Synthesis and Fungicidal Activity of 1,3-Thiazoline Derivatives Bearing Nitrophenyl Group on the 2-Position

Qiuying Zhao,[a,b] Jing Li,[a,b] Xiaojing Yan,[a,b] Huizhu Yuan,[a,b]* Zhaohai Qin,[a,b] and Bin Fu[a,b]*

[a]Key Laboratory of Pesticide Chemistry and Application Technology, Department of Applied Chemistry, China Agricultural University, Beijing 100193, People's Republic of China
[b]Institute of Plant Protection, Chinese Academy of Agricultural Science, Beijing 100193, People's Republic of China
*E-mail: hzhyuan@gmail.com or fubinchem@cau.edu.cn

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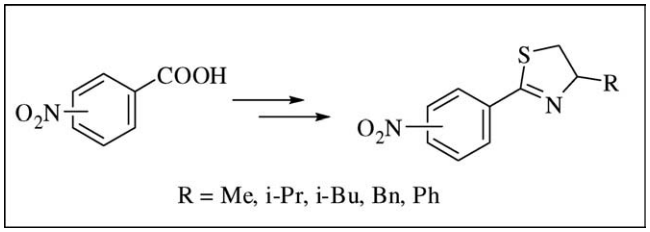

Ortho-, *meta*-, or *para*-nitro benzoic acid were refluxed with excess $SOCl_2$ to give acyl chloride, which condensed with β-amino alcohol in the presence of Et_3N in dichloromethane to afford β-hydroxyamide; finally, sulphonation and cyclization were simultaneously conducted to afford 1,3-thiazoline derivatives. Fungicidal activity of these new thiazolines against eight agrocultural fungi were evaluated, and two of this type of compounds displayed good fungicidal activity comparable or superior to commercial fungicide chlorothalonil against two fungi at a concentration of 50 mg/L.

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INTRODUCTION

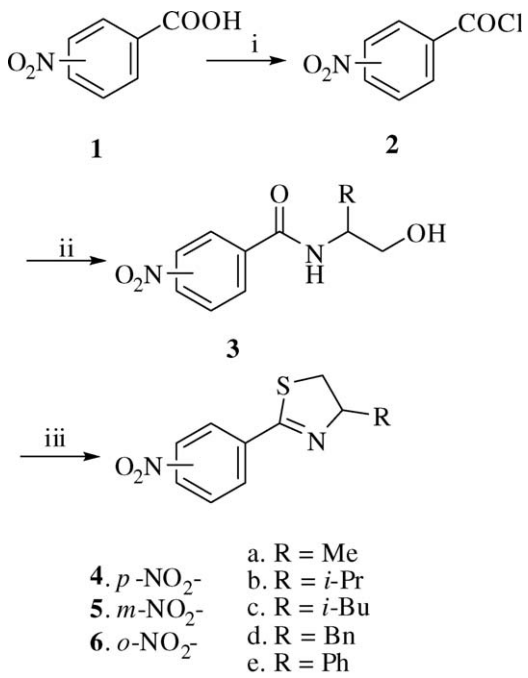
Thiazoline rings have been found in a large number of biological active natural products, such as thiangazole [1], curacin A [2], and lissoclinamides [3]. Moreover, thiazoline compounds have been widely applied as food additives [4], agrochemicals [5], chiral catalysts [6], and so on. In view of the versatile properties of thiazoline compounds, to date, many methods have been developed for the construction of thiazoline ring system [7–10]. In recent years, direct cyclization of β-hydroxyamide has been used as one convenient method for its simplicity and practicability. Some mono-, bis- and tris-thiazoline compounds have been synthesized with Lawesson reagent or phosphorus pentasulfide (P_2S_5) as cyclizing reagent [11–13]. The 1,3-thiazolines with aryl or tertiary alkyl group at 2-position can be synthesized conveniently by this method.

