Pergamon

SCIENCE DIRECT®

Tetrahedron 59 (2003) 3511–3520

TETRAHEDRON

Cyclization reactions of methylthioacetanilides

Yu-Jen Liao, Yi-Lung Wu and Che-Ping Chuang*

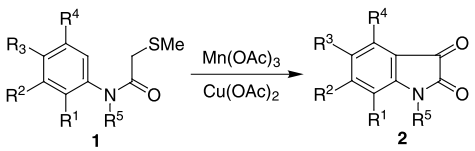
Department of Chemistry, National Cheng Kung University, Tainan 70101, Taiwan, ROC

Received 29 October 2002; revised 27 February 2003; accepted 20 March 2003

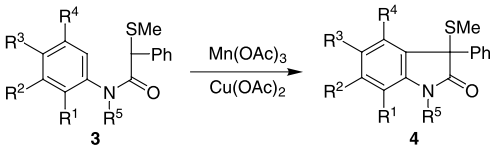
Abstract—The cyclization reactions of methylthioacetanilides mediated by manganese(III) acetate and/or copper(II) acetate are described. Indolinones and indolinediones can be produced effectively via a 5-membered ring cyclization of methylthioacetanilides. The product distributions are highly dependent on the reaction conditions. In most cases, the electronic effect of the substituents on the aryl ring was found to significantly affect the yields of cyclization products. This cyclization reaction proceeded faster with manganese(III) acetate/copper(II) acetate.

1. Introduction

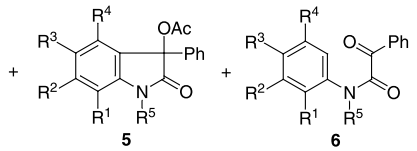
Free radical reactions have become increasingly important in organic synthesis in the last two decades.[1] The biological activity of compounds possessing the indolinone or indolinedione nucleus and their structural relationship to indoles continue to make these compounds attractive targets in synthetic organic chemistry.[2,3] The reaction of carbon-centered radicals mediated by metal salts has received considerable attention in the organic synthesis for the construction of carbon–carbon bonds. Among these, manganese(III) acetate and cerium(IV) ammonium nitrate have been used most efficiently.[1d–f,4] The manganese(III) acetate mediated cyclization reaction of methylthioacetamides has been reported recently.[5] Previously, we reported that the reaction between methylthioacetanilide **1**, manganese(III) acetate and copper(II) acetate produced indolinedione **2** effectively (Eq. 1).[5b] In this paper, we continue to describe our results on the cyclization reactions of methylthioacetanilides.

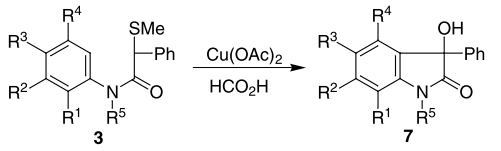


(1)

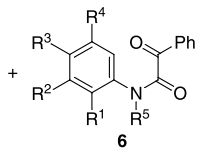


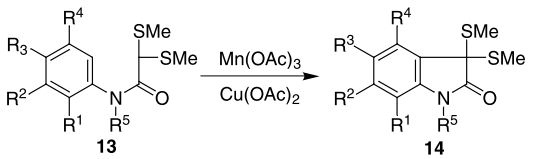
(2)

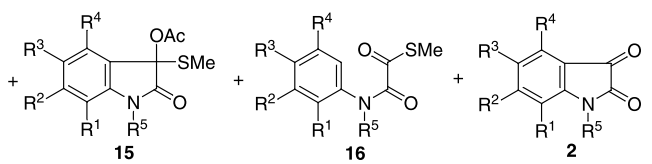




(3)





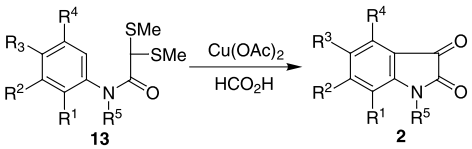


(4)

Keywords: methylthioacetanilides; cyclization reaction; manganese(III) acetate; copper(II) acetate.

* Corresponding author. Fax: +886-6-2740552;
e-mail: cpchuang@mail.ncku.edu.tw

0040–4020/03/$ - see front matter
doi:10.1016/S0040-4020(03)00486-1



(5)

2. Results and discussion

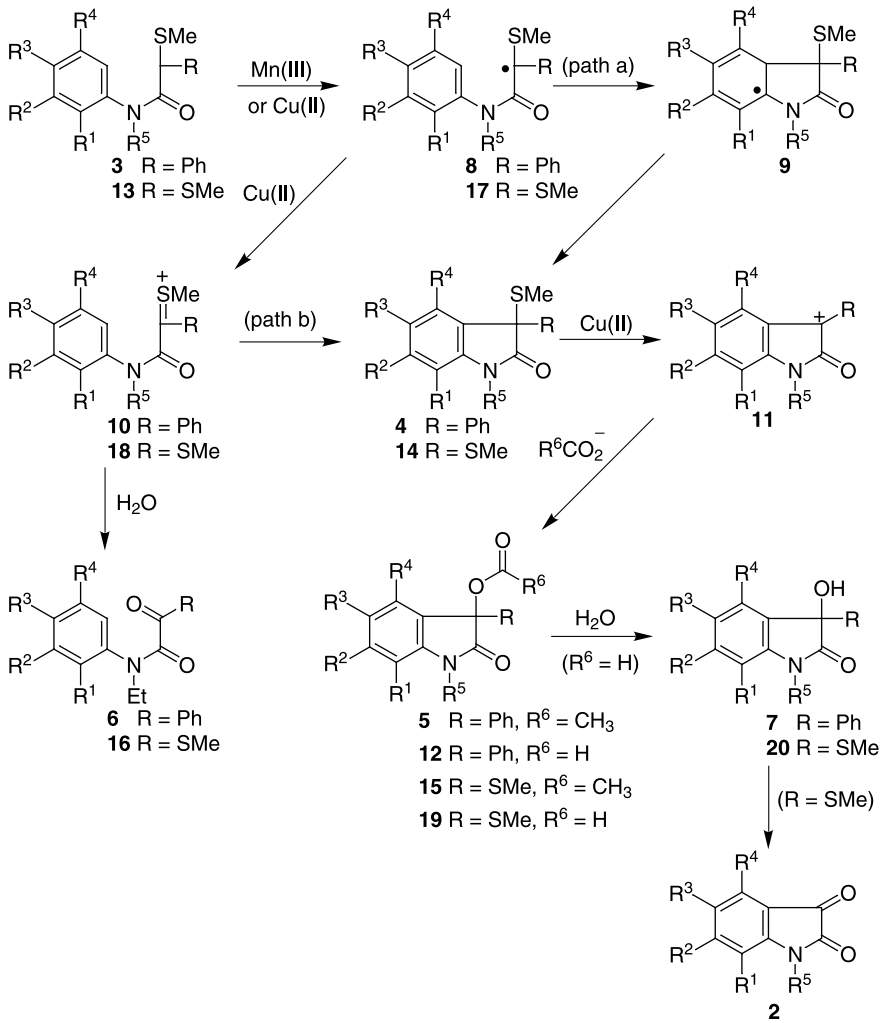
We began our studies by examining the reaction behavior of **3a** (Eq. 2). When **3a** was treated with manganese(III) acetate and copper(II) acetate in CF_3CH_2OH at 90°C, **4a** and **6a** were obtained in 87 and 5% yields, respectively (Table 1, entry 1). In an attempt to investigate the range of solvents compatible with the reaction, we also performed this reaction with **3a** in different solvents and the results are shown in Table 1. In acetonitrile, the yields of **4a** and **6a** are 74% and 11%, respectively (entry 2). In acetic acid, the products are **5a** (74%) and **6a** (12%) and no trace of **4a** can be found (entry 3). A mechanism for this reaction is proposed in Scheme 1 (R=Ph). Oxidation of **3a** by manganese(III) acetate produces radical **8a**, which undergoes a 5-membered ring free radical cyclization onto the aromatic ring and subsequent oxidation of radical intermediate **9a** to give indolinone **4a** (path a).[6] In acetic acid, indolinone **4a** undergoes a further displacement reaction to give **5a**. It has been shown that the thionium ion produced via a Pummerer type reaction undergoes a carbon–carbon bond forming reaction such as the Friedel–Crafts reaction.[7] An alternative possibility for the formation of **4a** via the electrophilic aromatic substitution reaction of thionium ion **10a** produced by the oxidation of **8a** cannot be ruled out (path b). Simple oxidation product **6a** was produced by the direct hydrolysis of **10a**. Results of this cyclization reaction in different solvents are summarized in Table 1. In CF_3CH_2OH and acetonitrile, substrates **3b–g** underwent efficient cyclization under conditions resembling those developed for **3a**. Indolinone **4** is formed in moderate to good yield and the electronic effect of the substituents on the aryl ring has little effect on the reaction yields. It is well known that the electron-withdrawing group retards the electrophilic substitution reaction and the product is afforded in poor yield. We believe that free radical cyclization of **8** (path a) is the major route for the cyclization reaction of **3** in CF_3CH_2OH and acetonitrile. In acetic acid, on the contrary, the reaction yield of cyclization product **5** is reduced significantly for those with an electron-withdrawing group on the aryl ring (entries 18, 22 and 25). These findings then strongly support that the electrophilic aromatic substitution reaction of thionium ion **10** (path b) is the major route for the cyclization reaction of **3** in acetic acid. This different reaction behavior can be ascribed to the acidity of acetic acid, which promotes the oxidation of radical intermediate **8→10**.

