Chinese Chemical Letters 25 (2014) 61–64

Contents lists available at ScienceDirect

Chinese Chemical Letters

journal homepage: www.elsevier.com/locate/cclet

Original article

Synthesis and bioactivity of novel strobilurin derivatives containing the pyrrolidine-2,4-dione moiety

Gui-Hua Lu [a,c], Hai-Bin Chu [b,c], Min Chen [a,b,c], Chun-Long Yang [a,b,c,*]

[a] Jiangsu Key Laboratory of Pesticide Science, Nanjing Agricultural University, Nanjing 210095, China
[b] Key Laboratory of Monitoring and Management of Crop Diseases and Pest Insects, Ministry of Agriculture, Nanjing Agricultural University, Nanjing 210095, China
[c] College of Science, Nanjing Agricultural University, Nanjing 210095, China

ARTICLE INFO

Article history:
Received 21 May 2013
Received in revised form 16 September 2013
Accepted 21 September 2013
Available online 12 November 2013

Keywords:
Strobilurin
Pyrrolidine-2,4-dione
Synthesis
Fungicidal activity

ABSTRACT

(*E*)-Methyl-2-(2-(bromomethyl)phenyl)-3-methoxyacrylate was reacted with substituted 1-acetylpyrrolidine-2,4-diones and 3-(1-(hydroxylamino)ethylidene)pyrrolidine-2,4-diones respectively to synthesize two series of β-methoxyacrylate derivatives containing the pyrrolidine-2,4-dione moiety. The structures of the targeted compounds were confirmed by IR, ^{1}H NMR, ^{13}C NMR, MS and elemental analysis. The fungicidal activity against *Rhizoctonia solani*, *Botrytis cinerea* and *Fusarium graminearum* was evaluated. The bioassay results demonstrated that these compounds showed visible fungicidal activity.

1. Introduction

As nitrogenous heterocyclic compounds with the pyrrolidine-2,4-dione moiety, natural tetramic acids often exhibit not only antitumor and antiviral [1,2], but also herbicidal, insecticidal and fungicidal activity [3–5]. Using natural tetramic acid as the lead compound, many pyrrolidine-2,4-dione derivatives were designed and synthesized, a considerable part of which was found to present remarkable biological activity [6–10]. It is noteworthy that when proper groups, such as oxime ethers and Schiff bases, were introduced to the 3-position of the pyrrolidine-2,4-dione, the corresponding tetramic acid derivatives showed better inhibitory activity against phytopathogenic fungi than the naturally occurring tenuazonic acid (also called TeA) in the tetramic acid family [11–14].

Strobilurin fungicides were derived from another naturally occurring lead compound strobilurin A with a reactive group of β-methoxyacrylate. They have the outstanding characteristics of unique action mechanism, broad spectrum, long duration, high activity and outstanding environmental tolerability [15]. In this study, two reactive groups, namely pyrrolidine-2,4-dione and β-methoxyacrylate, were spliced in a same structure through an oxime ether bridging group or a methylene bridging group. This modification was expected to improve the fungicidal activity.

