

# 2-[5'-CH<sub>3</sub>(H)-苯并咪唑-2'-亚甲基]-5-取代-1,3,4-□二唑的合成及生长素活性

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**摘要** 以邻苯二胺(或4-甲基邻苯二胺)及一氯乙酸为原料,在酸性条件下,合成2-氯甲基苯并咪唑及2-氯甲基-5-甲基苯并咪唑;以取代羧酸为原料经酯化、腈解、再与CS<sub>2</sub>在氢氧化钾溶液中反应,合成10种2-巯基-5-取代-1,3,4-□二唑;将2种2-氯甲基-5-取代-苯并咪唑与10种2-巯基-5-取代-1,3,4-□二唑在氢氧化钠溶液中反应,合成14种2-[5'-CH<sub>3</sub>(H)-苯并咪唑-2'-亚甲基]-5-取代-1,3,4-□二唑衍生物。借助红外光谱、核磁共振氢谱和元素分析对化合物结构进行表征。初步生长素活性测试结果表明,所合成的化合物对小麦芽鞘和绿豆发芽有着不同程度的生长调节作用。

**关键词** 苯并咪唑, □二唑, 合成, 生长素活性

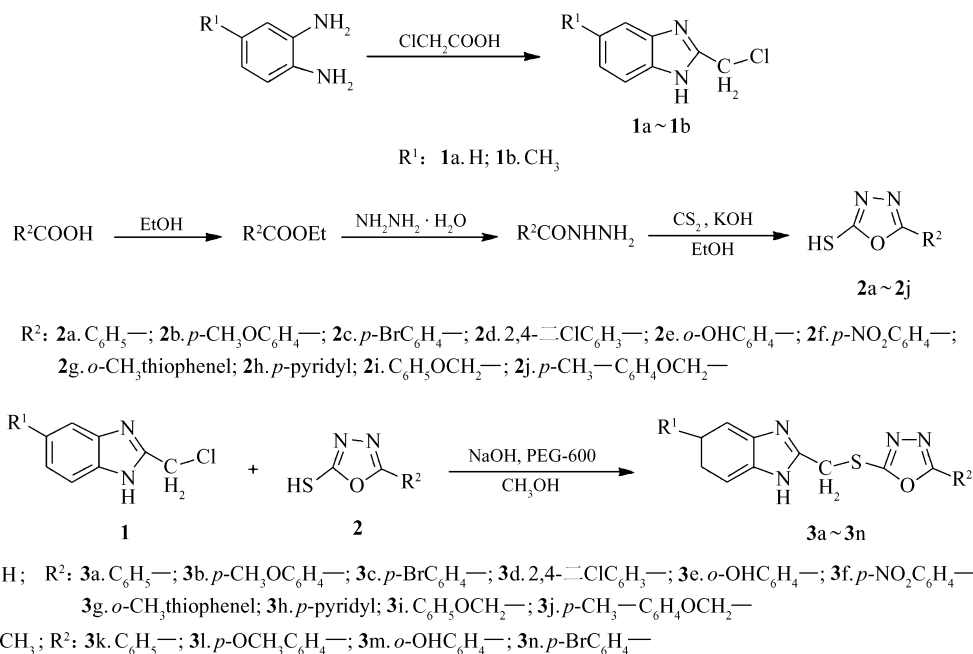
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杂环化合物种类繁多,其应用日益广泛。1,3,4-□二唑类化合物由于具有“N-C-O”结构,可以与多种金属离子螯合配位成为生物活性中间体,在杀菌<sup>[1]</sup>、除草<sup>[2]</sup>和植物生长调节<sup>[3]</sup>等领域均有广泛应用。苯并咪唑也具有植物生长调节、杀菌<sup>[4]</sup>、抗肿瘤<sup>[5-6]</sup>、抗病毒和降血压<sup>[7]</sup>等多种生物和药理活性。本文利用活性拼接原理,将这2种结构单元结合在一起,设计合成了系列新的化合物。通过在□二唑分子中增加硫醚键活性基团,期待实现生物活性叠加,获得更高的生物活性,合成路线如 Scheme 1 所示。