Usually, different substituents on the thiazoline ring have different effects on the biological activity and other properties. Nitro group is an important substituted group which existed in a number of pharmaceuticals and agrochemical products [14–16]. Owing to its strong electron-withdrawing property and regio effect at different position on the aryl ring, the biological activity of the compounds containing nitro group can be tuned well. To further explore the application of thiazoline derivatives in biological activities as a continuation of our research interest in thiazoline chemistry [17,10], herein we would like to report the synthesis and fungicidal activity of 2-(*o*-, *m*-, *p*-)nitrophenyl-substituted 1,3-thiazoline derivatives.

RESULTS AND DISCUSSION

The synthetic pathway to the title thiazoline involves one-pot and three-step sequence [13]. The starting material *m*- or *p*-nitrophenyl carboxylic acid was refluxed in $SOCl_2$ for 12 h and the excess $SOCl_2$ was removed *in vacuo*. The crude acyl chlorides were dissolved in CH_2Cl_2 and added dropwise to the solution of amino alcohols and Et_3N in CH_2Cl_2 at 0°C. After being stirring for 4 h, the solvent was removed *in vacuo*, and the crude intermediate β-hydroxyamides were used in the cyclization step without further purification. The mixture of P_2S_5 with β-hydroxyamides was refluxed in toluene for 4–6 h in the presence of Et_3N. The desired thiazolines **4** and **5** bearing *p*- or *m*-nitrophenyl at 2-position were obtained in 65–90% yield after column chromatographic purification. However, the thiazoline **6** with *o*-nitrophenyl at 2-position was not obtained following the same procedure, to our surprise, the thiazoline compounds bearing *o*-aminophenyl at 2-position was

Scheme 1



produced, that is to say, the nitro group was reduced to the amino group when the thiazoline ring formed under the presence of excess P_2S_5, even if decreasing the amount of P_2S_5 to 1 equiv. and other reaction condition was not changed, no desired product was produced, then the cyclization reagent was changed. Lawesson reagent was used in the cyclizing step to lead to the expected thiazoline **6**; however, the yield was only in 16–40% after purification (Scheme 1). The structure of new nitrophenyl thiazoline compounds were characterized by spectroscopic methods.

Bioassay of fungicidal activities. Fungicidal activities of the title compounds against eight agrocultural fungi (including: *Rhizoctonia solani* Kühn; *Botrytis cinerea* Pers.; *Phytophthora parasitica* Dast.; *Sclerotinia sclerotiorum* (Lib.) de Bary; *Valsa mali* Miyabe et Yamada; *Phytophthora capsici* Leon; *Phomopsis asparagi* (Sacc.) Bubak; and *Pyricularia oryzae* Cav.) were evaluated at 50 μg/mL using the mycelium growth rate test. All results were outlined in Table 1. Most compounds showed some fungicidal activities *in vitro* against the above eight strains. Among them, the thiazoline **6a–e** bearing *o*-nitrophenyl group at 2-position showed low to common fungicidal activity. **4b** and **5b** with *i*-propyl group showed good activity against *B. cinerea* Pers with inhibitory rates of 79.6 and 87.9%; in addition, **4b** and **5b** showed good activity against *P. oryzae* Cav. with inhibitory rates of 81.1 and 90.9%, respectively, and the fungicidal activity was comparable and better than that of the commercial fungicide chlorothalonil.

CONCLUSIONS

In conclusion, a series of 2-(*p*-, *m*-, *o*-nitrophenyl) thiazoline compounds were synthesized *via* convenient

Table 1

Fungicidal activity of compounds **4a–e**, **5a–e**, and **6a–e**.