Copper salts are very efficient reagents in the hydrolysis of thioderivatives of carbonyl compounds and it presumably occurs via the hydrolysis of thionium ion intermediate.[8] We also examined this cyclization reaction of **3** with copper(II) salt alone (Eq. 3). The reaction of **3a** with copper(II) acetate in 60% formic acid at 90°C was very sluggish. After heating

Table 1. Cyclization reactions of methylthioacetanilide **3**

Entry	Substrate						Method[a]	Product (yield (%))	
		R^1	R^2	R^3	R^4	R^5			
1	**3a**	H	H	H	H	Et	A	**4a** (87)	**6a** (5)
2							B	**4a** (74)	**6a** (11)
3							C	**5a** (74)	**6a** (12)
4							D	**6a** (16)	**7a** (53)
5	**3b**	H	H	Me	H	Et	A	**4b** (84)	**6b** (5)
6							B	**4b** (68)	**6b** (10)
7							C	**5b** (65)	**6b** (13)
8							D	**6b** (14)	**7b** (65)
9	**3c**	H	H	OMe	H	Et	A	**4c** (69)	**6c** (3)
10							C	**5c** (66)	**6c** (11)
11							D	**6c** (8)	**7c** (34)
12	**3d**	H	Me	H	Me	Et	A	**4d** (87)	**6d** (5)
13							B	**4d** (77)	**6d** (8)
14							C	**5d** (60)	**6d** (12)
15							D	**4d** (10)	**7d** (74)
16	**3e**	H	H	Br	H	Et	A	**4e** (79)	**6e** (9)
17							B	**4e** (71)	**6e** (16)
18							C	**5e** (30)	**6e** (12)
19							D	**6e** (38)	**7e** (38)
20	**3f**	H	H	Cl	H	Et	A	**4f** (72)	**6f** (17)
21							B	**4f** (60)	**6f** (24)
22							C	**5f** (33)	**6f** (10)
23							D	**6f** (61)	**7f** (25)
24	**3g**	H	H	CO_2Et	H	Et	A	**4g** (77)	**6g** (12)
25							C	**5g** (0)	**6g** (97)
26							D	**6g** (43)	**7g** (0)
27	**3h**	H	H	H	H	Ph	C	**5h** (80)	**6h** (10)
28	**3i**	H	H	OMe	H	4-MeOPh	C	**5i** (83)	**6i** (11)

[a] Method A: $Mn(OAc)_3$, $Cu(OAc)_2$ in CF_3CH_2OH. Method B: $Mn(OAc)_3$, $Cu(OAc)_2$ in acetonitrile. Method C: $Mn(OAc)_3$, $Cu(OAc)_2$ in acetic acid. Method D: $Cu(OAc)_2$ in 60% formic acid.



Scheme 1.

for 96 h (the starting material **3a** disappeared), **4a**, **6a** and **7a** were obtained in 24, 16 and 39%, respectively. Indolinone **7a** was formed presumably by the hydrolysis of **12a** produced from **4a**. As expected, indolinone **4a** was converted to **7a** completely by increasing the reaction time (156 h), the yields of **6a** and **7a** were 16 and 53%, respectively (entry 4). The results of this copper(II) mediated cyclization of **3** are also summarized in Table 1 (method D). Once again, electronic effects appear to play a major role in the reaction yield. With an electron-withdrawing group on the aryl ring, the yields of **7e**–**7g** are reduced substantially (entries 19, 23 and 26). These results indicate that the electron deficiency of thionium ion **10** disfavors the intramolecular cyclization of the aryl ring having an electron-withdrawing group and path b shown in Scheme 1 is the most likely reaction route for the formation of **7**.

The oxidative cyclization of **13** with manganese(III) acetate/copper(II) acetate was next studied (Eq. 4). We first tested the cyclization of **13b** in acetic acid and it gave indolinedione **2b** in 18% yield (Table 2, entry 5). To improve the reaction result, we also performed this reaction with **13b** in different solvents. In CF_3CH_2OH, indolinone **14b** was obtained in 75% yield (entry 3). In acetonitrile, the yield of **14b** is 86% and **15b** is also obtained in 11% (entry 4). Indolinone **15b** was formed from cyclization product **14b** via the displacement of methylthio group. The generalities of this cyclization reaction are shown in Table 2 (method B). While **13b**, **13c** and **13f** having an electron-donating group cyclized in good yields, cyclization of **13d** and **13e** having an electron-withdrawing halogeno group was less productive, **15d** (19%) and **15e** (12%) were afforded in poor yields and no **14d** and **14e** could be obtained. (entries 8 and 10.) Direct oxidation product **16d** and **16e** were also obtained in 40 and 38% yields, respectively. Copper(II) mediated cyclization reaction of **13** was also examined (Eq. 5). Treatment of **13b** with copper(II) acetate in 60% formic acid at 90°C gave indolinedione **2b** in 82%. Other examples are also shown in Table 2 (method D). Once again, with an electron-withdrawing group on the aryl ring, the yields of **2d** (48%) and **2e** (32%) are reduced substantially (entries 9 and 11). In method B and D, the yields of cyclization products are affected significantly by the electronic effect of the substituents. This reveals the electrophilic nature of the cyclization reaction of **13**. Indolinone **14**, **15** and indolinedione **2** are formed mainly via an ionic cyclization of thionium ion **18** shown in Scheme 1 (R=SMe, path b). These different behaviors between **3** and **13** in acetonitrile

Table 2. Cyclization reactions of dimethylthioacetanilide **13**

Entry	Substrate						Method[a]	Product (yield (%))	
		R^1	R^2	R^3	R^4	R^5			
1	**13a**	H	H	H	H	Et	B	**14a** (85)	**15a** (12)
2							D	**2a** (75)	
3	**13b**	H	H	Me	H	Et	A	**14b** (75)	
4							B	**14b** (86)	**15b** (11)
5							C	**2b** (18)	
6							D	**2b** (82)	
7	**13c**	H	H	OMe	H	Et	D	**2c** (78)	
8	**13d**	H	H	Br	H	Et	B	**15d** (19)	**16d** (40)
9							D	**2d** (48)	
10	**13e**	H	H	Cl	H	Et	B	**15e** (12)	**16e** (38)
11							D	**2e** (32)	
12	**13f**	Me	H	Me	H	Et	B	**14f** (71)	**15f** (13)
13							D	**2f** (82)	
14	**13g**	H	H	H	H	Ph	B	**14g** (70)	**16g** (9)
15	**13h**	H	H	OMe	H	4-MeOPh	B	**14h** (60)	**16h** (10)

[a] Method A: $Mn(OAc)_3$, $Cu(OAc)_2$ in CF_3CH_2OH. Method B: $Mn(OAc)_3$, $Cu(OAc)_2$ in acetonitrile. Method C: $Mn(OAc)_3$, $Cu(OAc)_2$ in acetic acid. Method D: $Cu(OAc)_2$ in 60% formic acid.

are presumably due to the faster oxidation of **13→18** over the oxidation of **3→10**.

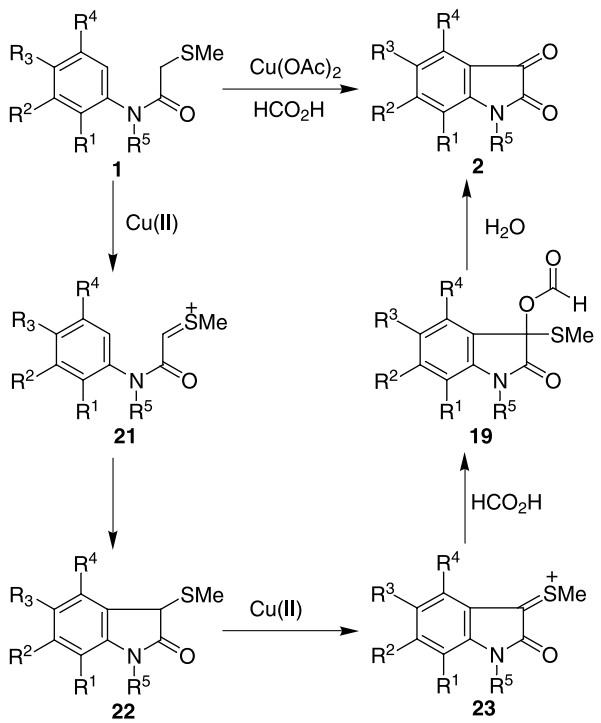
We reported recently that the manganese(III) acetate mediated reaction of methylthioacetanilide **1** produced indolinedione **2** effectively (Eq. 1).[5b] We continue this 5-membered ring cyclization with copper(II) acetate alone. When **1b** was treated with copper(II) acetate in 60% formic acid, indolinedione **2b** was obtained in 77% yield. This reaction proceeded at a much slower reaction rate (144 h) than that performed with manganese(III) acetate/copper(II) acetate (6 h). The scope of this copper(II) mediated reaction is illustrated in Table 3 (Method B). Indolinedione **2** was produced in lower reaction yield from **1** with halogeno substituents (entries 8 and 10). Based on these results, we believe that **2** is formed mainly via an ionic reaction route outlined in Scheme 2.

In conclusion, an efficient method for the synthesis of indolinones and indolinediones via a 5-membered ring cyclization reaction of methylthioacetanilides has been developed. This reaction accommodates a variety of functional groups and affords the anticipated products in modest to good yield. The product distributions are highly

Table 3. Cyclization reactions of methylthioanilide **1**

Entry	Substrate						Method[a]	Product (Yield(%))
		R^1	R^2	R^3	R^4	R^5		
1	**1a**	H	H	H	H	Et	A	**2a** (76)[10]
2							B	**2a** (72)
3	**1b**	H	H	Me	H	Et	A	**2b** (89)[10]
4							B	**2b** (77)
5	**1c**	H	H	OMe	H	Et	A	**2c** (67)[10]
6							B	**2c** (89)
7	**1d**	H	H	Br	H	Et	A	**2d** (36)[10]
8							B	**2d** (50)
9	**1e**	H	H	Cl	H	Et	A	**2e** (35)[10]
10							B	**2e** (44)
11	**1f**	Me	H	Me	H	Et	B	**2f** (67)
12	**1g**	H	Me	H	Me	Et	B	**2g** (72)

[a] Method A: $Mn(OAc)_3$, $Cu(OAc)_2$ in 60% formic acid. Method B: $Cu(OAc)_2$ in 60% formic acid.



Scheme 2.

dependent on the reaction conditions. In most cases, the electronic effect of the substituents on the aryl ring was found to significantly affect the yields of cyclization products. This cyclization reaction proceeded faster with manganese(III) acetate/copper(II) acetate.