Scheme 1 Synthetical route of new compounds 3

## 1 实验部分

### 1.1 仪器和试剂

X-5 型显微熔点测定仪(北京泰克仪器有限公司),温度未经校正;Perkin Elmer 2400CHN 型元素分析仪(美国 PE 公司);Bruker AXS TENSOR-27 FT-IR 型红外光谱仪(瑞士 Bruker 公司);BrukerAvance-500 MHz 型核磁共振仪(瑞士 Bruker 公司),TMS 内标,DMSO-d<sub>6</sub>为溶剂;所有试剂均为分析纯或化学纯。中间体 2-氯甲基-5-取代苯并咪唑(**1a**,**1b**)按文献[8]方法,由 4-取代-邻苯二胺和氯乙酸制备;中间体 2-巯基-5-取代-1,3,4-□二唑(**2a**~**2f**)分别按文献[9-11]方法,由取代的芳香酸乙酯、水合肼和 CS<sub>2</sub> 制备。

### 1.2 目标化合物 2-[5'-CH<sub>3</sub>(H)-苯并咪唑-2'-亚甲硫基]-5-取代-1,3,4-□二唑(**3a**~**3n**)的合成

将 0.36 g(2 mmol)化合物 **2a** 悬浮于 15 mL 甲醇中,室温搅拌下加入 0.08 g(2 mmol)固体 NaOH,加入 1~3 滴 PEG-600,待溶液澄清后加入 0.33 g(2.4 mmol)化合物 **1a**。缓慢升温,回流,TLC 跟踪(展开剂:V(丙酮):V(氯仿)=1:1)至反应完全,向反应液中加入饱和 NaHCO<sub>3</sub>溶液至 pH=7,过夜,滤积沉淀,用 DMF/水或甲醇/水重结晶,干燥后,得目标产物 **3a**~**3n**。

2-(苯并咪唑-2'-亚甲硫基)-5-苯基-1,3,4-□二唑(**3a**):C<sub>16</sub>H<sub>12</sub>N<sub>4</sub>OS,黄色小针状,产率 57.65%,mp 170.0~172.3 °C;<sup>1</sup>H NMR(DMSO-d<sub>6</sub>,500 MHz), $\delta$ :12.57(s,1H,NH),7.94(d,1H,J=2.5 Hz,Ph<sub>1</sub>),7.92(d,1H,J=2.5 Hz,Ph<sub>1</sub>),7.51~7.64(m,5H,Ph<sub>2</sub>),7.15~7.19(m,2H,Ph<sub>1</sub>),4.81(s,2H,SCH<sub>2</sub>);IR(KBr), $\sigma/\text{cm}^{-1}$ :3204,1608,1598,1504,1440,1310,1270;C<sub>16</sub>H<sub>12</sub>N<sub>4</sub>OS 元素分析值(计算值)/%:C 62.32(62.30),H 3.89(3.92),N 18.13(18.17)。

2-(苯并咪唑-2'-亚甲硫基)-5-(4"-甲氧基苯基)-1,3,4-□二唑(**3b**):亮黄色晶体,产率 76.15%,mp 196.0~197.8 °C;<sup>1</sup>H NMR(DMSO-d<sub>6</sub>,500 MHz), $\delta$ :12.53(s,1H,NH),7.88(d,1H,J=6.8 Hz,Ph<sub>1</sub>),7.86(d,1H,J=6.8 Hz,Ph<sub>1</sub>),7.45(m,1H,Ph<sub>2</sub>),7.49~7.56(d,2H,J<sub>1</sub>=J<sub>2</sub>=7.0 Hz,Ph<sub>2</sub>),7.14~7.19(m,2H,Ph<sub>1</sub>),7.13(d,1H,J=2.0 Hz,Ph<sub>2</sub>),7.11(d,1H,J=2.0 Hz,Ph<sub>2</sub>),4.78(s,2H,SCH<sub>2</sub>),3.85(s,3H,Ph<sub>2</sub>-OCH<sub>3</sub>);IR(KBr), $\sigma/\text{cm}^{-1}$ :3208,1628,1596,1558,1434,1310,1282;C<sub>17</sub>H<sub>14</sub>N<sub>4</sub>O<sub>2</sub>S 元素分析值(计算值)/%:C 60.31(60.34),H 4.19(4.17),N 16.64(16.56)。