	The rate of inhibition							
Compounds	*Rhizoctonia solani* Kühn	*Botrytis cinerea* Pers.	*Phytophthora parasitica* Dast.	*Sclerotinia sclerotiorum* (Lib.) de Bary	*Valsa mali* Miyabe et Yamada	*Phytophthora capsici* Leon	*Phomopsis asparagi* (Sacc.) Bubak	*Pyricularia oryzae* Cav.
4a	66.6	74.5	64.6	36.6	37.8	53.8	4.0	55.9
4b	73.3	79.6	57.9	32.0	15.0	57.2	50.6	81.1
4c	72.4	59.4	35.8	20.3	52.1	4.8	−8.0	34.5
4d	29.0	52.0	9.3	76.0	11.7	2.2	50.7	21.9
4e	48.3	38.4	29.2	25.2	29.1	41.4	26.7	38.7
5a	70.6	68.8	60.2	38.6	55.2	36.6	37.3	37.6
5b	61.7	87.9	58.0	8.9	56.8	30.7	32.0	90.9
5c	45.8	20.0	6.7	39.0	38.8	25.5	13.9	68.0
5d	37.7	21.1	24.8	7.7	33.4	29.6	38.7	27.2
5e	48.8	40.6	44.7	0	31.1	0	0	34.5
6a	34.6	39.1	27.0	0	11.7	23.7	0	20.9
6b	34.1	38.7	0	0	40.8	33.9	0	39.7
6c	62.2	60.5	0	0	50.8	33.9	56.7	49.2
6d	29.2	53.0	44.7	0	28.4	0	0	49.2
6e	43.0	45.5	27.0	29.3	21.4	2.2	57.3	29.3
Chlorothalonil	87	76	65	100	92	55	79	84

method, their fungicidal activity against eight agricultural fungi were evaluated. The 2-(*p*-, *m*-)nitrophenylthiazoline with 4-*iso*-propyl group displayed good fungicidal activities against two agricultural fungi compared with commercial fungicide chlorothalonil.

EXPERIMENTAL

NMR spectra were recorded on a Bruker Avance DPX300 spectrometer with tetramethylsilane as internal standard and $CDCl_3$ as solvent. Infrared spectra were obtained on a Nicolet AVATAR 330 FTIR spectrometer. Elemental analyses were carried out on an Elementar Vario EL instrument. Melting points were measured on an XT-4 melting point apparatus and were uncorrected. Solvents were purified and dried following standard procedures.

General procedure for the synthesis of thiazoline 4a–e, 5a–e. The *p*- or *m*-nitrobenzoic acid (0.5 g, 2.99 mmol) was refluxed with $SOCl_2$ (3.0 mL) for 12 h, then the excess $SOCl_2$ was removed *in vacuo*. Benzene (5 mL) was added and removed again to dryness to remove the trace amount of $SOCl_2$ and afforded the acyl chloride. The acyl chloride in CH_2Cl_2 (15 mL) was added dropwise to a solution of amino alcohol (3.10 mmol) and Et_3N (2 mL, 14.5 mmol) in CH_2Cl_2 (15 mL) at 0°C and stirred at room temperature for 4–6 h. The reaction mixture was evaporated to remove the solvent *in vacuo*, and toluene (20 mL) and Et_3N (4 mL, 28.9 mmol) were added to the crude hydroxyl amide, P_2S_5 (1.0 g, 4.5 mmol) was added under refluxing in three portions within 1 h, and the suspension was continued to reflux for another 4–6 h. After being cooled to room temperature, the solution was washed with H_2O (5 mL × 2), dried over anhydrous Na_2SO_4, and concentrated to give the crude product. Column chromatographic purification on silica gel (V/V, ethyl acetate/petroleum ether, 1:5) afforded the thiazoline compounds **4a–e** and **5a–e**.

4a. Mp: 57.0–58.0°C. ^{1}H-NMR (300 MHz, $CDCl_3$): δ 8.24–8.28 (m, 2H, ArH), 7.97–8.01 (m, 2H, ArH), 4.77–4.85 (m, 1H, CHN=), 3.62 (dd, J = 8.34, 10.86 Hz, 1H), 3.13 (dd, J = 7.86, 10.89 Hz, 1H), 1.49 (d, J = 6.72 Hz, 3H, CH_3); ^{13}C-NMR (75 MHz, $CDCl_3$): δ 20.23, 40.43, 73.31, 77.2, 123.57, 129.18, 138.88, 149.20, 164.51. IR (cm^{-1}): 1588, 1519, 1361, 1317, 1110, 965, 860, 690. Anal. Calcd for $C_{10}H_{10}N_2O_2S$ (222.271): C 54.04, H 4.54, N 12.60. Found: C 54.25, H 4.25, N 12.64.

