthesis

Iminophosphorane **2** was obtained in satisfactory yield when **1**[23] was treated with triphenylphosphine, hexachloroethane, and Et_3N. Iminophosphorane **2** reacted with arylisocyanate to give carbodiimides **3**. The direct reaction of **3** with substituted thiophenols did not produce 6-aryl-5-arylthio-3,6-dihydro-3-phenyl-1,2,3-triazolo[4,5-*d*]pyrimidin-7-ones **5**; however, the reaction took place to give **5a–5l** in good yields under the condition of heating for 2–3 h in the presence of a catalytic amount of K_2CO_3. The formation of **5** could be initiated by the selective nucleophilic addition of thiophenols to carbodiimides **3**, which produced intermediate **4**. Target products **5** were finally furnished via the intramolecular cyclization of 4 and Table 1. Both electron-withdrawing and electron-donating group functionalized thiophenols were well tolerated.

Herbicidal Activity

The herbicidal activity of all compounds **5** against rape and barnyard grass has been investigated at the dosages of 100 mg/L and 10 mg/L using a known procedure[24] and compared with distilled water. The results of the bioassay showed that



Scheme 1. Synthesis of the title compounds **5a–l**.

Table 1. Synthesis of **5a–l**

Compound **5**	**a**	**b**	**c**	**d**	**e**	**f**	**g**	**h**	**i**	**j**	**k**	**l**
$\mathbf{Ar_1}$	Ph	Ph	Ph	Ph	4-Cl Ph	4-Cl Ph	4-Cl Ph	4-Cl Ph	3-Cl Ph	3-Cl Ph	3-Cl Ph	3-Cl Ph
$\mathbf{Ar_2}$	Ph	4-Cl Ph	2-Cl Ph	4-CH_3 Ph	Ph	4-Cl Ph	2-Cl Ph	4-CH_3 Ph	Ph	4-Cl Ph	2-Cl Ph	4-CH_3 Ph

Table 2. Herbicidal activity of compounds **5**

	Relative inhibition root (%)/Stalk (%)			
Compound	Rape 100 mg/L	Rape 10 mg/L	Barnyard grass 100 mg/L	Barnyard grass 10 mg/L
5a	71.0/48.0	52.1/3.50	69.3/83.2	51.4/28.0
5b	97.6/98.7	85.1/33.1	97.8/92.8	92.6/90.5
5c	67.6/59.7	32.7/3.70	54.8/34.8	51.1/16.4
5d	64.2/46.3	33.2/9.40	52.8/34.7	47.5/17.8
5e	98.5/96.5	85.1/89.2	100/100	98.6/89.6
5f	97.6/95.3	93.3/90.2	100/100	95.6/92.5
5g	98.3/96.5	92.1/89.2	100/100	94.3/95.7
5h	98.7/97.6	95.3/83.0	100/100	90.4/91.2
5i	76.5/56.5	51.4/9.50	63.2/73.2	52.8/40.0
5j	92.5/90.7	85.2/81.4	98.6/92.3	94.4/89.8
5k	79.5/54.2	72.7/38.7	68.5/56.7	48.6/38.6
5l	87.2/654	70.5/44.6	77.5/34.8	57.3/13.4
2,4-D	92.6/90.2	94.1/90.2	95.3/38.3	85.8/38.8

many of these compounds exhibit good herbicidal activity (the inhibition rates are listed in Table 2). It showed that most of compounds **5** in Table 2 exhibit good inhibition rates (90–100%) against the root and stalk of barnyard grass at 10 mg/L. For example, **5b, 5e, 5f, 5g, 5h,** and **5j** showed >90% inhibitory rate to root and stalk of barnyard grass. Most of compounds **5** in Table 2 exhibit good inhibition rates (97–100%) against the root of rape and barnyard grass at 100 mg/L. For example, **5b, 5e, 5f, 5g,** and **5h** showed >97% inhibitory rate to root of rape and barnyard grass.