3. Experimental

3.1. General considerations

Melting points are uncorrected. The NMR spectra were recorded on a Bruker AVANCE-300 or AMX-400 spectrometer. Chemical shifts are reported in ppm relative to TMS as internal reference. Analytical thin-layer chromatography

was performed with precoated silica gel 60 F-254 plates (0.25 mm thick) from EM Laboratories and visualized by UV. The reaction mixture was purified by column chromatography over EM Laboratories silica gel (70–230 mesh). The spectral data for **2a** -**2e** have been reported.[5b,9]

3.2. Typical experimental procedure for the reaction of 3 mediated by manganese(III) acetate and copper(II) acetate in CF_3CH_2OH

A solution of 151 mg (0.53 mmol) of **3a**, 282 mg (1.05 mmol) of manganese(III) acetate and 210 mg (1.05 mmol) of copper(II) acetate in 10 mL of CF_3CH_2OH was heated at 90°C for 16 h (the dark brown color of manganese(III) acetate disappeared), followed by the addition of 285 mg (1.06 mmol) of manganese(III) acetate and 213 mg (1.06 mmol) of copper(II) acetate. The reaction mixture was stirred for another 11 h and then diluted with 100 mL of ethyl acetate, washed with 50 mL of saturated aqueous sodium bisulfite, three 50 mL portions of water, dried (Na_2SO_4), and concentrated in vacuo. The residue was chromatographed over 20 g of silica gel (eluted with 1:20 ethyl acetate–hexane and then 1:10 ethyl acetate–hexane) to give 130 mg (87%) of **4a** and 7 mg (5%) of **6a**.

3.3. Typical experimental procedure for the reaction of 3 mediated by manganese(III) acetate and copper(II) acetate in acetonitrile

A solution of 149 mg (0.41 mmol) of **3e**, 221 mg (0.82 mmol) of manganese(III) acetate and 165 mg (0.82 mmol) of copper(II) acetate in 10 mL of acetonitrile was heated at 90°C for 46 h. After workup as described above, the residue was chromatographed over 20 g of silica gel (eluted with 1:20 ethyl acetate–hexane and then 1:10 ethyl acetate–hexane) to give 105 mg (71%) of **4e** and 22 mg (16%) of **6e**.

3.3.1. 1-Ethyl-3-methylsulfanyl-3-phenyl-2-indolinone 4a. White crystals; mp 89–90°C; IR ($CHCl_3$) 3005, 2925, 1710, 1615, 1470, 1350 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 1.30 (t, J=7.4 Hz, 3H, CH_3), 1.94 (s, 3H, SCH_3), 3.75–3.91 (m, 2H, NCH_2), 6.90 (d, J=8.0 Hz, 1H, ArH), 7.07 (t, J=7.6 Hz, 1H, ArH), 7.23–7.37 (m, 5H, ArH), 7.62 (d, J=8.0 Hz, 2H, ArH); ^{13}C NMR (100.6 MHz, $CDCl_3$) δ 12.6(q), 12.7(q), 35.0(t), 57.5(s), 108.4(d), 122.7(d), 125.4(d), 127.6(d), 127.9(d), 128.6(d), 128.8(d), 130.3(s), 136.5(s), 141.6(s), 175.3(s); Anal. Calcd for $C_{17}H_{17}NOS$: C, 72.05; H, 6.05; N, 4.94. Found: C, 71.94; H, 6.05; N, 4.97.

3.3.2. 1-Ethyl-5-methyl-3-methylsulfanyl-3-phenyl-2-indolinone 4b. White needles; mp 84–85°C; IR ($CHCl_3$) 3005, 2925, 1705, 1605, 1495, 1360 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 1.30 (t, J=7.2 Hz, 3H, CH_3), 1.96 (s, 3H, SCH_3), 2.32 (s, 3H, $ArCH_3$), 3.74–3.90 (m, 2H, NCH_2), 6.79 (d, J=7.9 Hz, 1H, ArH), 7.09 (d, J=8.1 Hz, 1H, ArH), 7.14 (s, 1H, ArH), 7.20–7.31 (m, 1H, ArH), 7.31–7.42 (m, 2H, ArH), 7.58–7.65 (m, 2H, ArH); ^{13}C NMR (100.6 MHz, $CDCl_3$) δ 12.6(q), 12.7(q), 21.1(q), 35.0(t), 57.6(s), 108.1(d), 126.0(d), 127.7(d), 127.8(d), 128.6(d), 129.2(d), 130.4(s), 132.4(s), 136.7(s), 139.3(s), 175.3(s); Anal. Calcd for $C_{18}H_{19}NOS$: C, 72.69; H, 6.44; N, 4.71. Found: C, 72.64; H, 6.47; N, 4.68.

3.3.3. 1-Ethyl-5-methoxy-3-methylsulfanyl-3-phenyl-2-indolinone 4c. Colorless oil; IR ($CHCl_3$) 3010, 1705, 1605, 1495, 1460, 1340 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 1.30 (t, J=7.0 Hz, 3H, CH_3), 1.95 (s, 3H, SCH_3), 3.78 (s, 3H, OCH_3), 3.73–3.90 (m, 2H, NCH_2), 6.79–6.87 (m, 2H, ArH), 6.96 (d, J=2.4 Hz, 1H, ArH), 7.27–7.32 (m, 1H, ArH), 7.32–7.39 (m, 2H, ArH), 7.58–7.64 (m, 2H, ArH); ^{13}C NMR (100.6 MHz, $CDCl_3$) δ 12.67(q), 12.72(q), 35.1(t), 55.8(q), 58.1(s), 108.8(d), 112.4(d), 113.6(d), 127.6(d), 127.9(d), 128.7(d), 131.6(s), 135.2(s), 136.6(s), 156.1(s), 175.1(s); HRMS calcd for $C_{18}H_{19}NO_2S$ m/z 313.1137, found m/z 313.1135.

3.3.4. 1-Ethyl-4,6-dimethyl-3-methylsulfanyl-3-phenyl-2-indolinone 4d. White crystals; mp 138–139°C; IR ($CHCl_3$) 3005, 2920, 1710, 1620, 1450, 1350 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 1.27 (t, J=7.2 Hz, 3H, CH_3), 1.82 (s, 3H, SCH_3), 2.12 (s, 3H, $ArCH_3$), 2.38 (s, 3H, $ArCH_3$), 3.71 (dq, J=14.3, 7.2 Hz, 1H, NCH), 3.82 (dq, J=14.3, 7.2 Hz, 1H, NCH), 6.59 (s, 1H, ArH), 6.70 (s, 1H, $ArH_)$, 7.23–7.33 (m, 3H, ArH), 7.39–7.44 (m, 2H, ArH); ^{13}C NMR (100.6 MHz, $CDCl_3$) δ 12.2(q), 12.8(q), 18.1(q), 21.7(q), 35.1(t), 59.0(s), 106.8(d), 124.2(s), 126.0(d), 127.6(d), 127.8(d), 128.5(d), 135.9(s), 136.4(s), 139.0(s), 142.6(s), 175.6(s); Anal. Calcd for $C_{19}H_{21}NOS$: C, 73.27; H, 6.80; N, 4.50. Found: C, 73.26; H, 6.89; N, 4.50.

3.3.5. 5-Bromo-1-ethyl-3-methylsulfanyl-3-phenyl-2-indolinone 4e. Colorless oil; IR ($CHCl_3$) 3070, 2990, 2930, 1715, 1610, 1480 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 1.21 (t, J=7.2 Hz, 3H, CH_3), 1.89 (s, 3H, SCH_3), 3.65–3.83 (m, 2H, NCH_2), 6.70 (d, J=8.2 Hz, 1H, ArH), 7.16–7.39 (m, 5H, ArH), 7.48–7.55 (m, 2H, ArH); ^{13}C NMR (100.6 MHz, $CDCl_3$) δ 12.6(q), 35.1(t), 57.4(s), 109.8(d), 115.4(s), 127.6(d), 128.2(d), 128.4(d), 128.8(d), 131.7(d), 132.5(s), 135.8(s), 140.7(s), 174.8(s); HRMS calcd for $C_{17}H_{16}$ BrNOS m/z 361.0136, found m/z 361.0133.

3.3.6. 5-Chloro-1-ethyl-3-methylsulfanyl-3-phenyl-2-indolinone 4f. Colorless oil; IR ($CHCl_3$) 3005, 2945, 1715, 1610, 1485, 1340 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 1.29 (t, J=7.1 Hz, 3H, CH_3), 1.97 (s, 3H, SCH_3), 3.70–3.91 (m, 2H, NCH_2), 6.82 (d, J=8.2 Hz, 1H, ArH), 7.23–7.33 (m, 3H, ArH), 7.33–7.40 (m, 2H, ArH), 7.56–7.61 (m, 2H, ArH); ^{13}C NMR (100.6 MHz, $CDCl_3$) δ 12.6(q), 35.1(t), 57.4(s), 109.3(d), 125.7(d), 127.5(d), 128.1(d), 128.8(d), 132.1(s), 135.8(s), 140.2(s), 174.9(s); HRMS calcd for $C_{17}H_{16}ClNOS$ m/z 317.0641, found m/z 317.0643.

3.3.7. 5-Ethoxycarbonyl-1-ethyl-3-methylsulfanyl-3-phenyl-2-indolinone 4g. Colorless oil; IR ($CHCl_3$) 2990, 2940, 1715, 1615, 1385, 1340 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 1.32 (t, J=7.1 Hz, 3H, CH_3), 1.37 (t, J=7.1 Hz, 3H, CH_3), 1.97 (s, 3H, SCH_3), 3.79–3.96 (m, 2H, NCH_2), 4.35 (q, J=7.1 Hz, 2H, OCH_2), 6.95 (d, J=8.2 Hz, 1H, ArH), 7.26–7.34 (m, 1H, ArH), 7.34–7.42 (m, 2H, ArH), 7.59–7.67 (m, 2H, ArH), 8.02 (d, J=1.6 Hz, 1H, ArH), 8.07 (dd, J=8.2, 1.6 Hz, 1H, ArH); ^{13}C NMR (100.6 MHz, $CDCl_3$) (12.5(q), 12.6(q), 14.2(q), 35.2(t), 57.0(s), 60.8(t), 107.8(d), 125.0(s), 126.4(d), 127.5(d), 128.0(d), 128.7(d), 130.3(s), 131.3(d), 135.7(s), 145.5(s), 165.9(s), 175.5(s); HRMS calcd for $C_{20}H_{21}NO_3S$ m/z 355.1242, found m/z 355.1240.

3.3.8. *N*-Ethyl-2-oxo-2,*N*-diphenylacetamide 6a. Pale yellow oil; IR ($CHCl_3$) 3010, 1725, 1615, 1490, 1450, 1340 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 1.31 (t, J=7.2 Hz, 3H, CH_3), 4.02 (q, J=7.2 Hz, 2H, NCH_2), 7.14–7.20 (m, 2H, ArH), 7.24–7.32 (m, 3H, ArH), 7.44–7.51 (m, 2H, ArH), 7.57–7.61 (m, 2H, ArH), 7.86–7.91 (m, 2H, ArH); ^{13}C NMR (100.6 MHz, $CDCl_3$) δ 12.8(q), 43.5(t), 128.2(d), 128.3(d), 128.7(d), 129.2(d), 129.4(d), 133.5(s), 134.1(d), 139.2(s), 166.5(s), 190.7(s); HRMS calcd for $C_{16}H_{15}NO_2$ m/z 253.1103, found m/z 253.1101.