4b. Mp: 49–51°C. ^{1}H-NMR (300 MHz, $CDCl_3$): δ 8.23–8.28 (m, 2H, ArH), 7.97–8.01 (m, 2H, ArH), 4.43–4.51 (m, 1H, CHN=), 3.49 (dd, J = 8.82, 10.95 Hz, 1H), 3.22 (dd, J = 9.75, 10.95 Hz, 1H), 2.06–2.17 (m, 1H, CH), 1.13 (d, J = 6.75 Hz, 3H, CH_3), 1.04 (d, J = 6.75 Hz, 3H, CH_3). ^{13}C-NMR (75 MHz, $CDCl_3$): δ 19.07, 19.71, 33.30, 36.06, 84.49, 123.55, 129.16, 139.01, 149.14, 164.16. IR (cm^{-1}): 2955, 1604, 1578, 1012, 785, 747, 697. Anal. Calcd for $C_{12}H_{14}N_2O_2S$ (250.325): C 57.58, H 5.64, N 11.19. Found: C 57.45, H 5.45, N 11.44.

4c. Mp: 38.5–39.5°C. ^{1}H-NMR (300 MHz, $CDCl_3$): δ 8.22–8.27 (m, 2H, ArH), 7.95–8.00 (m, 2H, ArH), 4.68–4.78 (m, 1H, CHN=), 3.75 (dd, J = 8.35, 10.85 Hz,1H), 3.12 (dd, J = 8.39, 10.86 Hz, 1H), 1.78–1.96 (m, 2H, CH_2), 1.47–1.56 (m, 1H, CH), 1.04 (d, J = 6.49 Hz, 3H, CH_3), 1.01 (d, J = 6.18 Hz, 3H, CH_3). ^{13}C-NMR (75 MHz, $CDCl_3$): δ 22.51, 22.66, 25.80, 38.99, 44.04, 76.37, 123.39, 129.03, 138.84, 149.97, 163.87. IR (cm^{-1}): 2955, 1593, 1522, 1347, 1007, 858, 690. Anal. Calcd for $C_{13}H_{16}N_2O_2S$ (264.35): C 59.07, H 6.10, N 10.60. Found: C 59.35, H 6.25, N 10.45.

4d. Mp: 116–117°C. ^{1}H-NMR (300 MHz, $CDCl_3$): δ 8.24–8.27 (m, 2H, ArH), 7.97–8.02 (m, 2H, ArH), 7.24–7.37 (m, 5H, ArH), 4.93–5.03 (m, 1H, CHN=), 3.42 (dd, J = 8.35, 11.14 Hz, 1H), 3.20–3.34 (m, 2H, CH_2), 2.88 (dd, J = 8.73, 13.63 Hz,1H). ^{13}C-NMR (75 MHz, $CDCl_3$): δ 37.84, 40.16, 78.98, 123.58, 126.61, 128.55, 129.18, 129.25, 138.02, 138.76, 149.22, 165.28. IR (cm^{-1}): 2930, 1510, 1495, 1336, 1230, 1108, 740. Anal. Calcd for $C_{16}H_{14}N_2O_2S$ (298.369): C 64.41, H 4.73, N 9.39. Found: C 64.55, H 4.88, N 9.43.

4e. Mp: 85.0–86.0°C. ^{1}H-NMR (300 MHz, $CDCl_3$): δ 8.27–8.32 (m, 2H, ArH), 8.07–8.11 (m, 2H, ArH), 7.33–7.42 (m, 5H, ArH), 5.76 (t, J = 9.33 Hz, 1H, CHN=), 3.90 (dd, J = 8.85, 11.06 Hz, 1H), 3.42 (dd, J = 9.81, 11.05 Hz, 1H); ^{13}C-NMR (75 MHz, $CDCl_3$): δ 41.72, 81.55, 124.46, 127.39, 128.80, 129.67, 130.21, 139.58, 142.20, 150.36, 167.58. IR (cm^{-1}): 1593, 1521, 1349, 1026, 851, 754, 690. Anal. Calcd for $C_{15}H_{12}N_2O_2S$ (284.342): C 63.36, H 4.25, N 9.85. Found: C 63.36, H 4.36, N 9.69.