EXPERIMENTAL

Melting points were measured on an Electrothermal melting-point apparatus and are uncorrected. Mass spectra were measured on a Finnigan Trace MS 2000 spectrometer. Infrared (IR) spectra were recorded on an FTS-185 IR spectrometer as KBr pellets with absorption in cm^{-1}. ^1H NMR were recorded in $CDCl_3$ as solvent on a Bruker AC-P400 spectrometer, and resonances are given in parts per million (d) relative to tetramethylsilane (TMS). Elementary analyses were taken on a Vario EL III elementary analysis instrument. All of the solvents and materials were reagent grade and purified as required.

Synthesis of Iminophosphorane 2

Ph_3P (7.86 g, 30 mmol), C_2Cl_6(7.11 g, 30 mmol), and Et_3N (6.06 g, 60 mmol) were added in this order to a solution of **1** (2.26 g, 10 mmol) in CH_3CN (60 mL). The mixture was stirred for 3 h at rt. Then, the solution was concentrated, and the residue was recrystallized from EtOH to give **2** in 90.7% yield. Mp: 196–198 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 1.04 (t, 3 H, $CH_2\underline{CH_3}$, $J = 6.8$ Hz), 3.91 (q, 2 H, $\underline{CH_2}CH_3$, $J = 7.2$ Hz), 7.37–7.75 (m, 20 H, Ar-H); Elemental anal. calcd. for $C_{29}H_{25}N_4O_2P$: C, 70.72; H, 5.12; N, 11.38. Found: C, 70.47; H, 5.23; N, 11.57.

Preparation of 6-Aryl-5-arylthio-3,6-dihydro-3-phenyl-1,2,3-triazolo [4,5-*d*]pyrimidin-7-ones 5

Phenylisocyanate (3 mmol) was added to a solution of iminophosphorane **2** (3 mmol) in dry methylene chloride (15 mL) under nitrogen at room temperature. After the reaction mixture was left unstirred for 2–3 h, the solvent was removed under vacuum, and anhydrous ethanol (10 mL) was added to precipitate triphenylphosphineoxide. Removal of the solvent gave carbodiimides **3** [mp: 121–123 °C, ^{1}H NMR (TMS, $CDCl_3$): δ 1.07 (t, 3 H, $CH_2\underline{CH_3}$, $J = 6.8$ Hz), 4.12 (q, 2 H, $\underline{CH_2}CH_3$, $J = 7.2$ Hz), 7.38–7.78 (m, 10 H, Ar-H)], which were used directly without further purification.

Substituted thiophenol (3 mmol) and cat. solid K_2CO_3(0.24 g, 2 mmol) was added to the solution of **3** prepared in CH_3CN (15 mL). The mixture was stirred for 2–3 h at 50 °C and filtered; the filtrate was condensed and the residue was recrystallized from dichloromethane / petroleum ether to give pure 6-aryl-5-arylthio-3,6-dihydro-3-phenyl-1,2,3-triazolo[4,5-*d*]pyrimidin-7-ones.

3,6-Dihydro-3,6-diphenyl-5-phenylthio-1,2,3-triazolo[4,5-*d*]pyrimidine-7-ones (5a). White solid, yield 84.5%, mp: 252–254 °C; IR (KBr, υ/cm^{-1}): 1733 (C=O), 1566, 1524, 714; ^{1}H NMR ($CDCl_3$, 400 MHz): 7.26–7.84 (m, 15 H, Ar-H); MS (EI, *m/z*, %): 397 (M^+, 8), 369 (16), 341 (12), 196 (24), 129 (45), 91 (51), 77 (100). Anal. calcd. (%) for $C_{22}H_{15}N_5OS$: C, 66.48; H, 3.80; N, 17.62. Found: C, 66.21; H, 3.69; N, 17.57.

5-[(4-Chlorophenyl)thio]-3,6-dihydro-3,6-diphenyl-1,2,3-triazolo[4,5-*d*] pyrimidine-7-ones (5b). White solid, yield 82.3%, mp: 248–250 °C; IR (KBr, υ/cm^{-1}): 1743 (C=O), 1567, 1523, 713; ^{1}H NMR ($CDCl_3$, 400 MHz): 7.26–7.81 (m, 14 H, Ar-H); MS (EI, *m/z*, %): 431 (M^+, 6), 403 (12), 375 (21), 231 (17), 129 (30), 91 (23), 77 (100), Anal. calcd. (%) for $C_{22}H_{14}ClN_5OS$: C, 61.18; H, 3.27; N, 16.22. Found: C, 61.31; H, 3.24; N, 16.47.