3.3.9. *N*-Ethyl-2-oxo-2-phenyl-*N*-*p*-tolylacetamide 6b. Pale yellow oil; IR ($CHCl_3$) 3010, 2930, 1725, 1685, 1645, 1450 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 1.25 (t, J=7.2 Hz, 3H, CH_3), 2.25 (s, 3H, $ArCH_3$), 3.94 (q, J=7.2 Hz, 2H, NCH_2), 6.96–7.09 (m, 4H, ArH), 7.43 (t, J=7.5 Hz, 2H, ArH), 7.56 (t, J=7.5 Hz, 1H, ArH), 7.84 (d, J=8.6 Hz, 2H, ArH); ^{13}C NMR (100.6 MHz, $CDCl_3$) δ 12.9(q), 21.0(q), 43.5(t), 128.1(d), 128.7(d), 129.3(d), 130.1(d), 133.6(s), 134.1(d), 136.6(s), 138.3(s), 166.6(s), 190.9(s); HRMS calcd for $C_{17}H_{17}NO_2$ m/z 267.1259, found m/z 267.1256.

3.3.10. *N*-Ethyl-*N*-(4-methoxyphenyl)-2-oxo-2-phenylacetamide 6c. Pale yellow oil; IR ($CHCl_3$) 3010, 2940, 1685, 1645, 1600, 1510 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 1.25 (t, J=7.2 Hz, 3H, CH_3), 3.73 (s, 3H, OCH_3), 3.91 (q, J=7.2 Hz, 2H, NCH_2), 6.73 (d, J=8.9 Hz, 2H, ArH), 7.04 (t, J=8.9 Hz, 2H, ArH), 7.43 (t, J=7.6 Hz, 2H, ArH), 7.56 (t, J=7.6 Hz, 1H, ArH), 7.83 (d, J=7.6 Hz, 2H, ArH); ^{13}C NMR (100.6 MHz, $CDCl_3$) δ 12.8(q), 43.5(t), 53.3(q), 114.5(d), 128.7(d), 129.3(d), 129.8(d), 131.6(s), 133.5(s), 134.1(d), 159.2(s), 166.8(s), 191.1(s); HRMS calcd for $C_{17}H_{17}NO_3$ m/z 283.1208, found m/z 283.1205.

3.3.11. *N*-Ethyl-*N*-(3,5-dimethylphenyl)-2-oxo-2-phenylacetamide 6d. Pale yellow oil; IR ($CHCl_3$) 3010, 1680, 1600, 1450, 1230 cm^{-1}; ^1H NMR(400 MHz, $CDCl_3$) δ 1.13 (t, J=7.1 Hz, 3H, CH_3), 2.15 (s, 6H, CH_3), 3.94 (q, J=7.1 Hz, 2H, CH_2), 6.70 (s, 2H, ArH), 6.83 (s, 1H, ArH), 7.44 (t, J=7.6 Hz, 2H, ArH), 7.56 (d, J=7.6 Hz, 1H, ArH), 7.84 (d, J=7.6 Hz, 2H, ArH); ^{13}C NMR(75.4 MHz, $CDCl_3$) δ 12.9(q), 21.0(q), 43.4(t), 125.7(d), 128.6(d), 129.0(s), 129.3(d), 129.7(s), 129.9(d), 133.8(d), 139.1(s), 166.6(s), 190.8 (s); HRMS calcd for $C_{18}H_{19}NO_2$ m/z 281.1416, found m/z 281.1414.

3.3.12. *N*-(4-Bromophenyl)-*N*-ethyl-2-oxo-2-phenylacetamide 6e. Pale yellow oil; IR ($CHCl_3$) 3010, 2940, 1685, 1650, 1600, 1490 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 1.25 (t, J=7.2 Hz, 3H, CH_3), 3.94 (q, J=7.2 Hz, 2H, NCH_2), 7.00 (d, J=8.6 Hz, 2H, ArH), 7.37 (d, J=8.6 Hz, 2H, ArH), 7.44 (t, J=7.7 Hz, 2H, ArH), 7.57–7.60 (m, 1H, ArH), 7.84 (d, J=7.7 Hz, 2H, ArH); ^{13}C NMR (100.6 MHz, $CDCl_3$) δ 12.8(q), 43.5(t), 122.4(s), 128.8(d), 129.3(d), 129.8(d), 132.9(d), 134.4(d), 138.4(s), 166.2(s), 190.5(s); HRMS calcd for $C_{16}H_{14}BrNO_2$ m/z 331.0208, found m/z 331.0208.

3.3.13. *N*-(4-Chlorophenyl)-*N*-ethyl-2-oxo-2-phenylacetamide 6f. Pale yellow oil; IR ($CHCl_3$) 3010, 2940, 1730, 1685, 1650, 1600 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 1.25 (t, J=7.2 Hz, 3H, CH_3), 3.94 (q, J=7.2 Hz, 2H, NCH_2), 7.07 (d, J=8.6 Hz, 2H, ArH), 7.20 (d, J=8.6 Hz, 2H, ArH), 7.44 (t, J=7.5 Hz, 2H, ArH), 7.58 (t, J=7.5 Hz, 1H, ArH), 7.84 (d, J=7.5 Hz, 2H, ArH); ^{13}C NMR (100.6 MHz, $CDCl_3$) δ 12.8(q), 43.5(t), 128.8(d), 129.2(d), 129.5(d), 129.6(d), 133.3(s), 134.1(s), 134.3(d), 137.8(s), 166.3(s), 190.5(s); HRMS calcd for $C_{16}H_{14}ClNO_2$ m/z 287.0713, found m/z 287.0712.

3.3.14. *N*-(4-Ethoxycarbonylphenyl)-*N*-ethyl-2-oxo-2-phenylacetamide 6g. Colorless oil; IR ($CHCl_3$) 2990, 1715, 1685, 1655, 1610, 1425 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 1.27 (t, J=7.1 Hz, 3H, CH_3), 1.35 (t, J=7.1 Hz, 3H, CH_3), 4.01 (q, J=7.1 Hz, 2H, NCH_2), 4.33 (q, J=7.1 Hz, 2H, OCH_2), 7.20 (d, J=8.3 Hz, 2H, ArH), 7.45 (t, J=7.8 Hz, 2H, ArH), 7.59 (t, J=7.8 Hz, 1H, ArH), 7.86 (d, J=7.8 Hz, 2H, ArH), 7.93 (d, J=8.3 Hz, 2H, ArH); ^{13}C NMR (100.6 MHz, $CDCl_3$) δ 12.9(q), 14.2(q), 43.5(t), 61.2(t), 127.5(d), 128.8(d), 129.3(d), 130.1(s), 130.8(d), 133.3(s), 134.4(d), 143.5(s), 165.4(s), 166.2(s), 190.2(s); HRMS calcd for $C_{19}H_{19}NO_4$ m/z 325.1314, found m/z 325.1312.

3.4. Typical experimental procedure for the reaction of 3 mediated by manganese(III) acetate and copper(II) acetate in acetic acid

A solution of 150 mg (0.53 mmol) of **3a**, 706 mg (2.63 mmol) of manganese(III) acetate and 210 mg (1.05 mmol) of copper(II) acetate in 10 mL of acetic acid was heated at 90°C for 42 h. After workup as described above, the residue was chromatographed over 20 g of silica gel (eluted with 1:20 ethyl acetate–hexane and then 1:10 ethyl acetate–hexane) to give 16 mg (12%) of **6a** and 115 mg (74%) of **5a**.

3.4.1. 3-Acetoxy-1-ethyl-3-phenyl-2-indolinone 5a. White crystals; mp 132–133°C; IR ($CHCl_3$) 3010, 1730, 1470, 1370, 1235 cm^{-1}; ^1H NMR(400 MHz, $CDCl_3$) δ 1.27 (t, J=7.2 Hz, 3H, CH_3), 2.14 (s, 3H, $COCH_3$), 3.69 (dq, J=14.3, 7.2 Hz, 1H, NCH), 3.82 (dq, J=14.3, 7.2 Hz, 1H, NCH), 6.92 (d, J=7.6 Hz, 1H, ArH), 7.07 (t, J=7.6 Hz, 1H, ArH), 7.22 (d, J=7.3 Hz, 1H, ArH), 7.29–7.40 (m, 6H, ArH); ^{13}C NMR(75.4 MHz, $CDCl_3$) δ 11.7(q), 20.7(q), 35.0(t), 81.2(s), 108.7(d), 122.7(d), 124.2(d), 126.1(d), 128.5(d), 128.7(d), 130.0(d), 136.4(s), 143.6(s), 169.0(s), 173.5(s); Anal. calcd for $C_{18}H_{17}NO_3$: C, 73.20; H, 5.80; N, 4.74. Found: C, 73.09; H, 5.86; N, 4.74.

3.4.2. 3-Acetoxy-1-ethyl-5-methyl-3-phenyl-2-indolinone 5b. White crystals; mp 132–133°C; IR ($CHCl_3$) 3010, 1725, 1625, 1610, 1240 cm^{-1}; ^1H NMR(400 MHz, $CDCl_3$) δ 1.27 (t, J=7.2 Hz, 3H, CH_3), 2.16 (s, 3H, $COCH_3$), 2.32 (s, 3H, CH_3), 3.68 (dq, J=14.2, 7.2 Hz, 1H, NCH), 3.81 (dq, J=14.2, 7.2 Hz, 1H, NCH), 6.82 (d, J=7.9 Hz, 1H, ArH), 7.03 (s, 1H, ArH), 7.16 (d, J=7.9 Hz, 1H, ArH), 7.30–7.37 (m, 5H, ArH); ^{13}C NMR(75.4 MHz, $CDCl_3$) δ 11.8(q), 20.9(q), 21.1(q), 35.1(t), 81.4(s), 108.5(d), 124.9(d), 126.1(d), 128.5(d), 128.7(d), 130.3(d), 132.4(s), 136.7(s), 141.2(s), 169.0(s), 173.5(s); Anal. calcd for $C_{19}H_{19}NO_3$: C, 73.77; H, 6.19; N, 4.53. Found: C, 73.73; H, 6.28; N, 4.58.