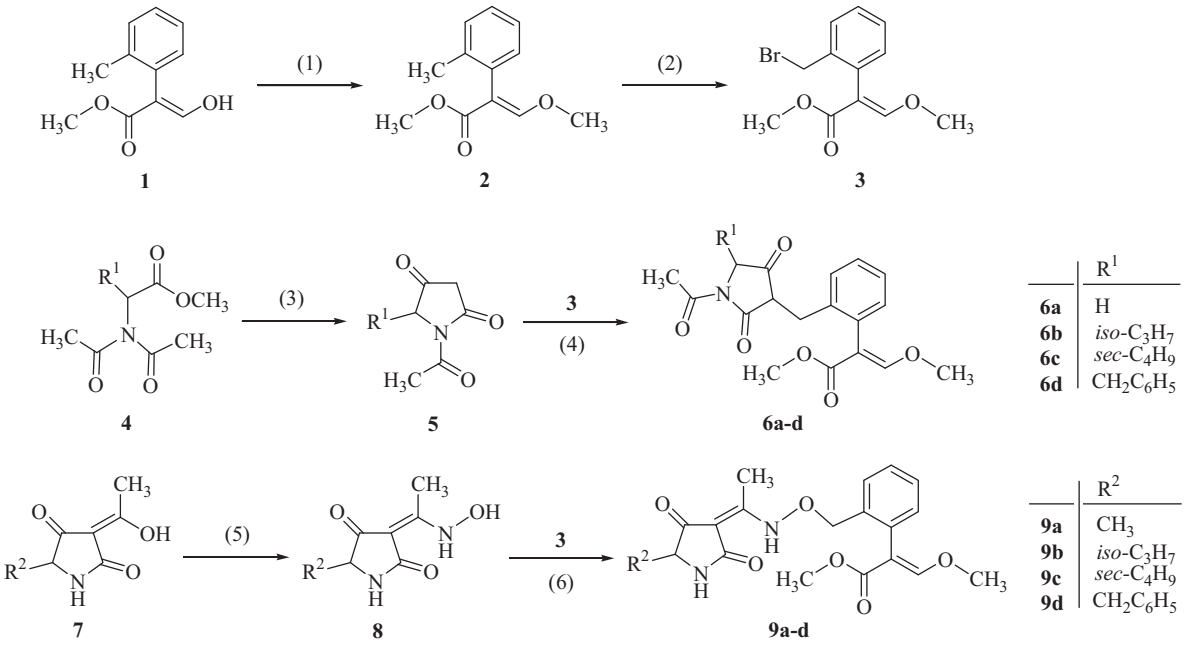
2. Experimental

The melting points of the synthesized compounds were measured on a WRS-1B digital melting point apparatus. IR spectra were recorded on a Bruker Tensor 27 FT-IR spectrometer with a KBr disk. Elemental analyses were determined on an Elementar Vario EL cube analyser. ^{1}H NMR and ^{13}C NMR spectra were collected on a Bruker AV 400 MHz spectrometer with $CDCl_3$ as the solvent and TMS as the internal reference. Mass spectra were recorded on a GC/MS-QP2010 spectrometer using a direct injection technique.

The synthetic routes for the targeted compounds were illustrated in Scheme 1. (*E*)-Methyl-2-(2-(bromomethyl)phenyl)-3-methoxyacrylate **3** was prepared by the methylation of the hydroxy group followed by a bromination of the methyl group in (*E*)-methyl-2-(2-methylphenyl)-3-hydroxyacrylate **1** according to the method reported in the literatures [16,17]. 1-Acetylpyrrolidine-2,4-diones **5** were prepared by the cyclization of *N*,*N*-diacetyl-amino acid methyl esters **4** according to the method reported in the literature [18]. Compound **5** (5 mmol) and K_2CO_3 (10 mmol) were stirred in DMF (50 mL) at room temperature for 30 min, then compound **3** (5 mmol) was added. The mixture was heated at 60 °C for 8 h and the reaction was monitored by TLC analysis. After the reaction completed, the mixture was diluted with 300 mL of water and extracted with ethyl acetate. The organic

* Corresponding author at: Jiangsu Key Laboratory of Pesticide Science, Nanjing Agricultural University, Nanjing 210095, China.
E-mail address: ycl@njau.edu.cn (C.-L. Yang).

1001-8417/$ – see front matter © 2013 Chun-Long Yang. Published by Elsevier B.V. on behalf of Chinese Chemical Society. All rights reserved.
http://dx.doi.org/10.1016/j.cclet.2013.10.007



Scheme 1. Synthetic routes for the compounds **6** and **9**. Condition and regent: (1) $(CH_3)_2CO$, K_2CO_3, $(CH_3)_2SO_4$; (2) CCl_4, NBS, AIBN; (3) Na, xylene; (4) DMF, K_2CO_3; (5) $NH_2OH^{\bullet}HCl$, C_2H_5OH; (6) DMF, K_2CO_3.

layer was washed with water and saturated NaCl solution sequentially, dried over $MgSO_4$, and concentrated in *vacuo*. The residue was separated by a silica gel column to afford the targeted compounds **6a**–**6d**.

3-(1-(Hydroxylamino)ethylidene)pyrrolidine-2,4-diones **8** were prepared by the reaction of 3-(1-hydroxyethylidene)pyrrolidine-2,4-diones **7** with hydroxylamine according to the method reported in the literatures [7,19]. K_2CO_3 (10 mmol) and compound **8** (5 mmol) were stirred in DMF (40 mL) at room temperature for 1 h. Then compound **3** (5 mmol) was dissolved in DMF (10 mL) and dripped slowly to above solution over 2 h. The mixture was stirred at room temperature for 1 h and the reaction was monitored by TLC analysis. After the reaction completed, the mixture was diluted with 200 mL of water and extracted with ethyl acetate. The organic layer was washed with water, dried over $MgSO_4$ and concentrated in *vacuo*. The residue was separated by a silica gel column (for **9a**, **9c** and **9d)**, or was recrystallized from ethanol (for **9b)** to give the targeted compounds.