5-[(2-Chlorophenyl)thio]-3,6-dihydro-3,6-diphenyl-1,2,3-triazolo[4,5-*d*] pyrimidine-7-ones (5c). White solid, yield 76.5%, mp 218–219 °C; IR (KBr, υ/cm^{-1}): 1733 (C=O); 1564, 1524, 714; ^{1}H NMR ($CDCl_3$, 400 MHz): 7.26–7.80 (m, 14 H, Ar-H); MS (EI, *m/z*, %): 431 (M^+, 4), 403 (14), 375 (17), 231 (11), 129 (32), 91 (37), 77 (100). Anal. calcd. (%) for $C_{22}H_{14}ClN_5OS$: C, 61.18; H, 3.27; N, 16.22. Found: C, 61.33; H, 3.42; N, 16.43.

3,6-Dihydro-3,6-diphenyl-5-[(4-methylphenyl)thio]-1,2,3-triazolo[4,5-*d*] pyrimidine-7-ones (5d). White solid, yield 77.7%, mp 263–265 °C; IR (KBr, υ/cm^{-1}): 1739 (C=O), 1567, 1523, 714; ^1H NMR ($CDCl_3$, 400 MHz): 2.50 (s, CH_3Ph), 7.26–7.87 (m, 14 H, Ar-H); MS (EI, *m/z*, %): 411 (M^+, 5), 383 (23), 355 (14), 210 (21), 128 (32), 91 (43), 77 (100). Anal. calcd. (%) for $C_{23}H_{17}N_5OS$: C, 67.13; H, 4.16; N, 17.02. Found: C, 67.30; H, 4.22; N, 17.16.

6-(4-Chlorophenyl)-3,6-dihydro-3-phenyl-5-phenylthio-1,2,3-triazolo[4,5-*d*]pyrimidine-7-ones (5e). White solid, yield 76.2%, mp 230–232 °C; IR (KBr, υ/cm^{-1}): 1737 (C=O), 1564, 1524, 733; ^1H NMR ($CDCl_3$, 400 MHz): 7.26–7.82 (m, 14 H, Ar-H); MS (EI, *m/z*, %): 431 (M^+, 11), 403 (3), 375 (21), 231 (13), 129 (26), 91 (42), 77 (100); Anal. calcd. (%) for $C_{22}H_{14}ClN_5OS$: C, 61.18; H, 3.27; N, 16.22. Found: C, 61.21; H, 3.32; N, 16.36.

6-(4-Chlorophenyl)-5-[(4-chlorophenyl)thio]-3,6-dihydro-3-phenyl-1,2,3-triazolo[4,5-*d*]pyrimidine-7-ones (5f). White solid, yield 74.3%, mp 195–197 °C; IR (KBr, υ/cm^{-1}): 1736 (C=O); 1562, 1524, 735; ^1H NMR ($CDCl_3$, 400 MHz): 7.26–7.79 (m, 13 H, Ar-H); MS (EI, *m/z*, %): 465 (M^+, 6), 437 (16), 409 (9), 267 (23), 128 (22), 91 (36), 77 (100). Anal. calcd. (%) for $C_{22}H_{13}Cl_2N_5OS$: C, 56.66; H, 2.81; N, 15.02. Found: C, 56.40; H, 3.02; N, 15.28.

6-(4-Chlorophenyl)-5-[(2-chlorophenyl)thio]-3,6-dihydro-3-phenyl-1,2,3-triazolo[4,5-*d*]pyrimidine-7-ones (5g). White solid, yield 78.2%, mp 221–223 °C; IR (KBr, υ/cm^{-1}): 1736 (C=O), 1563, 1523, 733; ^1H NMR ($CDCl_3$, 400 MHz): 7.26–7.82 (m, 13 H, Ar-H); MS (EI, *m/z*, %): 465 (M^+, 9), 437 (18), 409 (5), 267 (11), 128 (25), 91(29), 77 (100). Anal. calcd. (%) for $C_{22}H_{13}Cl_2N_5OS$: C, 56.66; H, 2.81; N, 15.02. Found: C, 56.42; H, 3.01; N, 15.27.