5a. Mp: 49.0–50.0°C. ^{1}H-NMR (300 MHz,$CDCl_3$): δ 8.67 (t, J = 1.92 Hz, 1H, ArH), 8.28–8.33 (m, 1H, ArH), 8.12–8.16 (m, 1H, ArH), 7.57–7.62 (m, 1H, ArH), 4.77–4.84 (m, 1H, CHN=), 3.62 (dd, J = 10.88, 8.28 Hz, 1H), 3.13 (dd, J = 10.88, 7.77 Hz, 1H), 1.49 (d, J = 6.72 Hz, 3H, CH_3). ^{13}C-NMR (75 MHz, $CDCl_3$): δ 20.3, 40.5, 73.1, 123.2, 125.4, 129.4, 133.9, 135.0, 148.2, 164.3. IR (cm^{-1}): 2981, 1567, 1517, 1345, 1110, 960, 836, 681. Anal. Calcd for $C_{10}H_{10}N_2O_2S$ (222.271): C 54.04, H 4.54, N 12.60. Found: C 54.28, H 4.50, N 12.69.

5b. Mp: 53.5–54.5°C. ^{1}H-NMR (300 MHz, $CDCl_3$): δ 8.64 (t, J = 1.85 Hz, 1H, ArH), 8.28 (dd, J = 1.32, 8.21 Hz, 1H, ArH), 8.12 (d, J = 8.85 Hz, 1H, ArH), 7.59 (t, J = 7.76 Hz, 1H, ArH), 4.41–4.49 (m, 1H, CHN=), 3.49 (dd, J = 8.80, 10.92 Hz, 1H), 3.22 (t, J = 9.88 Hz, 1H), 2.04–2.15 (m, 1H, CH), 1.13 (d, J = 6.75 Hz, 3H, CH_3), 1.03 (t, J = 6.75 Hz, 3H, CH_3). ^{13}C-NMR (75 MHz, $CDCl_3$): δ 18.87, 19.50, 33.07, 35.87, 84.08, 122.72, 124.99, 129.17, 133.72, 134.82, 147.89, 163.52. IR (cm^{-1}): 2985, 1603, 1565, 1009, 947, 785, 697. Anal. Calcd for $C_{12}H_{14}N_2O_2S$ (250.325): C 57.58, H 5.64, N 11.19. Found: C 57.45, H 5.66, N 11.07.

5c. ^{1}H-NMR (300 MHz, $CDCl_3$): δ 8.78 (t, J = 1.89 Hz, 1H, ArH), 8.31–8.35 (m, 1H, ArH), 8.26–8.34 (m, 2H, ArH), 7.57–7.62 (m, 1H, ArH), 4.57 (dd, J = 8.07, 9.39 Hz, 1H), 4.33–4.44 (m, 1H, CHN=), 4.05 (t, J = 8.04 Hz, 1H), 1.81–1.90 (m, 1H, CH_2), 1.67–1.76 (m, 1H, CH_2), 1.36–1.45 (m, 1H, CH, 0.95–1.05 (m, 6H, CH_3). ^{13}C-NMR (75 MHz, $CDCl_3$): δ 22.72, 22.76, 25.50, 45.48, 65.48, 73.65, 123.28, 125.64, 129.37, 129.85, 133.93, 148.23, 161.26. IR (cm^{-1}): 2982, 1536, 1349, 838, 758, 714, 681. Anal. Calcd for $C_{13}H_{16}N_2O_2S$ (264.35): C 59.07, H 6.10, N 10.60. Found: C 59.38, H 6.05, N 10.84.

5d. Mp: 56.0–57.0°C. ^{1}H-NMR (300 MHz, $CDCl_3$): δ 8.67 (t, J = 1.89 Hz, 1H, ArH), 8.29–8.33 (m, 1H, ArH), 8.17–8.31 (m, 1H, ArH), 7.60 (t, J = 7.83 Hz, 1H, ArH), 7.23–7.34 (m, 5H, ArH), 4.94–4.99 (m, 1H, CHN=), 3.42 (dd, J = 11.13, 8.31 Hz, 1H), 3.21–3.34 (m, 2H, CH_2), 2.87 (dd, J = 8.85, 16.80 Hz, 1H). ^{13}C-NMR (75 MHz, $CDCl_3$): δ 37.85, 40.16, 78.82, 123.21, 125.52, 126.53, 129.27, 129.47, 133.94, 134.92, 138.06, 148.25, 165.17. IR: 1602, 1530, 1347, 1246, 725, 682.