2-(苯并咪唑-2'-亚甲硫基)-5-(4"-溴苯基)-1,3,4-□二唑(**3c**):淡黄色大针状,产率 41.33%,mp 177.6~178.9 °C;<sup>1</sup>H NMR(DMSO-d<sub>6</sub>,500 MHz), $\delta$ :12.53(s,1H,NH),7.89(d,1H,J=4.1 Hz,Ph<sub>1</sub>),7.86(d,1H,J=4.1 Hz,Ph<sub>1</sub>),7.80(d,1H,J=3.5 Hz,Ph<sub>2</sub>),7.78(d,1H,J=3.5 Hz,Ph<sub>2</sub>),7.55(d,1H,J=7.5 Hz,Ph<sub>2</sub>),7.48(d,1H,J=7.5 Hz,Ph<sub>2</sub>),7.14~7.20(m,2H,Ph<sub>1</sub>),4.81(s,2H,SCH<sub>2</sub>);IR(KBr), $\sigma/\text{cm}^{-1}$ :3226,1602,1598,1496,1445,1310,1275;C<sub>16</sub>H<sub>11</sub>N<sub>4</sub>OSBr 元素分析值(计算值)/%:C 49.69(49.67),H 2.83(2.86),N 14.49(14.47)。

2-(苯并咪唑-2'-亚甲硫基)-5-(2",4"-二氯苯基)-1,3,4-□二唑(**3d**):白色针状,产率 61.233%,mp 185.6~186.4 °C;<sup>1</sup>H NMR(DMSO-d<sub>6</sub>,500 MHz), $\delta$ :12.54(s,1H,NH),7.97(d,1H,J=7.5 Hz,Ph<sub>2</sub>),7.91(d,1H,J=2.0 Hz,Ph<sub>2</sub>),7.65(s,1H,Ph<sub>2</sub>),7.56(d,1H,J=7.5 Hz,Ph<sub>1</sub>),7.49(d,1H,J=7.5 Hz,Ph<sub>1</sub>),7.48(d,1H,J=7.5 Hz,Ph<sub>2</sub>),7.14~7.21(m,2H,Ph<sub>1</sub>),4.82(s,2H,SCH<sub>2</sub>);IR(KBr), $\sigma/\text{cm}^{-1}$ :3200,1632,1593,1466,1442,1307,1272;C<sub>16</sub>H<sub>10</sub>N<sub>4</sub>OSCl<sub>2</sub> 元素分析值(计算值)/%:C 50.98(50.94),H 2.65(2.67),N 14.82(14.85)。

2-(苯并咪唑-2'-亚甲硫基)-5-(2"-羟基苯基)-1,3,4-□二唑(**3e**):亮黄色晶体,产率 57.60%,mp 195.8~196.9 °C;<sup>1</sup>H NMR(DMSO-d<sub>6</sub>,500 MHz), $\delta$ :12.52(s,1H,NH),10.24(s,1H,Ph<sub>2</sub>-OH),7.71(m,1H,Ph<sub>2</sub>),7.47(d,1H,J=6.0 Hz,Ph<sub>1</sub>),7.49(d,1H,J=6.0 Hz,Ph<sub>1</sub>),7.45(m,1H,Ph<sub>2</sub>),7.15~7.19(m,2H,Ph<sub>1</sub>),6.96~7.08(m,2H,Ph<sub>2</sub>),4.81(s,2H,SCH<sub>2</sub>);IR(KBr), $\sigma/\text{cm}^{-1}$ :3432,1612,1587,1501,1456,1314,1265;C<sub>16</sub>H<sub>12</sub>N<sub>4</sub>O<sub>2</sub>S 元素分析值(计算值)/%:C 59.21(59.25),H 3.76(3.73),N 12.25(12.27)。