6-(4-Chlorophenyl)-3,6-dihydro-5-[(4-methylphenyl)thio]-3-phenyl-1,2,3-triazolo[4,5-*d*]pyrimidine-7-ones (5h). White solid, yield 73.5%, mp 203–205 °C; IR (KBr, υ/cm^{-1}): 1738 (C=O), 1563, 1524, 735; ^1H NMR ($CDCl_3$, 400 MHz): 2.51 (s, CH_3Ph), 7.26–7.85 (m, 13 H, Ar-H); MS (EI, *m/z*, %): 445 (M^+, 4), 417 (22), 389 (15), 245 (12), 128 (29), 91 (16), 77 (100); Anal. calcd. (%) for $C_{23}H_{16}ClN_5OS$: C, 61.95; H, 3.62; N, 15.71. Found: C, 61.83; H, 3.43; N, 15.56.

6-(3-Chlorophenyl)-3,6-dihydro-3-phenyl-5-phenylthio-1,2,3-triazolo[4, 5-*d*]pyrimidine-7-ones (5i). White solid, yield 77.9%, mp 235–237 °C; IR (KBr, υ/cm^{-1}): 1741 (C=O), 1563, 1525, 732; ^1H NMR ($CDCl_3$, 400 MHz): 7.26–7.82 (m, 14 H, Ar-H); MS (EI, *m/z*, %): 431 (M^+, 7), 403 (28), 375 (19), 231 (30), 128 (21), 91 (14), 77 (100). Anal. calcd. (%) for $C_{22}H_{14}ClN_5OS$: C, 61.18; H, 3.27; N 16.22. Found: C, 61.24; H, 3.36; N, 16.11.

6-(3-Chlorophenyl)-5-[(4-chlorophenyl)thio]-3,6-dihydro-3-phenyl-1,2,3-triazolo[4,5-*d*]pyrimidine-7-ones (5j). White solid, yield 78.6%, mp 245–247 °C; IR (KBr, υ/cm^{-1}): 1751 (C=O), 1571, 1524, 734; ^1H NMR ($CDCl_3$, 400 MHz): 7.26–7.81 (m, 13 H, Ar-H); MS (EI, *m/z*, %): 465 (M^+, 5), 437 (17), 409 (32), 267 (15), 129 (22), 91 (41), 77 (100). Anal. calcd. (%) for $C_{22}H_{13}Cl_2N_5OS$: C, 56.66; H, 2.81; N, 15.02. Found: C, 56.78; H, 3.00; N, 15.22.

6-(3-Chlorophenyl)-5-[(2-chlorophenyl)thio]-3,6-dihydro-3-phenyl-1,2,3-triazolo[4,5-*d*]pyrimidine-7-ones (5k). White solid, yield 72.8%, mp 243–245 °C; IR (KBr, υ/cm^{-1}): 1729 (C=O), 1565, 1523, 735; ^1H NMR ($CDCl_3$, 400 MHz): 7.26∼7.79 (m, 13 H, Ar-H); MS (EI, m/z, %): 465 (M^+, 5), 437 (16), 409 (34), 267 (13), 129 (42), 91 (34), 77 (100); Anal. calcd. (%) for $C_{22}H_{13}Cl_2N_5OS$: C, 56.66; H, 2.81; N, 15.02. Found: C, 56.49; H, 3.03; N, 15.19.

6-(3-Chlorophenyl)-3,6-dihydro-5-[(4-methylphenyl)thio]-3-phenyl-1,2,3-triazolo[4,5-*d*]pyrimidine-7-ones (5l). White solid, yield 75.2%, mp 238–240 °C; IR (KBr, υ/cm^{-1}): 1737 (C=O); 1567, 1524, 714; ^1H NMR ($CDCl_3$, 400 MHz): 2.51 (s, CH_3Ph), 7.26–7.85 (m, 13 H, Ar-H); MS (EI, m/z, %): 445 (M^+, 7), 417 (19), 389 (32), 245 (16), 129 (39), 91 (42), 77 (100). Anal. calcd. (%) for $C_{23}H_{16}ClN_5OS$: C, 61.95; H, 3.62; N, 15.71. Found: C, 61.86; H, 3.39; N, 15.93.

