Palladium-Catalyzed Arylation and Heteroarylation of Azolopyrimidines

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Supporting Information

CONTENTS

-12 pages

-Experimental details and characterization data for compounds:

11, 13a-i, 14a, 14d, 14f-h, 15a,b, and 16a,b, 16d

General Methods. Column chromatography was performed using silica gel (60 F₂₅₄, 70–200 mm) as the stationary phase. All melting points are uncorrected. NMR spectra were obtained at 300 or 500 MHz (¹H) and 75 MHz (¹³C). Chemical shifts are reported in ppm relative to tetramethylsilane. 5-Bromo-3-methoxycarbonylpyrimido[1,6-*a*]indole (**5**) and 5-bromo-7-methoxycarbonyl-pyrido[3',2':4,5]pyrrolo[1,2-*c*]pyrimidine (**6**) were prepared according to the methods described in reference 9. 2-Methylthio-4-trimethylstannyl-pyrimidine employed in the synthesis of **16c** was prepared following the methods described in reference 20.

5-Bis(3-methoxycarbonylpyrimido[1,6-*a*]indole) (11). To a mixture of 100 mg (0.328 mmol) of **5** in dry DMF (4 mL) was added a solution of 62 mg (0.164 mmol) of Me₆Sn₂ in dry DMF (1 mL) and Pd(PPh₃)₄ (5%). The mixture was heated to 80 °C under argon for 20 h. After cooling, the reaction mixture was filtered through Celite and the Celite was washed with DMF and a mixture of CH₂Cl₂:MeOH (8:2) saturated with NH₃. The latter washes were evaporated under reduced pressure yielding 7.4 mg of **11** (5%) as an orange solid. Mp >300 °C; IR (KBr) $\nu_{\max}$ 3415, 2924, 1718, 1459, 1371, 1257, 1239 cm⁻¹; ¹H NMR (500 MHz, CDCl₃) δ 3.91 (s, 6H); 7.62–7.50 (m, 4H); 7.67 (d, 2H, *J* = 7.7 Hz); 8.01 (s, 2H); 8.18 (d, 2H, *J* = 7.5 Hz); 9.31 (s, 2H); MS (EI) *m/z* (relative intensity) 450 (M⁺, 100); 199 (54); 165 (59). Anal. Calcd for C₂₆H₁₈N₄O₄ (450.46): C, 69.33; H, 4.03; N, 12.44. Found: C, 69.65; H, 3.76; N, 12.01.

Synthesis of derivatives 13. General procedure. To a mixture of **5** (1.0 mmol), the aryl or heteroaryl boronic acid (1.0 mmol) and K₂CO₃ (192 mg, 1.4 mmol) in toluene/MeOH (20:1)

(25 mL) was added Pd(PPh₃)₄ (57 mg, 0.049 mmol) under argon and the mixture was heated under reflux for 10 h. The reaction mixture was cooled and the resulting precipitate was filtered off and washed with toluene and EtOAc. The solid was dissolved in CH₂Cl₂ and the organic solution washed with water and dried over Na₂SO₄. The organic phase was filtered through Celite, the Celite was washed with CH₂Cl₂ and the combined organic phases evaporated under reduced pressure to afford pure compounds **13a–j**.

3-Methoxycarbonyl-5-phenylpyrimido[1,6-*a*]indole (13a). 85%; yellow solid; mp 278–279 °C; IR (KBr) ν_{max} 1718, 1458, 1430, 1368, 1296, 1231, 1085 cm⁻¹; ¹H NMR (500 MHz, CDCl₃) δ 4.00 (s, 3H); 7.46–7.39 (m, 1H); 7.70–7.53 (m, 6H); 8.12–8.03 (m, 2H); 8.41 (d, 1H, *J* = 1.4 Hz), 9.24 (d, 1H, *J* = 1.4 Hz); ¹³C NMR (75 MHz CDCl₃) δ 165.2; 138.4; 134.3; 132.6; 129.6; 129.1; 128.8; 127.2; 125.4; 123.7; 120.4; 117.2; 113.0; 110.8; 52.8; MS (EI) *m/z* (relative intensity) 302 (M⁺, 100); 242 (20). Anal. Calcd for C₁₉H₁₄N₂O₂: C, 75.44; H, 4.69; N, 9.26. Found: C, 75.48; H, 4.67; N, 9.27.