3.4.3. 3-Acetoxy-1-ethyl-5-methoxy-3-phenyl-2-indolinone 5c. White crystals; mp 166–167°C; IR ($CHCl_3$) 3010, 1725, 1495, 1370, 1220 cm^{-1}; ^1H NMR(400 MHz, $CDCl_3$) δ 1.26 (t, J=7.1 Hz, 3H, CH_3), 2.16 (s, 3H,

$COCH_3$), 3.67 (dq, J=14.2, 7.1 Hz, 1H, NCH), 3.76 (s, 3H, OCH_3), 3.81 (dq, J=14.2, 7.1 Hz, 1H, NCH), 6.83 (d, J=8.5 Hz, 1H, ArH), 6.84 (d, J=2.5 Hz, 1H, ArH), 6.90 (dd, J=8.5, 2.5 Hz, 1H, ArH), 7.31–7.37 (m, 5H, ArH); ^{13}C NMR(75.4 MHz, $CDCl_3$) δ 11.8(q), 20.8(q), 35.1(t), 55.7(q), 81.5(s), 109.1(d), 111.5(d), 114.2(d), 126.1(d), 128.5(d), 128.8(d), 129.8(s), 136.5(s), 136.9(s), 156.0(s), 169.0(s), 173.3(s); Anal. calcd for $C_{19}H_{19}NO_4$: C, 70.14; H, 5.89; N, 4.31. Found: C, 69.90; H, 5.92; N, 4.30.

3.4.4. 3-Acetoxy-1-ethyl-4,6-dimethyl-3-phenyl-2-indolinone 5d. White crystals; mp 130–131°C; IR ($CHCl_3$) 3010, 1730, 1620, 1450, 1230 cm^{-1}; ^{1}H NMR(400 MHz, $CDCl_3$) δ 1.25 (t, J=7.1 Hz, 3H, CH_3), 2.00 (s, 3H, CH_3), 2.16 (s, 3H, $COCH_3$), 2.37 (s, 3H, CH_3), 3.64 (dq, J=14.2, 7.1 Hz, 1H, NCH), 3.78 (dq, J=14.2, 7.1 Hz, 1H, NCH), 6.59 (s, 1H, ArH), 6.67 (s, 1H, ArH), 7.29–7.33 (m, 5H, ArH); ^{13}C NMR(75.4 MHz, $CDCl_3$) δ 11.8(q), 17.5(q), 20.5(q), 21.9(q), 34.9(t), 81.8(s), 107.2(d), 123.1(s), 125.4(d), 125.7(d), 128.5(d), 128.6(d), 135.0(s), 135.6(s), 140.2(s), 143.9(s), 168.9(s), 173.6(s); Anal. calcd for $C_{20}H_{21}NO_3$: C, 74.28; H, 6.55; N, 4.33. Found: C, 74.25; H, 6.67; N, 4.32.

3.4.5. 3-Acetoxy-5-bromo-1-ethyl-3-phenyl-2-indolinone 5e. White crystals; mp 195–196°C; IR ($CHCl_3$) 1735, 1615, 1485, 1375, 1230 cm^{-1}; ^{1}H NMR(400 MHz, $CDCl_3$) δ 1.26 (t, J=7.1 Hz, 3H, CH_3), 2.18 (s, 3H, $COCH_3$), 3.67 (dq, J=14.2, 7.1 Hz, 1H, NCH), 3.82 (dq, J=14.2, 7.1 Hz, 1H, NCH), 6.81 (d, J=8.3 Hz, 1H, ArH), 7.30–7.37 (m, 6H, ArH), 7.50 (dd, J=8.3, 1.7 Hz, 1H, ArH); ^{13}C NMR(75.4 MHz, $CDCl_3$) δ 11.7(q), 20.8(q), 35.2(t), 80.8(s), 110.2(d), 115.3(s), 125.9(d), 127.3(d), 128.7(d), 129.0(d), 130.6(s), 132.8(d), 135.8(s), 142.7(s), 169.1(s), 173.1(s); Anal. calcd for $C_{18}H_{16}BrNO_3$: C, 57.77; H, 4.31; N, 3.74. Found: C, 57.98; H, 4.38; N, 3.65.

3.4.6. 3-Acetoxy-5-chloro-1-ethyl-3-phenyl-2-indolinone 5f. White crystals; mp 169–170°C; IR ($CHCl_3$) 2990, 1735, 1615, 1375, 1235 cm^{-1}; ^{1}H NMR(400 MHz, $CDCl_3$) δ 1.27 (t, J=7.2 Hz, 3H, CH_3), 2.18 (s, 3H, $COCH_3$), 3.68 (dq, J=14.3, 7.2 Hz, 1H, NCH), 3.83 (dq, J=14.3, 7.2 Hz, 1H, NCH), 6.86 (d, J=8.3 Hz, 1H, ArH), 7.20 (d, J=2.1 Hz, 1H, ArH), 7.32–7.35 (m, 5H, ArH), 7.36 (d, J=2.1 Hz, 1H, ArH),; ^{13}C NMR(75.4 MHz, $CDCl_3$) δ 11.7(q), 20.7(q), 35.2(t), 80.9(s), 109.7(d), 124.6(d), 126.0(d), 128.1(s), 128.7(d), 129.0(d), 129.9(d), 130.3(s), 135.8(s), 142.2(s), 169.1(s), 173.2(s); Anal. calcd for $C_{18}H_{16}ClNO_3$: C, 65.56; H, 4.89; N, 4.25. Found: C, 65.54; H, 4.92; N, 4.27.

3.4.7. 3-Acetoxy-1-ethyl-1,3-diphenyl-2-indolinone 5h. White crystals; mp 199–200°C; IR ($CHCl_3$) 3015, 1740, 1615, 1500, 1370 cm^{-1}; ^{1}H NMR(400 MHz, $CDCl_3$) δ 2.20 (s, 3H, $COCH_3$), 6.84 (d, J=7.7 Hz, 1H, ArH), 7.13 (t, J=7.7 Hz, 1H, ArH), 7.29 (d, J=7.6 Hz, 2H, ArH), 7.33–7.53 (m, 10H, ArH); ^{13}C NMR (75.4 MHz, $CDCl_3$) δ 20.8(q), 81.3(s), 109.8(d), 123.4(d), 124.4(d), 126.4(d), 126.9(d), 127.9(s), 128.3(d), 128.6(d), 129.0(d), 129.6(d), 130.0(d), 134.5(s), 136.4(s), 144.9(s), 169.4(s), 173.4(s); Anal. calcd for $C_{22}H_{17}NO_3$: C, 76.95; H, 4.99; N, 4.08. Found: C, 76.88; H, 5.03; N, 4.06.

3.4.8. 3-Acetoxy-5-methoxy-1-(4-methoxyphenyl)-3-phenyl-2-indolinone 5i. Pale yellow oil; IR ($CHCl_3$) 3010, 1735, 1605, 1515, 1250 cm^{-1}; ^{1}H NMR(400 MHz, $CDCl_3$) δ 2.20 (s, 3H, $COCH_3$), 3.76 (s, 3H, OCH_3), 3.82 (s, 3H, OCH_3), 6.70 (d, J=8.6 Hz, 1H, ArH), 6.82 (dd, J=8.6, 2.5 Hz, 1H, ArH), 6.87 (d, J=2.5 Hz, 1H, ArH), 6.97 (d, J=8.9 Hz, 2H, ArH), 7.31–7.40 (m, 5H, ArH), 7.43–7.49 (m, 2H, ArH); ^{13}C NMR(75.4 MHz, $CDCl_3$) δ 20.8(q), 55.5(q), 55.7(q), 81.5(s), 110.3(d), 111.1(d), 114.3(d), 114.8(d), 126.3(d), 127.4(s), 128.0(d), 128.6(d), 128.9(d), 129.1(s), 136.4(s), 138.8(s), 156.3(s), 159.2(s), 169.2(s), 173.5(s); HRMS calcd for $C_{24}H_{21}NO_5$ m/z 403.1420, found m/z 403.1419.

3.4.9. 2-Oxo-*N*,*N*-diphenyl-2-phenylacetamide 6h. Pale yellow oil; IR ($CHCl_3$) 3010, 1740, 1680, 1450, 1240 cm^{-1}; ^{1}H NMR(400 MHz, $CDCl_3$) δ 7.15–7.31 (m, 10H, ArH), 7.38–7.52 (m, 5H, ArH); ^{13}C NMR(75.4 MHz, $CDCl_3$) δ 125.8(d), 128.4(d), 128.8(d), 129.1(d), 129.5(d), 133.6(s), 134.3(d), 140.3(s), 166.3(s), 190.1(s); HRMS calcd for $C_{20}H_{15}NO_2$ m/z 301.1103, found m/z 301.1100.

3.4.10. *N*,*N*-Bis-(4-methoxyphenyl)-2-oxo-2-phenylacetamide 6i. Pale yellow oil; IR ($CHCl_3$) 3010, 1735, 1660, 1510, 1250 cm^{-1}; ^{1}H NMR(400 MHz, $CDCl_3$) δ 3.72 (s, 3H, OCH_3), 3.82 (s, 3H, OCH_3), 6.72 (d, J=8.9 Hz, 2H, ArH), 6.93 (d, J=8.9 Hz, 2H, ArH), 7.08 (d, J=8.9 Hz, 2H, ArH), 7.34 (d, J=8.9 Hz, 2H, ArH), 7.47 (t, J=7.6 Hz, 2H, ArH), 7.60 (t, J=7.6 Hz, 1H, ArH), 7.94 (d, J=7.6 Hz, 2H, ArH); ^{13}C NMR(75.4 MHz, $CDCl_3$) δ 55.4(q), 55.5(q), 114.3(d), 114.7(d), 126.7(d), 128.8(d), 129.4(d), 129.6(d), 133.0(s), 133.6(s), 134.0(s), 134.2(d), 158.1(s), 159.2(s), 166.5(s), 190.6(s); HRMS calcd for $C_{22}H_{19}NO_4$ m/z 361.1314, found m/z 361.1313.