2-(苯并咪唑-2'-亚甲硫基)-5-(4''-硝基苯基)-1,3,4-□二唑(**3f**):亮黄色晶体,产率 67.82%, mp 205.6 ~ 206.8 °C;  $^1\text{H}$  NMR (DMSO- $d_6$ , 500 MHz),  $\delta$ : 12.57 (s, 1H, NH), 8.41 (d, 1H,  $J_1 = 7.0$  Hz,  $\text{Ph}_2$ ), 8.39 (d, 1H,  $J_2 = 7.0$  Hz,  $\text{Ph}_2$ ), 8.21 (d, 1H,  $J = 6.0$  Hz,  $\text{Ph}_2$ ), 8.20 (d, 1H,  $J = 6.0$  Hz,  $\text{Ph}_2$ ), 7.54 (s, 2H,  $\text{Ph}_1$ ), 7.17 (m, 2H,  $\text{Ph}_1$ ), 4.85 (s, 2H,  $\text{SCH}_2$ ); IR (KBr),  $\sigma/\text{cm}^{-1}$ : 3268, 1608, 1564, 1514, 1456, 1312, 1270;  $\text{C}_{16}\text{H}_{11}\text{N}_5\text{O}_3\text{S}$  元素分析值(计算值)/%: C 54.36(54.39), H 3.18(3.14), N 19.85(19.82)。

2-(苯并咪唑-2'-亚甲硫基)-5-(2''-甲基噻吩基)-1,3,4-□二唑(**3g**):亮土黄色,产率 58.46%, mp 200.0 ~ 201.7 °C;  $^1\text{H}$  NMR (DMSO- $d_6$ , 500 MHz),  $\delta$ : 12.51 (s, 1H, NH), 7.81 (d, 1H,  $J = 5.0$  Hz,  $\text{Ph}_2$ ), 7.55 (d, 1H,  $J = 7.0$  Hz,  $\text{Ph}_1$ ), 7.47 (d, 1H,  $J = 7.0$  Hz,  $\text{Ph}_1$ ), 7.16 ~ 7.18 (m, 2H,  $\text{Ph}_1$ ), 7.11 (d, 1H,  $J = 5.0$  Hz,  $\text{Ph}_2$ ), 7.05 (d, 1H,  $J = 5.0$  Hz,  $\text{Ph}_2$ ), 4.77 (s, 2H,  $\text{SCH}_2$ ), 2.50 (s, 3H,  $\text{CH}_3$ ); IR (KBr),  $\sigma/\text{cm}^{-1}$ : 3188, 1623, 1576, 1476, 1456, 1310, 1272;  $\text{C}_{15}\text{H}_{12}\text{N}_4\text{OS}_2$  元素分析值(计算值)/%: C 54.88(54.86), H 3.66(3.68), N 17.09(17.06)。

2-(苯并咪唑-2'-亚甲硫基)-5-(4''-吡啶基)-1,3,4-□二唑(**3h**):亮黄色固体,产率 42.37%, mp 184.2 ~ 185.6 °C;  $^1\text{H}$  NMR (DMSO- $d_6$ , 500 MHz),  $\delta$ : 12.54 (s, 1H, NH), 8.81 (d, 1H,  $J = 1.5$  Hz,  $\text{Ph}_2$ ), 8.80 (d, 1H,  $J = 1.5$  Hz,  $\text{Ph}_2$ ), 7.88 (d, 1H,  $J = 1.5$  Hz,  $\text{Ph}_2$ ), 7.87 (d, 1H,  $J = 1.5$  Hz,  $\text{Ph}_2$ ), 7.53 (s, 2H,  $\text{Ph}_1$ ), 7.17 (s, 2H,  $\text{Ph}_1$ ), 4.85 (s, 2H,  $\text{SCH}_2$ ); IR (KBr),  $\sigma/\text{cm}^{-1}$ : 3400, 1614, 1552, 1464, 1448, 1314, 1272;  $\text{C}_{15}\text{H}_{11}\text{N}_5\text{OS}$  元素分析值(计算值)/%: C 58.21(58.24), H 3.59(3.58), N 22.67(22.64)。

