Supporting Information

The racemic synthesis of an intermediate for the formal synthesis of madindoline A and B

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3-n-Butyl-4-methylcyclobut-3-ene-1,2-dione (16). A solution of CH$_3$Li (1.6 M in Et$_2$O, 3.4 mL, 5.5 mmol) was added dropwise to a solution of diisopropyl squarate (17b) (990 mg, 5.0 mmol) in THF (20 mL) at –78°C under argon. After 5 min of stirring, a solution of n-BuLi (2.4 M in hexane, 2.5 mL, 6.0 mmol) was added dropwise to the system. 10 min later, the reaction was quenched with saturated ammonium chloride solution, and extracted with EtOAc. The organic layer was washed with water, brine, and dried over Na$_2$SO$_4$. Removal of the solvent, then a solution of concentrated hydrochloric acid in CH$_2$Cl$_2$ was added to a solution of the intermediate in CH$_2$Cl$_2$ and controlled pH = 3, stirred at room temperature about 30 min, and then the mixture was dried over Na$_2$SO$_4$. Removal of the solvent and flash chromatography of the residue on silica gel (PE/EtOAc = 10/1) afforded the 16 (600 mg, 79 %) brown oil. $R_f$ = 0.4 (PE/EtOAc = 4/1). $^1$H NMR (400 MHz, CDCl$_3$): $\delta$ 2.74 (t, $J$ = 8 Hz, 2H), 2.35 (s, 3H), 1.67-1.75 (m, 2H), 1.37-1.43 (m, 2H), 0.96 (t, $J$ = 8 Hz, 3H). $^{13}$C NMR (100 MHz, CDCl$_3$): $\delta$ 203.7, 199.7, 199.4, 199.2, 27.9, 26.2, 22.8, 13.6, 11.2. HRMS (ESI$^+$) m/z: [M + Na]$^+$ calcd for C$_9$H$_{12}$NaO$_2$, 175.0730; found, 175.0733.

4-butyl-2-methoxycarbonyl-2,5-dimethylcyclopent-4-ene-1,3-dione (14b). colorless oil. (146 mg, 80% (based on the recovery of 23% of 16)) $R_f$ = 0.6 (PE/EtOAc = 4/1). $^1$H NMR (400 MHz, CDCl$_3$): $\delta$ 3.67 (s, 3H), 2.52 (t, $J$ = 8 Hz, 3H), 2.09 (s, 3H), 1.48-1.55 (m, 2H), 1.44 (s, 3H), 1.33-1.39 (m, 2H), 0.94 (t, $J$ = 8 Hz, 3H). $^{13}$C NMR (100 MHz, CDCl$_3$): $\delta$ 199.7, 199.4, 167.1, 159.9, 155.5, 57.4, 53.2, 29.7, 24.1, 22.7, 15.3, 13.9, 9.7. HRMS (ESI$^+$) m/z: [M + Na]$^+$ calcd for C$_{13}$H$_{18}$NaO$_4$, 261.1097; found, 261.1090.

((4-butyl-2-methoxycarbonyl-2,5-dimethylcyclopent-4-ene-1,3-diy)bis(oxy))bis(tert-butyldimethylsilane) (13): 14b (50 mg, 0.21 mmol) and cerous chloride heptahydrate (16 mg, 0.04 mmol) was dissolved in methanol (5 mL), the mixture was then cooled to 0°C, and to the solution was
added NaBH$_4$ (32 mg, 0.84 mmol) slowly. The reaction mixture was warmed up to room temperature. After 3 h, the reaction mixture was quenched with saturated ammonium chloride solution. The aqueous phase was extracted with CH$_2$Cl$_2$ (3×20mL). The combined organic layer was washed with saturated brine and dried over Na$_2$SO$_4$. The solvent was removed under reduced pressure. Then tert-butylimidylsilyl trifluoromethanesulfonate (TBSOTf) (172 mg, 1.1 mmol) was added to the solution of the crude residue and triethylamine (213mg, 2.1 mmol) in CH$_2$Cl$_2$ (5 mL) at room temperature. After 1h, the reaction was quenched with water. The aqueous phase was extracted with CH$_2$Cl$_2$ and the combined organic layers were dried over Na$_2$SO$_4$. The solvent was removed under reduced pressure. The crude residue was purified by silica gel chromatography (PE/EtOAc, 100/1) to give 13 (52 mg, 53%) as a colorless oil. $R_f = 0.8$ (PE/EtOAc = 4/1). $^1$H NMR (400 MHz, CDCl$_3$): $\delta$ 4.82 (s, 1H), 4.69 (s, 1H), 3.69 (s, 3H), 2.04-2.08 (m, 1H), 1.92-1.95 (m, 1H), 1.57 (s, 3H), 1.30 (m, 4H), 1.01 (s, 3H), 0.89 (s, 21H), 0.48 (s, 6H), -0.06(s, 6H). $^{13}$C NMR (100 MHz, CDCl$_3$): $\delta$ 178.4, 137.3, 133.0, 82.2, 81.1, 60.9, 51.8, 31.0, 26.0(6C), 25.3, 23.1, 18.3, 18.2, 14.2, 11.5, 11.4, -4.4, -4.6, -4.7, -4.8. HRMS (ESI$^+$) m/z: [M + Na]$^+$ calcd for C$_{25}$H$_{50}$NaO$_4$Si$_2$, 493.3140; found, 493.3120.