Herbicidal Testing

Herbicidal testing of the newly synthesized compounds **5** was carried out in a plant growth room. 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 9 cm in 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 and 2,4-dichlorophenoxyl acetic acid (2, 4-D), a commercially available herbicide, were used as comparison compounds. The herbicidal activity was assessed as the inhibition rate in comparison with the distilled water. The herbicidal rating score is based on visual observation. Range is from 0% to 100%; 0% means no effect, and 100% means complete killing.

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REFERENCES

1. Santana, L.; Teijeira, M.; Uriarte, E.; Balzarini, J.; De Clercq, E. Synthesis, conformational analysis, and antiviral and antitumoral activity of new 1,2-disubstituted carbocyclic nucleosides. *Eur. J. Med. Chem.* **2002**, *37*(9), 755.
2. Blanco, J. M.; Caamano, O.; Fernandez, F.; Garcia-Mera, X.; Hergueta, A. R.; Lopez, C.; Rodriguez-Borges, J. E.; Balzarini, J.; De Clerco, E. Synthesis and antiviral and antineoplastic activities of some novel carbocyclic guanosine analogues with a cyclobutane ring. *Chem. Pharm. Bull.* **1999**, *47*(9), 1314.
3. Peng, H.; Kumaravel, G.; Yao, G.; Sha, L.; Wang, J.; Vlijmen, H. V.; Bohnert, T.; Huang, C.; Vu, C. B.; Ensinger, C. L.; Chang, H.; Engber, T. M.; Whalley, E. T.; Petter, R. C. Novel bicyclic piperazine derivatives of triazolotriazine and triazolopyrimidine as highly potent and selective adenosine A_{2A} receptor antagonists. *J. Med. Chem.* **2004**, *47*(25), 6218.