2-(苯并咪唑-2'-亚甲硫基)-5-苯氧甲基-1,3,4-□二唑(**3i**):黄色粉末,产率 46.67%, mp 155.3 ~ 155.6 °C;  $^1\text{H}$  NMR (DMSO- $d_6$ , 500 MHz),  $\delta$ : 12.51 (s, 1H, NH), 7.55 (d, 1H,  $J = 7.5$  Hz,  $\text{Ph}_1$ ), 7.47 (d, 1H,  $J = 7.5$  Hz,  $\text{Ph}_1$ ), 7.16 ~ 7.20 (m, 2H,  $\text{Ph}_2$ ), 7.16 ~ 7.29 (m, 2H,  $\text{Ph}_1$ ), 7.15 (d, 1H,  $J = 8.0$  Hz,  $\text{Ph}_2$ ), 7.08 (d, 1H,  $J = 8.0$  Hz,  $\text{Ph}_2$ ), 6.92 (d, 1H,  $J = 2.0$  Hz,  $\text{Ph}_2$ ), 6.91 (d, 1H,  $J = 2.0$  Hz,  $\text{Ph}_2$ ), 5.32 (s, 2H,  $\text{OCH}_2$ ), 4.76 (s, 2H,  $\text{SCH}_2$ ); IR (KBr),  $\sigma/\text{cm}^{-1}$ : 3388, 1600, 1590, 1490, 1456, 1308, 1272;  $\text{C}_{17}\text{H}_{14}\text{N}_4\text{O}_2\text{S}$  元素分析值(计算值)/%: C 60.38(60.34), H 4.14(4.17), N 16.53(16.56)。

2-(苯并咪唑-2'-亚甲硫基)-5-(4''-甲基苯氧甲基)-1,3,4-□二唑(**3j**):亮黄色晶体,产率 59.94%, mp 136.8 ~ 137.9 °C;  $^1\text{H}$  NMR (DMSO- $d_6$ , 500 MHz),  $\delta$ : 12.51 (s, 1H, NH), 7.55 (d, 1H,  $J = 7.5$  Hz,  $\text{Ph}_1$ ), 7.47 (d, 1H,  $J = 7.5$  Hz,  $\text{Ph}_1$ ), 7.29 ~ 7.32 (m, 2H,  $\text{Ph}_2$ ), 7.14 ~ 7.29 (m, 2H,  $\text{Ph}_1$ ), 6.98 ~ 7.04 (m, 2H,  $\text{Ph}_2$ ), 5.38 (s, 2H,  $\text{OCH}_2$ ), 4.77 (s, 2H,  $\text{SCH}_2$ ), 2.50 (s, 3H,  $\text{CH}_3$ ); IR (KBr),  $\sigma/\text{cm}^{-1}$ : 3276, 1624, 1588, 1512, 1486, 1308, 1276;  $\text{C}_{18}\text{H}_{16}\text{N}_4\text{O}_2\text{S}$  元素分析值(计算值)/%: C 61.33(61.35), H 4.59(4.58), N 15.93(15.90)。