Anal. Calcd for $C_{16}H_{14}N_2O_2S$ (298.369): C 64.41, H 4.73, N 9.39. Found: C 64.70, H 4.98, N 9.56.

5e. ^{1}H-NMR (300 MHz, $CDCl_3$): δ 8.76 (t, J = 1.96 Hz, 1H, ArH), 8.31–8.35 (m, 1H, ArH), 8.21–8.25 (m, 1H, ArH), 7.62 (t, J = 7.80 Hz, 1H, ArH), 7.32–7.40 (m, 5H, ArH), 5.75 (t, J = 9.18 Hz, 1H, CHN=), 3.90 (dd, J = 11.06, 8.81 Hz,1H), 3.42 (dd, J = 11.04, 9.67 Hz, 1H). ^{13}C-NMR (75 MHz, $CDCl_3$): δ 41.34, 80.76, 123.24, 125.60, 127.80, 128.72, 129.48, 134.05, 134.73, 141.31, 148.20, 166.15. IR: 1603, 1528, 1346, 1010, 857, 755, 698. Anal. Calcd for $C_{15}H_{12}N_2O_2S$ (284.342): C 63.36, H 4.25, N 9.85. Found: C 63.54, H 4.10, N 9.99.

General procedure for the synthesis of thiazoline 6a–e, all the procedure was the same as the synthesis of 4a–e, except for using Lawesson reagent in place of P_2S_5

6a. ^{1}H-NMR (300 MHz, $CDCl_3$): δ 7.94–7.98 (m, 1H, ArH), 7.70–7.92 (m, 2H, ArH), 7.61–7.67 (m, 1H, ArH), 4.80–4.88 (m, 1H, CHN=), 3.72 (dd, J = 8.26, 10.78 Hz, 1H), 3.25 (dd, J = 7.34, 10.77 Hz, 1H), 1.52 (d, J = 6.73 Hz, 3H, CH_3). ^{13}C-NMR (75 MHz, $CDCl_3$): δ 19.52, 41.34, 73.48, 124.12, 128.90, 130.37, 130.66, 132.44, 148.31, 162.28. IR (cm^{-1}): 2919, 1602, 1574, 1530, 1493, 1351, 1020, 946, 769, 742, 698. Anal. Calcd for $C_{10}H_{10}N_2O_2S$ (222.271): C 54.04, H 4.54, N 12.60. Found: C 54.35, H 4.34, N 12.88.

6b. ^{1}H-NMR (300 MHz, $CDCl_3$): δ 7.83–7.86 (m, 1H, ArH), 7.51–7.62 (m, 3H, ArH), 4.37–4.46 (m, 1H, CHN=), 3.49 (dd, J = 8.77, 10.80 Hz, 1H), 3.28 (dd, J = 9.88, 10.80 Hz, 1H), 2.06–2.13 (m, 1H, CH), 1.07 (d, J = 6.76 Hz, 3H, CH_3), 1.03 (d, J = 6.76 Hz, 3H, CH_3). ^{13}C-NMR (75 MHz, $CDCl_3$): δ 19.10, 19.56, 32.83, 36.85, 84.78, 123.99, 128.85, 130.35, 130.56, 132.27, 148.37, 162.07. IR (cm^{-1}): 2955, 1605, 1565, 1002, 940, 782, 749, 697. Anal. Calcd for $C_{12}H_{14}N_2O_2S$ (250.325): C 57.58, H 5.64, N 11.19. Found: C 57.42, H 5.52, N 11.39.