14a yellow oil. (144 mg, 86% ) $R_f = 0.6$ (PE/EtOAc = 4/1). $^1$H NMR (400 MHz, CDCl$_3$): $\delta$ 4.04-4.09 (m, 2H), 2.42-2.49 (m, 2H), 2.02 (s, 3H), 1.43-1.47 (m, 2H), 1.34 (s, 3H), 1.28-1.31 (m, 2H), 1.09 (t, J = 8 Hz, 3H), 0.86 (t, J = 8 Hz, 3H). $^{13}$C NMR (100 MHz, CDCl$_3$): $\delta$ 199.8, 199.5, 166.6, 159.9, 155.4, 62.2, 57.5, 29.6, 24.0, 22.6, 15.0, 13.9, 13.8, 9.7. HRMS (ESI$^+$) m/z: [M + Na]$^+$ calcd for C$_{14}$H$_{20}$NaO$_4$, 275.1254; found, 275.1249.

14c
yellow oil. (282 mg, 77%) \( R_f = 0.6 \) (PE/EtOAc = 4/1). \(^1\)H NMR (400 MHz, CDCl\(_3\)): \( \delta \) 3.95-4.01 (m, 2H), 2.41-2.47 (m, 2H), 2.01 (s, 3H), 1.41-1.44 (m, 2H), 1.35 (s, 3H), 1.26-1.31 (m, 2H), 1.16-1.19 (m, 2H), 0.85 (t, \( J = 8 \) Hz, 3H), 0.79 (t, \( J = 8 \) Hz, 3H). \(^{13}\)C NMR (100 MHz, CDCl\(_3\)): \( \delta \) 199.8, 199.5, 166.6, 159.8, 155.5, 65.9, 57.6, 30.3, 29.7, 24.0, 22.7, 18.9, 15.0, 13.9, 13.6, 9.6. HRMS (ESI\(^+\)) \( m/z \): [M + Na]\(^+\) calcd for C\(_{16}\)H\(_{24}\)NaO\(_4\), 303.1567; found, 303.1563.

14d

yellow oil. (275 mg, 83%) \( R_f = 0.6 \) (PE/EtOAc = 4/1). \(^1\)H NMR (400 MHz, CDCl\(_3\)): \( \delta \) 3.58 (s, 3H), 2.46 (t, \( J = 8 \) Hz, 2H), 2.40-2.10 (m, 2H), 2.02 (s, 3H), 1.42-1.47 (m, 2H), 1.26-1.32 (m, 2H), 0.86 (t, \( J = 8 \) Hz, 3H), 0.62 (t, \( J = 8 \) Hz, 3H). \(^{13}\)C NMR (100 MHz, CDCl\(_3\)): \( \delta \) 199.7, 199.4, 166.8, 161.2, 156.9, 62.1, 53.1, 29.8, 24.1, 23.5, 22.7, 13.9, 9.6, 8.5. HRMS (ESI\(^+\)) \( m/z \): [M + Na]\(^+\) calcd for C\(_{14}\)H\(_{20}\)NaO\(_4\), 275.1254; found, 275.1258.

14e

yellow oil. (299 mg, 81%) \( R_f = 0.6 \) (PE/EtOAc = 4/1). \(^1\)H NMR (400 MHz, CDCl\(_3\)): \( \delta \) 4.01-4.05 (m, 2H), 2.35-2.53 (m, 2H), 2.00 (s, 3H), 1.41-1.47 (m, 2H), 1.28 (s, 14H), 0.86 (t, \( J = 8 \) Hz, 3H). \(^{13}\)C NMR (100 MHz, CDCl\(_3\)): \( \delta \) 200.3, 200.0, 165.5, 159.6, 155.3, 83.0, 58.4, 29.8, 27.7, 24.0, 22.7, 14.7, 13.9, 9.6. HRMS (ESI\(^+\)) \( m/z \): [M + Na]\(^+\) calcd for C\(_{16}\)H\(_{24}\)NaO\(_4\), 303.1567; found, 303.1560.

14f

yellow oil. (286 mg, 78%) \( R_f = 0.6 \) (PE/EtOAc = 4/1). \(^1\)H NMR (400 MHz, CDCl\(_3\)): \( \delta \) 2.35-2.53 (m, 2H), 2.00 (s, 3H), 1.41-1.47 (m, 2H), 1.28 (s, 14H), 0.86 (t, \( J = 8 \) Hz, 3H). \(^{13}\)C NMR (100 MHz, CDCl\(_3\)): \( \delta \) 200.3, 200.0, 165.5, 159.6, 155.3, 83.0, 58.4, 29.8, 27.7, 24.0, 22.7, 14.7, 13.9, 9.6. HRMS (ESI\(^+\)) \( m/z \): [M + Na]\(^+\) calcd for C\(_{16}\)H\(_{24}\)NaO\(_4\), 303.1567; found, 303.1569.
$^{1}$H and $^{13}$C NMR Spectra of Compounds

$^1$H NMR Spectrum for compound 16

$^{13}$C NMR Spectrum for compound 16
$^1$H NMR Spectrum for compound 14b

$^{13}$C NMR Spectrum for compound 14b
$^1$H NMR Spectrum for compound 13

$^{13}$C NMR Spectrum for compound 13
\(^1\)H NMR Spectrum for compound 14a

\(^{13}\)C NMR Spectrum for compound 14a
$^1$H NMR Spectrum for compound 14c

$^{13}$C NMR Spectrum for compound 14c
$^1$H NMR Spectrum for compound 14d

$^{13}$C NMR Spectrum for compound 14d
$^1$H NMR Spectrum for compound 14e

$^{13}$C NMR Spectrum for compound 14e
\(^1\)H NMR Spectrum for compound 14f

\(^{13}\)C NMR Spectrum for compound 14f