3.5. Typical experimental procedure for the reaction of 3 mediated by copper(II) acetate in formic acid

To a solution of 150 mg (0.53 mmol) of **3a** in 10 mL of 60% of aqueous formic acid heated at 90°C was added 630 mg (3.15 mmol) of copper(II) acetate in three portions at 48 h intervals. The reaction was heated at 90°C for another 60 h and then diluted with 100 mL of ethyl acetate, washed with three 50 mL portions of water, dried (Na_2SO_4), and concentrated in vacuo. The residue was chromatographed over 20 g of silica gel (eluted with 1:10 ethyl acetate–hexane and then 1:3 ethyl acetate–hexane) to give 16 mg (16%) of **6a** and 70 mg (53%) of **7a**.

3.5.1. 1-Ethyl-3-hydroxy-3-phenyl-2-indolinone 7a. White powders; mp 153–154°C; IR ($CHCl_3$) 3555, 3400, 3010, 2990, 1720, 1615, 1470 cm^{-1}; ^{1}H NMR (300 MHz, $CDCl_3$) δ 1.29 (t, J=7.2 Hz, 3H, CH_3), 3.67–3.89 (m, 2H, NCH_2), 3.69 (s, 1H, OH), 6.91 (d, J=7.5 Hz, 1H, ArH), 7.05 (t, J=7.5 Hz, 1H, ArH), 7.26–7.40 (m, 7H, ArH); ^{13}C NMR (75.4 MHz, $CDCl_3$) δ 12.5(q), 35.0(t), 77.9(s), 108.8(d), 123.3(d), 125.1(d), 125.2(d), 128.1(d), 128.5(d), 129.7(d), 132.0(s), 140.3(s), 142.5(s), 177.2(s); Anal. Calcd for $C_{16}H_{15}NO_2$: C, 75.89; H, 5.97; N, 5.53. Found: C, 75.82; H, 6.06; N, 5.52.

3.5.2. 1-Ethyl-3-hydroxy-5-methyl-3-phenyl-2-indolinone 7b. White powders; mp 147–148°C; IR ($CHCl_3$) 3555, 3390, 2990, 1715, 1625, 1495 cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$) δ 1.27 (t, J=7.2 Hz, 3H, CH_3), 2.27 (s,

3H, $ArCH_3$), 3.65–3.84 (m, 2H, NCH_2), 4.05 (s, 1H, OH), 6.79 (d, J=7.9 Hz, 1H, ArH), 7.07 (s, 1H, ArH), 7.11 (d, J=7.9 Hz, 1H, ArH), 7.23–7.40 (m, 5H, ArH); ^{13}C NMR (75.4 MHz, $CDCl_3$) δ 12.5(q), 20.9(q), 34.9(t), 78.0(s), 108.5(d), 125.1(d), 125.7(d), 128.0(d), 128.5(d), 129.8(d), 132.1(s), 132.9(s), 139.9(s), 140.5(s), 177.2(s); Anal. Calcd for $C_{17}H_{17}NO_2$: C, 76.38; H, 6.41; N, 5.24. Found: C, 76.23; H, 6.37; N, 5.24.

3.5.3. 1-Ethyl-3-hydroxy-5-methoxy-3-phenyl-2-indolinone 7c. White crystals; mp 199–200°C; IR ($CHCl_3$) 3555, 3405, 3010, 2945, 1715, 1605, 1495 cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$) δ 1.27 (t, J=7.2 Hz, 3H, CH_3), 3.61–3.85 (m, 2H, NCH_2), 3.72 (s, 3H, OCH_3), 4.05 (s, 1H, OH), 6.78–6.89 (m, 3H, ArH), 7.23–7.39 (m, 5H, ArH); ^{13}C NMR (75.4 MHz, $CDCl_3$) δ 12.5(q), 35.0(t), 55.7(q), 78.2(s), 109.3(d), 111.7(d), 114.6(d), 125.1(d), 128.1(d), 128.5(d), 133.2(s), 135.6(s), 140.3(s), 156.4(s), 177.0(s); Anal. Calcd for $C_{17}H_{17}NO_3$: C, 72.07; H, 6.05; N, 4.94. Found: C, 72.05; H, 6.17; N, 4.98.

3.5.4. 1-Ethyl-3-hydroxy-4,6-dimethyl-3-phenyl-2-indolinone 7d. White crystals; mp 167–168°C; IR ($CHCl_3$) 3555, 3405, 3010, 2940, 1715, 1620, 1455 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 1.28 (t, J=7.2 Hz, 3H, CH_3), 2.03 (s, 3H, $ArCH_3$), 2.37 (s, 3H, $ArCH_3$), 3.47 (s, 1H, OH), 3.63–3.82 (m, 2H, NCH_2), 6.60 (s, 1H, ArH), 6.66 (s, 1H, ArH), 7.23–7.33 (m, 5H, ArH); ^{13}C NMR (100.6 MHz, $CDCl_3$) δ 12.6(q), 17.4(q), 21.8(q), 34.9(t), 78.2(s), 107.1(d), 125.0(d), 125.9(d), 126.7(s), 127.8(d), 128.4(d), 136.4(s), 139.2(s), 139.9(s), 142.9(s), 177.4(s); Anal. Calcd for $C_{18}H_{19}NO_2$: C, 76.84; H, 6.81; N, 4.98. Found: C, 76.86; H, 6.81; N, 5.01.

3.5.5. 5-Bromo-1-ethyl-3-hydroxy-3-phenyl-2-indolinone 7e. White needles; mp 190–191°C; IR ($CHCl_3$) 3555, 3405, 2930, 1725, 1610, 1485 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 1.29 (t, J=7.2 Hz, 3H, CH_3), 3.67–3.86 (m, 2H, NCH_2), 3.81 (s, 1H, OH), 6.80 (d, J=8.3 Hz, 1H, ArH), 7.27–7.36 (m, 5H, ArH), 7.37 (d, J=2.0 Hz, 1H, ArH), 7.45 (dd, J=8.3, 2.0 Hz, 1H, ArH); ^{13}C NMR (100.6 MHz, $CDCl_3$) δ 12.5(q), 35.1(t), 77.8(s), 110.3(d), 116.0(s), 125.0(d), 128.4(d), 128.5(d), 128.7(d), 132.5(d), 133.9(s), 139.6(s), 141.5(s), 176.8(s); Anal. Calcd for $C_{16}H_{14}BrNO_2$: C, 57.85; H, 4.25; N, 4.22. Found: C, 57.69; H, 4.25; N, 4.21.

3.5.6. 5-Chloro-1-ethyl-3-hydroxy-3-phenyl-2-indolinone 7f. White crystals; mp 192–193°C; IR ($CHCl_3$) 3555, 2930, 1725, 1615, 1490, 1340 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 1.30 (t, J=7.2 Hz, 3H, CH_3), 3.68–3.88 (m, 2H, NCH_2), 3.80 (s, 1H, OH), 6.84 (d, J=8.3 Hz, 1H, ArH), 7.22–7.39 (m, 7H, ArH); ^{13}C NMR (100.6 MHz, $CDCl_3$) δ 12.5(q), 35.2(t), 77.9(s), 109.8(d), 125.0(d), 125.6(d), 128.5(d), 128.7(d), 129.6(d), 133.5(s), 139.6(s), 140.9(s), 176.9(s); Anal. Calcd for $C_{16}H_{14}ClNO_2$: C, 66.79; H, 4.90; N, 4.87. Found: C, 66.65; H, 4.92; N, 4.83.

3.6. Typical experimental procedure for the reaction of 13 mediated by manganese(III) acetate and copper(II) acetate in acetonitrile

A solution of 156 mg (0.55 mmol) of **13f**, 286 mg (1.06 mmol) of manganese(III) acetate and 213 mg (1.07 mmol) of copper(II) acetate in 10 mL of acetonitrile was heated at 90°C for 23 h (the dark brown color of manganese(III) acetate disappeared), followed by the addition of 285 mg (1.06 mmol) of manganese(III) acetate and 211 mg (1.06 mmol) of copper(II) acetate. The reaction mixture was stirred for another 9 h. After workup as described as above, the residue was chromatographed over 20 g of silica gel (eluted with 1:20 ethyl acetate–hexane) to give 110 mg (71%) of **14f** and 21 mg (13%) of **15f**.

3.6.1. 1-Ethyl-3,3-bismethylsulfanyl-2-indolinone 14a. Pale yellow oil; IR ($CHCl_3$) 3020, 1660, 1470, 1375, 1210 cm^{-1}; ^1H NMR(400 MHz, $CDCl_3$) δ 1.27 (t, J=7.2 Hz, 3H, CH_3), 2.15 (s, 6H, SCH_3), 3.79 (q, J=7.2 Hz, 2H, NCH_2), 6.88 (dd, J=7.8, 0.8 Hz, 1H, ArH), 7.10 (td, J=7.8, 0.8 Hz, 1H, ArH), 7.32 (td, J=7.7, 0.8 Hz, 1H, ArH), 7.40 (dd, J=7.7, 0.8 Hz, 1H, ArH); ^{13}C NMR(75.4 MHz, $CDCl_3$) δ 11.3(q), 12.4(q), 35.1(t), 56.0(s), 108.4(d), 122.9(d), 124.6(d), 127.5(s), 129.5(d), 141.2(s), 173.1(s); HRMS calcd for $C_{12}H_{15}NOS_2$ m/z 253.0595. found m/z 253.0596.

3.6.2. 1-Ethyl-5-methyl-3,3-bismethylsulfanyl-2-indolinone 14b. Pale yellow oil; IR ($CHCl_3$) 3005, 1710, 1605, 1360, 1100 cm^{-1}; ^1H NMR(400 MHz, $CDCl_3$) δ 1.26 (t, J=7.2 Hz, 3H, CH_3), 2.15 (s, 6H, SCH_3), 2.36 (s, 3H, $ArCH_3$), 3.77 (q, J=7.2 Hz, 2H, NCH_2), 6.76 (d, J=7.9 Hz, 1H, ArH), 7.12 (d, J=7.9 Hz, 1H, ArH), 7.22 (s, 1H, ArH); ^{13}C NMR(75.4 MHz, $CDCl_3$) δ 11.3(q), 12.4(q), 21.0(q), 35.0(t), 55.9(s), 108.1(d), 125.1(d), 128.6(s), 129.8(d), 132.5(s), 138.8(s), 173.0(s); HRMS calcd for $C_{13}H_{17}NOS_2$ m/z 267.0752. found m/z 267.0749.