6c. ^{1}H-NMR (300 MHz, $CDCl_3$): δ 7.85–7.89 (m, 1H, ArH), 7.61–7.65 (m, 2H, ArH), 7.52–7.59 (m, 1H, ArH), 4.64–4.75 (m, 1H, CHN=), 3.59 (dd, J = 8.31, 10.74 Hz, 1H), 3.17 (dd, J = 7.92, 10.74 Hz, 1H), 1.76–1.87 (m, 2H, CH_2), 1.44–1.52 (m, 1H, CH), 0.97–1.01 (m, 6H, CH_3); ^{13}C NMR (75 MHz, $CDCl_3$): δ 22.54, 22.89, 26.18, 36.82, 44.62, 76.10, 114.91, 115.85, 116.14, 131.33, 132.25, 147.51, 167.13. IR (cm^{-1}): 2960, 1604, 1534, 1367, 1019, 985, 968, 783, 752. Anal. Calcd for $C_{13}H_{16}N_2O_2S$ (264.35): C 59.07, H 6.10, N 10.60. Found: C 59.31, H 6.29, N 10.75.

6d. ^{1}H-NMR (300 MHz, $CDCl_3$): δ 7.87–7.90 (m, 1H, ArH), 7.55–7.64 (m, 3H, ArH), 7.24–7.35 (m, 5H, ArH), 4.90–4.96 (m, 1H, CHN=), 3.45 (dd, J = 8.31, 11.04 Hz, 1H), 3.23–3.29 (m, 2H, CH_2), 2.82–2.90 (m, 1H); ^{13}C-NMR (75 MHz, $CDCl_3$): δ 38.77, 39.40, 79.35, 124.21, 126.54, 128.56, 128.92, 129.27, 130.43, 130.74, 132.45, 138.21, 163.31. IR (cm^{-1}): 2918, 1601, 1530, 1358, 945, 749, 702. Anal. Calcd for $C_{16}H_{14}N_2O_2S$ (298.369): C 64.41, H 4.73, N 9.39. Found: C 64.65, H 4.96, N 9.54.

6e. ^{1}H-NMR (300 MHz, $CDCl_3$): δ 7.90–7.93 (m, 1H, ArH), 7.57–7.68 (m, 3H, ArH), 7.30–7.40 (m, 5H, ArH), 5.65 (dd, J = 7.80, 10.68 Hz, 1H, CHN=), 3.89 (dd, J = 7.80, 10.98 Hz, 1H), 3.45 (d, J = 10.80 Hz, 1H); ^{13}C-NMR (75 MHz, $CDCl_3$): δ 42.52, 81.43, 124.28, 126.65, 127.73, 128.70, 128.96, 130.34, 130.81, 132.60, 133.4, 141.35, 148.23, 164.55. IR (cm^{-1}): 2918, 2849, 1603, 1530, 1351, 1019, 846, 757, 698. Anal. Calcd for $C_{15}H_{12}N_2O_2S$ (284.342): C 63.36, H 4.25, N 9.85. Found: C 63.46, H 4.46, N 9.60.

Fungicidal testing. Fungicidal activity of compounds (**4a–e**, **5a–e**, and **6a–e**) were tested against eight fungal isolates (including: *R. solani* Kühn; *B. cinerea* Pers.; *P. parasitica* Dast.; *S. sclerotiorum* (Lib.) de Bary; *V. mali* Miyabe er Yamada; *P. capsici* Leon; *P. asparagi* (Sacc.) Bubak; and *P. oryzae* Cav.) provided by Institute of Plant Protection, Chinese Academy of Agricultural Sciences. Two negative controls: one with acetone, the solvent of all tested compounds (no antifungal activity has been noted) and the other as untreated potato dextrose agar petri dishes used using the agar growth medium poison technique. The medium was potato dextrose agar and the concentration of the tested compounds was 50 ppm. After 5-days incubation at 25°C, the growth diameter of treatments was measured, and the percentage inhibition of growth for each compound was determined based on the negative control growth of each fungal species under the same incubation conditions. Chlorothalonil as a reference was included to compare with compounds. All tests were performed in triplicate and the average results, as a percentage (%) of the inhibition rate calculated according to the formula:

$$I = \frac{\overline{D}_1^2 - \overline{D}_0^2}{\overline{D}_1^2} \times 100\%$$

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