3. Results and discussion

Through the reactions of the key intermediate **3** with compounds **5** and **8** respectively, two series of novel β-methoxyacrylate derivatives **6a**–**6d** and **9a**–**9d** were prepared in yields of 35–55%. An efficient and operationally simple route was developed to introduce substituted benzyl moieties at the 3-position of pyrrolidine-2,4-dione. By contrast, the compounds 2-(substituted benzyl)-1,3-cyclopentadiones were prepared by a two-step procedure including a Knoevenagel condensation and a hydrogenation reaction [20]. And the compounds 2-(substituted benzyl)-1,3-cyclohexanediones were prepared by an organocatalytic reductive alkylation between an aldehyde and the hantzsch ester [21]. The targeted compounds **9a**–**9d** were prepared using a traditional method. The heterocyclic pyrrolidine-2,4-dione was attached to the reactive structure of β-methoxyacrylate through an oxime ether group.

The structures of the targeted compounds were confirmed by IR, ^1H NMR, ^{13}C NMR, MS and elemental analysis. The IR spectrum showed peaks at 1743–1627 cm^{-1} assigned to the carbonyl groups and peaks at 3268–3189 cm^{-1} due to N–H stretching vibration of compounds **9a**–**9d**. Compounds **6a**–**6d** gave peaks at 3367–3305 cm^{-1} due to O–H stretching vibration, because these four oily liquids belong to *N*-acyl tetramic acids and exist in both keto and enol forms [22]. The ^1H NMR spectrum of all the compounds showed peaks between δ 3.83 and 4.90 for the protons at the 5-postion of the pyrrolidine, and peaks between δ 3.69 and 3.85 for the protons of the OCH_3 group. Compounds **6a**–**6d** showed peaks at δ 1.98–2.06 for the $COCH_3$ protons at the 1-postion of the pyrrolidine. Compounds **9a**–**9d** showed peaks at δ 5.59–8.19 for the proton of N–H at the 1-postion. The ^{13}C NMR spectrum showed all corresponding peaks except that of $PhCH_2$ at the 3-position of compounds **6a**–**6d**. This phenomenon was also observed in the compounds 2-(substituted benzyl)-1,3-cyclohexanediones [21]. Only compounds **9a** and **9c** showed $[M^+]$ peaks, but other targeted compounds gave matched fragment ion peaks. Moreover, all the target compounds showed satisfactory elemental analysis data. Selected characterization data of the targeted compounds are listed below.

6a: Yellow viscous liquid, yield: 46%; IR (KBr, cm^{-1}): ν 3344, 3066, 2942, 2851, 1743, 1627, 1557, 1436, 1263, 1197, 1132; ^1H NMR (400 MHz, $CDCl_3$): δ 2.06 (s, 3H, CH_3CO), 3.71 (s, 3H, $COOCH_3$), 3.85 (d, 3H, J = 6.8 Hz, OCH_3), 4.02–4.08 (m, 2H, NCH_2), 5.10 (s, 2H, $PhCH_2$), 6.07 (s, 1H, COCHCO), 7.15–7.18 (m, 1H, PhH), 7.31–7.37 (m, 2H, PhH), 7.40–7.43 (m, 1H, PhH), 7.58 (d, 1H, J = 5.3 Hz, C=CH); ^{13}C NMR (100 MHz, $CDCl_3$): δ 22.45 (CH_3CO), 41.43 (NCH_2), 51.84 ($COOCH_3$), 62.16 (OCH_3), 65.41 (*C*OCHCO), 109.55 (*C*=CH), 128.11, 128.32, 128.76, 131.24, 132.19, 134.31 (6C, C_6H_4), 160.71 (C=*C*H), 168.24, 169.90, 172.06, 187.93 (4C, 4×CO); MS *m/z* (%): 321(1), 204(4), 190(100), 145(35); Anal. Calcd. for $C_{18}H_{19}NO_6$: C, 62.60; H, 5.55; N, 4.06; Found: C, 62.98; H, 5.46; N, 4.17.

6b: Yellow viscous liquid, yield: 55%; IR (KBr, cm^{-1}): ν 3361, 3066, 2964, 2876, 1738, 1634, 1528, 1435, 1258, 1200, 1145; ^1H NMR (400 MHz, $CDCl_3$): δ 0.87 (d, 3H, J = 6.9 Hz, CH_3CHCH_3), 0.93 (d, 3H, J = 6.8 Hz, CH_3CHCH_3), 2.14–2.18 (m, 1H, CH_3CHCH_3), 2.04 (s, 3H, CH_3CO), 3.72 (s, 3H, $COOCH_3$), 3.84 (s, 3H, OCH_3), 4.61 (dd, 1H, J = 8.8, 4.7 Hz, NCH), 5.07 (q, 2H, J = 12.6 Hz, $PhCH_2$), 6.00 (d, 1H, J = 7.8 Hz, COCHCO), 7.16–7.18 (dd, 1H, J = 8.3, 4.8 Hz, PhH), 7.32–7.38 (m, 2H, PhH), 7.39–7.45 (m, 1H, PhH), 7.59 (s, 1H,