3.6.3. 1-Ethyl-5,7-dimethyl-3,3-bismethylsulfanyl-2-indolinone 14f. White crystals: mp 109–110°C; IR ($CHCl_3$) 3005, 1710, 1615, 1345, 1265 cm^{-1}; ^1H NMR(400 MHz, $CDCl_3$) δ 1.26 (t, J=7.2 Hz, 3H, CH_3), 2.04 (s, 6H, SCH_3), 2.34 (s, 3H, $ArCH_3$), 2.54 (s, 3H, $ArCH_3$), 3.77 (q, J=7.2 Hz, 2H, NCH_2), 6.65 (s, 1H, ArH), 6.69 (s, 1H, ArH); ^{13}C NMR(75.4 MHz, $CDCl_3$) δ 12.6(q), 12.8(q), 17.7(q), 21.8(q), 35.1(t), 55.8(s), 106.8(d), 121.3(s), 126.3(d), 137.0(s), 139.6(s), 141.9(s), 173.4(s); Anal. Calcd for $C_{14}H_{19}NOS_2$: C, 59.75; H, 6.80; N, 4.98. Found: C, 59.79; H, 6.79; N, 5.00.

3.6.4. 3,3-Bismethylsulfanyl-1-phenyl-2-indolinone 14g. White crystals: mp 100–101°C; IR ($CHCl_3$) 3005, 1730, 1610, 1500, 1470 cm^{-1}; ^1H NMR(400 MHz, $CDCl_3$) δ 2.25 (s, 6H, SCH_3), 6.83 (d, J=7.7 Hz, 1H, ArH), 7.15 (t, J=7.7 Hz, 1H, ArH), 7.26 (t, J=7.3 Hz, 1H, ArH), 7.39–7.50 (m, 4H, ArH), 7.50–7.57 (m, 2H, ArH); ^{13}C NMR(75.4 MHz, $CDCl_3$) δ 12.8(q), 56.2(s), 109.6(d), 123.5(d), 124.7(d), 126.6(d), 128.3(d), 129.5(d), 129.7(d), 134.0(s), 142.2(s), 172.8(s); Anal. calcd for $C_{16}H_{15}NOS_2$: C, 63.75; H, 5.02; N, 4.65. Found: C, 63.71; H, 5.05; N, 4.61.

3.6.5. 5-Methoxy-1-(4-methoxyphenyl)-3,3-bismethylsulfanyl-2-indolinone 14h. White crystals; mp 93–94°C; IR ($CHCl_3$) 3015, 2920, 1715, 1515, 1490 cm^{-1}; ^1H NMR(400 MHz, $CDCl_3$) δ 2.23 (s, 6H, SCH_3), 3.82 (s, 3H, OCH_3), 3.86 (s, 3H, OCH_3), 6.69 (d, J=8.6 Hz, 1H, ArH), 6.79 (dd, J=8.6, 2.6 Hz, 1H, ArH), 7.03 (d, J=8.9 Hz,

2H, ArH), 7.06 (d, *J*=2.6 Hz, 1H, ArH), 7.31 (d, *J*=8.9 Hz, 2H, ArH); ^{13}C NMR(75.4 MHz, $CDCl_3$) δ 12.9(q), 55.6(q), 55.9(q), 56.5(s), 110.2(d), 110.9(d), 114.7(d), 114.9(d), 126.9(s), 127.8(d), 129.3(s), 136.1(s), 156.5(s), 159.2(s), 172.8(s); HRMS calcd for $C_{18}H_{19}NO_3S_2$ *m/z* 361.0806, found *m/z* 361.0808.

3.6.6. 3-Acetoxy-1-ethyl-3-methylsulfanyl-2-indolinone 15a. White crystals; mp 129–130°C; IR ($CHCl_3$) 2925, 1725, 1615, 1470, 1370 cm^{-1}; ^{1}H NMR(400 MHz, $CDCl_3$) δ 1.29 (t, *J*=7.2 Hz, 3H, CH_3), 2.12 (s, 3H, SCH_3), 2.43 (s, 3H, $COCH_3$), 3.73 (dq, *J*=14.3, 7.2 Hz, 1H, NCH), 3.86 (dq, *J*=14.3, 7.2 Hz, 1H, NCH), 6.86 (d, *J*=6.9 Hz, 1H, ArH), 7.04 (t, *J*=7.7 Hz, 1H, ArH), 7.25–7.37 (m, 2H, ArH); ^{13}C NMR(75.4 MHz, $CDCl_3$) δ 10.7(q), 11.9(q), 20.5(q), 34.9(t), 80.5(s), 108.7(d), 122.5(d), 122.9(d), 125.8(s), 130.5(d), 141.5(s), 169.1(s), 170.8(s); HRMS calcd for $C_{13}H_{15}NO_3S$ *m/z* 265.0773, found *m/z* 265.0775.

3.6.7. 3-Acetoxy-1-ethyl-5-methyl-3-methylsulfanyl-2-indolinone 15b. White crystals; mp 157–158°C; IR ($CHCl_3$) 3005, 1720, 1495, 1370, 1230 cm^{-1}; ^{1}H NMR(400 MHz, $CDCl_3$) δ 1.28 (t, *J*=7.2 Hz, 3H, CH_3), 2.12 (s, 3H, SCH_3), 2.34 (s, 3H, $ArCH_3$), 2.41 (s, 3H, $COCH_3$), 3.71 (dq, *J*=14.2, 7.1 Hz, 1H, NCH), 3.84 (dq, *J*=14.2, 7.1 Hz, 1H, NCH), 6.74 (d, *J*=7.8 Hz, 1H, ArH), 7.08–7.17 (m, 2H, ArH); ^{13}C NMR(75.4 MHz, $CDCl_3$) δ 10.8(q), 11.9(q), 20.6(q), 21.0(q), 34.9(t), 80.6(s), 108.5(d), 123.7(d), 125.8(s), 130.8(s), 132.2(s), 139.1(s), 169.1(s), 170.8(s); Anal. Calcd for $C_{14}H_{17}NO_3S$: C, 60.19; H, 6.13; N, 5.01. Found: C, 60.00; H, 6.09; N, 4.88.

3.6.8. 3-Acetoxy-5-bromo-1-ethyl-3-methylsulfanyl-2-indolinone 15d. White crystals; mp 154–155°C; IR ($CHCl_3$) 3020, 1730, 1650, 1480, 1205 cm^{-1}; ^{1}H NMR(400 MHz, $CDCl_3$) δ 1.27 (t, *J*=7.2 Hz, 3H, CH_3), 2.13 (s, 3H, SCH_3), 2.41 (s, 3H, $COCH_3$), 3.70 (dq, *J*=14.3, 7.2 Hz, 1H, NCH), 3.84 (dq, *J*=14.3, 7.2 Hz, 1H, NCH), 6.74 (d, *J*=8.4 Hz, 1H, ArH), 7.40 (d, *J*=2.0 Hz, 1H, ArH), 7.45 (dd, *J*=8.4, 2.0 Hz, 1H, ArH); ^{13}C NMR(75.4 MHz, $CDCl_3$) δ 10.7(q), 11.8(q), 20.5(q), 35.1(d), 80.0(s), 110.2(d), 115.0(s), 126.2(d), 127.8(s), 133.2(d), 140.6(s), 169.1(s), 170.3(s); Anal. Calcd for $C_{13}H_{14}BrNO_3S$: C, 45.36; H, 4.10; N, 4.07. Found: C, 45.31; H, 4.11; N, 3.92.

3.6.9. 3-Acetoxy-5-chloro-1-ethyl-3-methylsulfanyl-2-indolinone 15e. White crystals; mp 166–167°C; IR ($CHCl_3$) 3020, 1730, 1485, 1435, 1205 cm^{-1}; ^{1}H NMR(400 MHz, $CDCl_3$) δ 1.27 (t, *J*=7.2 Hz, 3H, CH_3), 2.13 (s, 3H, SCH_3), 2.41 (s, 3H, $COCH_3$), 3.71 (dq, *J*=14.4, 7.2 Hz, 1H, NCH), 3.85 (dq, *J*=14.4, 7.2 Hz, 1H, NCH), 6.79 (d, *J*=8.3 Hz, 1H, ArH), 7.26–7.30 (m, 2H, ArH); ^{13}C NMR(75.4 MHz, $CDCl_3$) δ 10.7(q), 11.8(q), 20.5(q), 35.1(t), 80.5(s), 109.7(d), 123.5(d), 127.4(s), 127.8(s), 130.3(d), 140.0(s), 169.1(s), 170.4(s); HRMS calcd for $C_{13}H_{14}ClNO_3S$ *m/z* 299.0383, found *m/z* 299.0381.

3.6.10. 3-Acetoxy-1-ethyl-5,7-dimethyl-3-methylsulfanyl-2-indolinone 15f. White crystals; mp 169–170°C; IR ($CHCl_3$) 3000, 1725, 1620, 1370, 1230 cm^{-1}; ^{1}H NMR(400 MHz, $CDCl_3$) δ 1.27 (t, *J*=7.2 Hz, 3H, CH_3), 2.13 (s, 3H, SCH_3), 2.32 (s, 3H, $COCH_3$), 2.39 (s, 6H, $ArCH_3$), 3.69 (dq, *J*=14.2, 7.2 Hz, 1H, NCH), 3.81 (dq, *J*=14.2, 7.2 Hz, 1H, NCH), 6.50 (s, 1H, ArH), 6.62 (s, 1H, ArH); ^{13}C NMR(75.4 MHz, $CDCl_3$) δ 10.2(q), 11.9(q), 17.2(q), 20.3(q), 21.9(q), 34.8(t), 81.1(s), 107.1(d), 120.1(s), 125.4(d), 135.0(s), 140.5(s), 141.7(s), 169.1(s), 170.9(s); HRMS calcd for $C_{15}H_{19}NO_3S$ *m/z* 293.1086, found *m/z* 293.1085.

3.6.11. *S*-Methyl 2-[(4-bromophenyl)-ethylamino]-2-oxo-ethanethioate 16d. Pale yellow oil; IR ($CHCl_3$) 2925, 1660, 1490, 1415, 1070 cm^{-1}; ^{1}H NMR(400 MHz, $CDCl_3$) δ 1.17 (t, *J*=7.1 Hz, 3H, CH_3), 2.21 (s, 3H, SCH_3), 3.80 (q, *J*=7.1 Hz, 2H, NCH_2), 7.04 (d, *J*=8.5 Hz, 2H, ArH), 7.51 (d, *J*=8.5 Hz, 2H, ArH); ^{13}C NMR(75.4 MHz, $CDCl_3$) δ 11.4(q), 12.3(q), 45.5(t), 122.1(s), 129.1(d), 132.6(d), 139.3(s), 161.8(s), 190.4(s); HRMS calcd for $C_{11}H_{12}BrNO_2S$ *m/z* 300.9772, found *m/z* 300.9774.