2-(5'-甲基苯并咪唑-2'-亚甲硫基)-5-苯基-1,3,4-□二唑(**3k**):黄色针状,产率 78.03%, mp 196.9 ~ 198.3 °C;  $^1\text{H}$  NMR (DMSO- $d_6$ , 500 MHz),  $\delta$ : 12.40 (s, 1H, NH), 7.94 (d, 1H,  $J = 8.0$  Hz,  $\text{Ph}_1$ ), 7.56 ~ 7.64 (m, 5H,  $\text{Ph}_2$ ), 7.30 (s, 1H,  $\text{Ph}_1$ ), 7.00 (d, 1H,  $J = 8.0$  Hz,  $\text{Ph}_1$ ), 4.78 (s, 2H,  $\text{SCH}_2$ ), 2.39 (s, 3H,  $\text{Ph}_1\text{-CH}_3$ ); IR (KBr),  $\sigma/\text{cm}^{-1}$ : 3196, 1612, 1594, 1558, 1454, 1300, 1276;  $\text{C}_{17}\text{H}_{14}\text{N}_4\text{OS}$  元素分析值(计算值)/%: C 61.38(61.34), H 4.36(4.38), N 17.34(17.38)。

2-(5'-甲基-苯并咪唑-2'-亚甲硫基)-5-(4''-甲氧基苯基)-1,3,4-□二唑(**3l**):白色针状,产率 59.98%, mp 195.1 ~ 196.8 °C;  $^1\text{H}$  NMR (DMSO- $d_6$ , 500 MHz),  $\delta$ : 12.39 (s, 1H, NH), 7.87 (d, 1H,  $J = 7.0$  Hz,  $\text{Ph}_1$ ), 7.86 (d, 1H,  $J = 7.0$  Hz,  $\text{Ph}_1$ ), 7.45 (m, 1H,  $\text{Ph}_2$ ), 7.27 ~ 7.43 (d, 1H,  $J_1 = J_2 = 6.8$  Hz,  $\text{Ph}_2$ ), 7.12 (d, 1H,  $J = 2.0$  Hz,  $\text{Ph}_2$ ), 7.10 (d, 1H,  $J = 2.0$  Hz,  $\text{Ph}_2$ ), 7.00 (s, 1H,  $\text{Ph}_1$ ), 4.75 (s, 2H,  $\text{SCH}_2$ ), 3.85 (s, 3H,  $\text{Ph}_2\text{-OCH}_3$ ), 2.39 (s, 3H,  $\text{Ph}_1\text{-CH}_3$ ); IR (KBr),  $\sigma/\text{cm}^{-1}$ : 3212, 1616, 1504, 1484, 1428, 1308, 1266;  $\text{C}_{18}\text{H}_{16}\text{N}_4\text{O}_2\text{S}$  元素分析值(计算值)/%: C 66.41(66.43), H 4.61(4.58), N 15.92(15.90)。

2-(5'-甲基-苯并咪唑-2'-亚甲硫基)-5-(2''-羟基-苯基)-1,3,4-□二唑(**3m**):亮橘黄色固体,产率 76.89%, mp 110.3 ~ 111.5 °C;  $^1\text{H}$  NMR (DMSO- $d_6$ , 500 MHz),  $\delta$ : 12.38 (s, 1H, NH), 10.24 (s, 1H,  $\text{Ph}_2\text{-OH}$ ), 7.71 (m, 1H,  $\text{Ph}_2$ ), 7.46 (d, 1H,  $J = 1.65$  Hz,  $\text{Ph}_1$ ), 7.44 (d, 1H,  $J = 1.65$  Hz,  $\text{Ph}_1$ ), 7.35 (s, 1H,  $\text{Ph}_1$ ), 7.26 (m, 1H,  $\text{Ph}_2$ ), 6.97 ~ 7.08 (m, 2H,  $\text{Ph}_2$ ), 4.81 (s, 2H,  $\text{SCH}_2$ ), 2.39 (s, 3H,  $\text{Ph}_1\text{-CH}_3$ ); IR