4. Said, S. A.; Amr, A.; El-Galil, E.; Sabry, N. M.; Abdalla, M. M. Analgesic, anticonvulsant, and anti-inflammatory activities of some synthesized benzodiazipine, triazolopyrimidine and bis-imide derivatives. *Eur. J. Med. Chem.* **2009**, *44*(12), 4787–4792.
5. Vu, C. B.; Shields, P.; Peng, B.; Kumaravel, G.; Jin, X.; Phadke, D.; Wang, J.; Engber, T.; Ayyub, E.; Petter, R. C. Triamino derivatives of triazolotriazine and triazolopyrimidine as adenosine A_{2A} receptor antagonists. *Bioorg. Med. Chem. Lett.* **2004**, *14*(19), 4835–4838.
6. Zhang, N.; Kaloustian, S. A.; Nguyen, T.; Afragola, J.; Hernandez, R.; Lucas, J.; Gibbons, J.; Beyer, C. Synthesis and SAR of [1,2,4]triazolo[1,5-*a*]pyrimidines, a class of anticancer agents with a unique mechanism of tubulin inhibition. *J. Med. Chem.* **2007**, *50*(2), 319.
7. Kleschich, W. A.; Costales, M. J.; Dunbar, J. E. New herbicidal derivatives of 1,2,4-triazolo[1,5-a]pyrimidine. *Pestic. Sci.* **1990**, *29*, 341–355.
8. Gerwick, B. C.; Subramanian, M. V.; Loney-Gallant, V. I.; Chandler, D. P. Mechanism of action of the 1,2,4-triazolo[1,5-a] pyrimidines. *Pestic. Sci.* **2006**, *29*(3), 357.
9. Bell, B. M.; Fanwick, P. E.; Graupner, P. R.; Roth, G. A. Application of the tisler triazolopyrimidine cyclization to the synthesis of a crop protection agent and an intermediate. *Org. Process Res. Dev.* **2006**, *10*(6), 1167.
10. Okamura, T.; Kurogi, Y.; Hashimoto, K.; Nishikawa, H.; Nagao, Y. Facile synthesis of fused 1,2,4-triazolo[1,5-*c*]pyrimidine derivatives as human adenosine A3 receptor ligands. *Bioorg. Med. Chem. Lett.* **2004**, *14*, 2443.
11. Loper, B. R.; Cobb, W. T.; Anderson, K. A. Chemical marker for ALS-inhibitor herbicides: 2-Aminobutyric acid proportional in sub-lethal applications. *J. Agric. Food Chem.* **2002**, *50*(9), 2601.
12. Girasolo, H. M. A.; Schillaci, D.; Salvo, C. D.; Barone, G.; Silvestri, A.; Ruisi, G. Synthesis, spectroscopic characterization, and in vitro antimicrobial activity of diorganotin(IV) dichloride adducts with [1,2,4]triazolo-[1,5-a]pyrimidine and 5,7-dimethyl-[1,2,4]-triazolo-[1,5-a]pyrimidine. *J. Organomet. Chem.* **2006**, *691*, 693–701.
13. Boer, S. G. J.; Thornburgh, S.; Her, R. J. Uptake, translocation and metabolism of the herbicide florasulam in wheat and broadleaf weeds. *Pest. Manag. Sci.* **2006**, *62*, 316–324.
14. Yang, G. F.; Liu, H. Y.; Yang, H. Z. QSAR and 3D-QSAR analysis of structurally diverse ALS inhibitors: Sulfonylureas and triazolopyrimidine-2-sulfonamides. *Pestic. Sci.* **1999**, *55*, 1143–1150.
15. Chen, C. N.; Lv, L. L.; Ji, F. Q.; Chen, Q.; Xu, H.; Niu, C. W.; Xi, Z.; Yang, G. F. Design and synthesis of *N*-2,6-difluorophenyl-5-methoxyl-1,2,4-triazolo[1,5-*a*]-pyrimidine-2-sulfonamide as acetohydroxyacid synthase inhibitor. *Bioorg. Med. Chem.* **2009**, *17*(8), 3011–3017.
16. Zhao, J. F.; Xie, C.; Xu, S. Z.; Ding, M. W.; Xiao, W. J. Iminophosphorane-mediated efficient synthesis of new tricyclic 3,5-dihydro-1,2,3-triazolo[4,5-*d*]-1,2,4-triazolo [1,5-*a*]pyrimidin-9-ones. *Org. Biomol. Chem.* **2006**, *4*, 130–134.
17. Bonini, C.; Auria, M. D.; Funicello, M.; Romaniello, G. Novel *N*-(2-benzo[*b*]thienyl) iminophosphoranes and their use in the synthesis of benzo[*b*]thieno[2,3-*b*]pyridines. *Tetrahedron* **2002**, *58*, 3507–3512.
18. Zhao, M. X.; Wang, M. X.; Yu, C. Y.; Huang, Z. T.; Fleet, G. W. J. A direct retro-Reformatsky fragmentation: Formal ring enlargement of cyclic ketones for novel and practical synthesis of heterocyclic enamines. *J. Org. Chem.* **2004**, *69*(3), 997–1000.
19. Csampai, A.; Turos, G.; Kudar, V.; Simon, K.; Oeynhausen, H.; Wamhoff, H.; Sohár, P. Ethyl α-(triphenylphosphoranylidene)amino-β-ferrocenylacrylate as a starting material for [2 + 2]cycloadditions, including the aza-Wittig reaction. *Eur. J. Org. Chem.* **2004**, *4*, 717–723.
20. Kurosawa, W.; Kan, T.; Fukuyama, T. Stereocontrolled total synthesis of (−)-ephedradine A (orantine). *J. Am. Chem. Soc.* **2003**, *125*, 8112.

21. Yadav, J. S.; Srinivas, C. Ring expansion approach for the synthesis of the (3*S*,4*S*)-hexahydroazepine core of balanol and ophiocordin. *Tetrahedron* **2003**, *59*, 10325.
22. Wang, H. Q.; Liu, H.; Liu, Z. J. Synthesis and biological activity of 1-[2-(2,4-dichlorophenoxyl)acetyl]-5-amino-1H-pyrazole derivatives. *Chin. J. Org. Chem.* **2004**, *24*, 797.
23. Zhao, J. F. *Studies on novel synthesis and properties of 8-azaguanine derivatives* (master's thesis), Central China Normal University, **2005**.
24. Yang, G. F.; Xu, L.; Lu, A. H. Synthesis and bioactivity of novel triazolo[1,5-*a*]pyrimidine derivatives. *Heteroatm. Chem.* **2001**, *12*, 491.