3.6.12. *S*-Methyl 2-[(4-chlorophenyl)-ethylamino]-2-oxo-ethanethioate 16e. Pale yellow oil; IR ($CHCl_3$) 3020, 1660, 1450, 1380, 1260 cm^{-1}; ^{1}H NMR(400 MHz, $CDCl_3$) δ 1.17 (t, *J*=7.2 Hz, 3H, CH_3), 2.21 (s, 3H, SCH_3), 3.80 (q, *J*=7.2 Hz, 2H, NCH_2), 7.10 (d, *J*=8.5 Hz, 2H, ArH), 7.36 (d, *J*=8.5 Hz, 2H, ArH); ^{13}C NMR(75.4 MHz, $CDCl_3$) δ 11.4(q), 12.4(q), 45.5(t), 128.9(d), 129.6(d), 134.1(s), 138.8(s), 161.9(s), 190.5(s); HRMS calcd for $C_{11}H_{12}ClNO_2S$ *m/z* 257.0277, found *m/z* 257.0280.

3.6.13. *S*-Methyl 2-oxo-2-diphenylamino-ethanethioate 16g. White crystals; mp 100–101°C; IR ($CHCl_3$) 2925, 1670, 1600, 1495, 1355 cm^{-1}; ^{1}H NMR(400 MHz, $CDCl_3$) δ 2.26 (s, 3H, SCH_3), 7.22–7.42 (m, 10H, ArH); ^{13}C NMR(75.4 MHz, $CDCl_3$) δ 11.4(q), 125.9(d), 127.0(d), 127.8(d), 128.2(d), 129.2(d), 129.5(d), 141.0(s), 141.2(s), 162.9(s), 190.8(s); HRMS calcd for $C_{15}H_{13}NO_2S$: *m/z* 271.0667, found *m/z* 271.0667.

3.6.14. *S*-Methyl 2-[bis-(4-methoxyphenyl)-amino]-2-oxo-ethanethioate 16h. White crystals; mp 107–108°C; IR ($CHCl_3$) 3010, 1735, 1660, 1495, 1370 cm^{-1}; ^{1}H NMR(400 MHz, $CDCl_3$) δ 2.27 (s, 3H, SCH_3), 3.80 (s, 3H, OCH_3), 3.81 (s, 3H, OCH_3), 6.86 (d, *J*=5.6 Hz, 2H, ArH), 6.88 (d, *J*=5.6 Hz, 2H, ArH), 7.16 (d, *J*=8.9 Hz, 2H, ArH), 7.19 (d, *J*=8.9 Hz, 2H, ArH); ^{13}C NMR(75.4 MHz, $CDCl_3$) δ 11.4(q), 55.4(q), 114.3(d), 114.6(d), 126.8(d), 128.9(d), 133.7(s), 134.4(s), 158.2(s), 159.1(s), 163.1(s), 191.1(s); Anal. calcd for $C_{17}H_{17}NO_4S$: C, 61.61; H, 5.17; N, 4.23. Found: C, 61.78; H, 5.21; N, 4.14.

3.7. Typical experimental procedure for the reaction of 13 mediated by copper(II) acetate in formic acid

A solution of 133 mg (0.49 mmol) of **13b**, and 196 mg (0.98 mmol) of copper(II) acetate in 10 mL of 60% formic acid was heated at 90°C for 24 h. After workup as described above, the residue was chromatographed over 20 g of silica gel (eluted with 1:6 ethyl acetate–hexane) to give 77 mg (82%) of **2b**.

3.8. Typical experimental procedure for the reaction of 1 mediated by copper(II) acetate in formic acid

To a solution of 161 mg (0.72 mmol) of **1b** in 10 mL of 60% of aqueous formic acid heated at 90°C was added 879 mg

(4.40 mmol) of copper(II) acetate in three portions at 48 h intervals. The reaction was heated at 90°C for another 48 h. After workup as described above, the residue was chromatographed over 20 g of silica gel (eluted with 1:6 ethyl acetate–hexane) to give 105 mg (77%) of **2b**.

3.8.1. 1-Ethyl-5,7-dimethyl-2,3-indolinedione 2f. red crystals; mp 159–160°C; IR ($CHCl_3$) 2985, 1730, 1620, 1600, 1490 cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$) δ 1.31 (t, J=7.1 Hz, 3H, CH_3), 2.27 (s, 3H, CH_3), 2.48(s, 3H, CH_3), 3.97 (q, J=7.1 Hz, 2H, CH_2), 7.14 (s, 1H, ArH), 7.26 (s, 1H, ArH); ^{13}C NMR (75.4 MHz, $CDCl_3$) (14.5(q), 18.5(q), 20.3(q), 36.8(t), 119.0(s), 121.1(s), 123.9(d), 133.4(s), 142.8(d), 146.2(s), 159.3(s), 184.4(s); Anal. Calcd for $C_{12}H_{13}NO_2$: C, 70.92; H, 6.45; N, 6.89. Found: C, 70.88; H, 6.45; N, 6.77.

3.8.2. 1-Ethyl-4,6-dimethyl-2,3-indolinedione 2g. red crystals; mp 133–134°C; IR ($CHCl_3$) 2990, 1730, 1615, 1455, 1370 cm^{-1}; ^1H NMR(400 MHz, $CDCl_3$) δ 1.29 (t, J=7.2 Hz, 3H, CH_3), 2.39 (s, 3H, CH_3), 2.52(s, 3H, CH_3), 3.75 (q, J=7.2 Hz, 2H, NCH_2), 6.52 (s, 1H, ArH), 6.68 (s, 1H, ArH); ^{13}C NMR(100.6 MHz, $CDCl_3$) δ 12.6(q), 18.0(q), 22.7(q), 34.7(t), 108.1(d), 113.7(s), 126.4(d), 141.2(s), 149.6(s), 151.0(s), 158.5(s), 183.3(s); Anal. Calcd for $C_{12}H_{13}NO_2$: C, 70.92; H, 6.45; N, 6.89. Found: C, 70.75; H, 6.40; N, 6.91.

Acknowledgements

We are grateful to the National Science Council of the ROC for financial support (Grant No. NSC-90-2113-M-006-014).

References

1. (a) Neumann, W. P. *Synthesis* **1987**, 665. (b) Curran, D. P. *Synthesis* **1988**, 417. See also p 489. (c) Melikyan, G. G. *Synthesis* **1993**, 833. (d) Iqbal, J.; Bhatia, B.; Nayyar, N. K. *Chem. Rev.* **1994**, *94*, 519. (e) Snider, B. B. *Chem. Rev.* **1996**, *96*, 339. (f) Bowman, W. R.; Cloonan, M. O.; Krintel, S. L. *J. Chem. Soc., Perkin Trans. 1* **2001**, 2885. (g) Ollivier, C.; Renaud, P. *Chem. Rev.* **2001**, *101*, 3415.
2. (a) Sundberg, R. J. In *The Chemistry of Indoles*; Blomquist, A. T., Ed.; Academic: New York, 1970; pp 357–364. (b) Sundberg, R. J. *Comprehensive Heterocyclic Chemistry*; Katritzky, A. R., Rees, C. W., Eds.; Pergamon: Oxford, 1984; Vol. 4, pp 314–376. (c) Mulzer, I. *Comprehensive Organic Synthesis*; Trost, B. M., Fleming, I., Eds.; Pergamon: Oxford, 1991; Vol. 6, pp 323–380.
3. (a) Karp, G. M. *Org. Prep. Proced. Int.* **1993**, *25*, 481. (b) Connolly, T. J.; Durst, T. *Can. J. Chem.* **1997**, *75*, 536. (c) Bryant, W. M.; Huhn, G. F.; Jensen, J. H.; Pierce, M. E. *Synth. Commun.* **1993**, *23*, 1617. (d) Venkatesan, H.; Davis, M. C.; Altas, Y.; Snyder, J. P.; Liotta, D. C. *J. Org. Chem.* **2001**, *66*, 3654. (e) Zhang, T. Y.; Zhang, H. *Tetrahedron Lett.* **2002**, *43*, 193.
4. (a) Oumar-Mahamat, H.; Moustrou, C.; Surzur, J.-M.; Berstrand, M. P. *J. Org. Chem.* **1989**, *54*, 5684. (b) Snider, B. B.; Wan, B. Y. F.; Buckman, B. O.; Foxman, B. M. *J. Org. Chem.* **1991**, *56*, 328.
5. (a) Ishibashi, H.; Toyao, A.; Takeda, Y. *Synlett* **1999**, 1468. (b) Wu, Y.-L.; Chuang, C.-P.; Lin, P.-Y. *Tetrahedron* **2000**, *56*, 6209. (c) Toyao, A.; Chikaoka, S.; Takeda, Y.; Tamura, O.; Muraoka, O.; Tanabe, G.; Ishibashi, H. *Tetrahedron Lett.* **2001**, *42*, 1729.
6. Similar free radical cyclization has been reported. See: Axon, J.; Boiteau, L.; Boivin, J.; Forbes, J. E.; Zard, S. Z. *Tetrahedron Lett.* **1994**, *35*, 1719.
7. (a) Oikawa, Y.; Yonemitsu, O. *Tetrahedon* **1974**, *30*, 2653. (b) Oikawa, Y.; Yonemitsu, O. *J. Org. Chem.* **1976**, *41*, 1118. (c) Tamura, Y.; Uenishi, J. I.; Maeda, H.; Choi, H. D.; Ishibashi, H. *Synthesis* **1981**, 534. (d) Wang, H.-M.; Lin, M.-C.; Chen, L.-C. *Heterocycles* **1994**, *38*, 1519.
8. (a) Grobel, B. T.; Seebach, D. *Synthesis* **1977**, 357. (b) Gregoire, B.; Carre, M.-C.; Caubere, P. *J. Org. Chem.* **1986**, *51*, 1419. (c) Ishibashi, H.; Matsuoka, K.; Ikeda, M. *Chem. Pharm. Bull.* **1991**, *39*, 1854.
9. Kaupp, G.; Matthies, D. *Chem. Ber.* **1987**, *120*, 1897.
10. These results have been reported in Ref. 5b.