(KBr),  $\sigma/\text{cm}^{-1}$ : 3440, 1628, 1594, 1488, 1448, 1304, 1277; C<sub>17</sub>H<sub>14</sub>N<sub>4</sub>O<sub>2</sub>S 元素分析值(计算值)/%: C 60.32(60.34), H 4.20(4.17), N 16.52(16.56)。

2-(5'-甲基苯并咪唑-2'-亚甲硫基)-5-(4"-溴苯基)-1,3,4-□二唑(**3n**):亮黄色固体,产率 48.34%, mp 120.8 ~ 121.2 °C; <sup>1</sup>H NMR(DMSO-d<sub>6</sub>, 500 MHz),  $\delta$ :12.39(s, 1H, NH), 7.88(d, 1H, *J* = 2.0 Hz, Ph<sub>1</sub>), 7.86(d, 1H, *J* = 2.0 Hz, Ph<sub>1</sub>), 7.80(d, 1H, *J* = 2.0 Hz, Ph<sub>2</sub>), 7.78(d, 1H, *J* = 2.0 Hz, Ph<sub>2</sub>), 7.41(s, 1H, Ph<sub>1</sub>), 7.29(d, 1H, *J* = 7.0 Hz, Ph<sub>2</sub>), 6.99(d, 1H, *J* = 7.0 Hz, Ph<sub>2</sub>), 4.78(s, 2H, SCH<sub>2</sub>), 2.39(s, 3H, Ph<sub>1</sub>-CH<sub>3</sub>); IR(KBr),  $\sigma/\text{cm}^{-1}$ : 3300, 1604, 1588, 1472, 1443, 1304, 1278; C<sub>17</sub>H<sub>13</sub>N<sub>4</sub>OSBr 元素分析值(计算值)/%: C 50.92(50.88), H 3.23(3.26), N 13.93(13.96)。

### 1.3 目标化合物对小麦芽鞘和绿豆发芽的生长素活性试验

小麦芽鞘法参考文献[12]方法进行。取适量被测样品,加少量乙醇使之溶解,再滴加 1 ~ 2 滴乳化剂,稀释至 1 × 10<sup>-2</sup> g/L。于培养皿中各加一片滤纸,分别注入 10 mL 目标化合物药液,放入切好的小麦芽鞘 10 枚,于 25 °C 在暗箱中培养 24 h 后,测量培养皿内 10 段芽鞘的总长度。按照效果 = (处理 - CK)/CK × 100%, 计算相对空白芽鞘长度的增长率。正值为促生长,负值为抑制生长。药效评价标准为:效果 ≥ 40% 为 A 级, 25% ≤ 效果 < 40% 为 B 级, 10% ≤ 效果 < 25% 为 C 级, 效果 < 10% 为 D 级。

目标化合物对绿豆发芽期间的影响试验参考文献[13]方法,用微量液体稀释法进行。以绿豆为实验标靶,选取饱满的绿豆种粒,分别在浓度为 0(对照试验), 5 × 10<sup>-3</sup> g/L 目标化合物的水溶液中浸种 24 h。将浸泡过的种子分别置于垫有保湿滤纸的培养皿中,在室温下用清水培养,每隔 24 h 测定种子的发芽率。

## 2 结果与讨论

### 2.1 目标产物的光谱学特征

目标产物的 IR 谱在 3200 cm<sup>-1</sup> 附近出现咪唑环的 N—H 伸缩振动吸收, 670 ~ 700 cm<sup>-1</sup> 处出现 C—S—C 的伸缩振动吸收峰。在 <sup>1</sup>H NMR 谱中,咪唑环上 N 原子上的氢的化学位移均出现在低场  $\delta$  12.40 ~ 12.60 之间,  $\delta$  4.8 处的峰为 S-CH<sub>2</sub> 的质子信号峰。结果表明,中间体 **1** 和 **2** 的反应在 SH—上, 且是单分子的亲核取代反应。对所有化合物在 <sup>1</sup>H NMR 谱中氢的化学位移数做了全面归属。

### 2.2 目标化合物对小麦芽鞘和绿豆发芽的生长素活性

目标化合物对小麦芽鞘生长的影响实验结果列于表 1。对绿豆发芽的影响试验结果列于表 2。

表 1 化合物 3 对小麦芽鞘的生长素活性  
Table 1 Biological activities of compounds 3 to wheat gemma

Compound	Effect/%	Grade	Compound	Effect/%	Grade
3a	8.86	D	3b	11.08	C
3c	-0.13	inhibition	3d	4.16	D
3e	2.34	inhibition	3f	-0.10	inhibition
3g	-1.12	inhibition	3h	9.86	D
3i	-0.05	inhibition	3j	0.38	D
3k	5.34	D	3l	8.64	D
3m	0.74	D	3n	-0.24	inhibition

表 2 化合物 3 对绿豆发芽的生长素活性  
Table 2 Biological activity of compounds 3 to germination of mung bean

Compound	Germination/%			
	1st day	2nd day	3rd day	4th day
3a	30	50	80	90
3b	50	70	75	100
3c	20	40	60	70
3d	30	50	55	90

continued from previous page

Compound	Germination/%			
	1st day	2nd day	3rd day	4th day
3e	20	55	70	85
3f	30	55	75	75
3g	10	30	55	65
3h	20	50	75	95
3i	10	30	50	60
3j	20	50	70	85
3k	40	60	70	100
3l	50	60	100	100
3m	20	40	80	80
3n	10	30	30	70
CK	10	50	70	80

由表 1 和表 2 结果可见,所有的目标化合物的小麦芽鞘生长素活性均不明显,部分属 D 级,只有化合物 3b 的促进效果达到 C 级,还有部分化合物具有抑制作用。而对于绿豆发芽的生长素活性,绝大多数化合物具有促进生长作用。从分子结构上看,当目标化合物中 1,3,4-□二唑 5 位取代基 R<sup>2</sup> 为卤素和硝基取代的苯基时,表现为抑制作用;为甲氧基取代的苯基时,表现为促进作用。此外,R<sup>1</sup> 的结构对于小麦芽鞘和绿豆发芽的生长素活性也有一定的影响,当其为甲基取代时,对小麦芽鞘的生长素活性促进作用减弱,而对绿豆发芽的生长素活性却表现出明显的促进作用。

### 3 结 论

采用 PEG-600 为相转移催化剂,甲醇为溶剂,合成了系列 2-[5'-CH<sub>3</sub>(H)-苯并咪唑-2'-亚甲基]-5-取代-1,3,4-□二唑,产物收率较高,纯度好。所有目标化合物均具有不同程度的生物活性,对于小麦芽鞘的生长素活性促进作用效果不明显,甚至有抑制作用;而对于绿豆发芽的生长素活性多数化合物具有明显的促进作用。因此,此类化合物可以选择性的进一步应用到植物生长调节方面。

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## Synthesis and Biological Activities of 2-{ [5'-Methyl(*H*)-benzoimidazol-2'-yl] methylthio } -5-substituted-1,3,4-oxadiazole Derivatives

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**Abstract** Two kinds of 2-chloromethyl-benzimidazole were synthesized by substituted *o*-diaminobenzene and monochloroacetic acid in hydrochloric acid solution. With substituted carboxylic acid as the starting materials, ten kinds of 1,3,4-oxadiazoles were prepared *via* esterification, hydrazinolysis, followed by reaction with carbon disulfide in potassium hydroxide solution. At last, fourteen new target compounds were synthesized by reacting 5-substituted-1,3,4-oxadiazole-3-thiol with 2-chloromethyl-5-substituted-benzoimidazole in sodium hydroxide solution. The structures of all the compounds were characterized by IR, <sup>1</sup>H NMR and elemental analysis. Preliminary biological activity experiments showed that the synthesized compounds had certain effects on the wheat gemma and germination of mung bean.

**Keywords** benzoimidazole, oxadiazole, synthesis, biological activity