5-(4-Methylphenyl)-3-methoxycarbonylpyrimido[1,6-*a*]indole (13b). 68%; orange solid; mp 283–285 °C; IR (KBr) ν_{max} 2953, 1727, 1428, 1433, 1370, 1230, 1090 cm⁻¹; ¹H NMR (500 MHz, CDCl₃) δ 2.45 (s, 3H); 3.97 (s, 3H); 7.36 (d, 2H, *J* = 8.1 Hz); 7.56–7.50 (m, 4H); 8.09–8.01 (m, 2H), 8.38 (d, 1H, *J* = 1.3 Hz); 9.20 (d, 1H, *J* = 1.3 Hz); Anal. Calcd for C₂₀H₁₆N₂O₂ (316.36): C, 75.93; H, 5.10; N, 8.80. Found: C, 75.67; H, 4.89; N, 8.46.

3-Methoxycarbonyl-5-(4-vinylphenyl)pyrimido[1,6-*a*]indole (13c). 56%; orange solid; mp 275-276 °C; IR (KBr) $\nu_{\max}$ 1720, 1458, 1433, 1370, 1295, 1231, 1091 cm^{-1} ; ^1H NMR (500 MHz, CDCl_3) δ 4.00 (s, 3H); 5.33 (d, 1H, $J = 10.9$ Hz); 5.86 (d, 1H, $J = 17.5$ Hz); 6.82 (dd, 1H, $J = 17.5, 10.9$ Hz); 7.68-7.53 (m, 6H); 8.13-8.03 (m, 2H); 8.41 (d, 1H, $J = 1.4$ Hz); 9.24 (d, 1H, $J = 1.4$ Hz). Anal. Calcd for $\text{C}_{21}\text{H}_{16}\text{N}_2\text{O}_2$ (328.37): C, 76.81; H, 4.91; N, 8.53. Found: C, 76.41; H, 4.63; N, 8.88.

3-Methoxycarbonyl-5-(4-methoxyphenyl)pyrimido[1,6-*a*]indole (13d). 49 %; orange-yellowish solid; mp 285-286 °C; IR (KBr) $\nu_{\max}$ 1713, 1457, 1432, 1369, 1252, 1231, 1178, 1088 cm^{-1} ; ^1H NMR (500 MHz, CDCl_3) δ 3.91 (s, 3H); 3.99 (s, 3H); 7.11 (d, 2H, $J = 8.7$ Hz); 7.61-7.51 (m, 2H); 7.59 (d, 2H, $J = 8.7$ Hz); 8.11-7.99 (m, 2H); 8.37 (d, 1H, 1.5 Hz); 9.21 (d, 1H, $J = 1.5$ Hz). Anal. Calcd for $\text{C}_{20}\text{H}_{16}\text{N}_2\text{O}_3$ (332.36): C, 72.28; H, 4.85; N, 8.43. Found: C, 72.67; H, 5.02; N, 8.64.

5-(4-Methylthiophenyl)-3-methoxycarbonylpyrimido[1,6-*a*]indole (13e). 71%; orange solid; mp 302-303 °C; IR (KBr) $\nu_{\max}$ 1717, 1457, 1432, 1370, 1295, 1232, 1092, 1083 cm^{-1} ;

^1H NMR (500 MHz, CDCl_3) δ 2.58 (s, 3H); 4.00 (s, 3H); 7.46 (d, 2H, $J = 8.4$ Hz); 7.57-7.51 (m, 2H); 7.59 (d, 2H, $J = 8.4$ Hz); 8.04-8.01 (m, 1H); 8.11-8.08 (m, 1H); 8.38 (d, 1H, $J = 1.5$ Hz); 9.23 (d, 1H, $J = 1.5$ Hz). Anal. Calcd for $\text{C}_{20}\text{H}_{16}\text{N}_2\text{O}_2$ (316.36): C, 75.93; H, 5.10; N, 8.85. Found: C, 75.65; H, 4.90; N, 8.37.

3-Methoxycarbonyl 5-(3,5-dichlorophenyl)pyrimido[1,6-a]indole (13f). 87%; yellow solid; mp 302-303°C; IR (KBr) ν_{max} 1741, 1586, 1452, 1433, 1348, 1224, 1098 cm^{-1} ; ^1H NMR (500 MHz, CDCl_3) δ 4.02 (s, 3H); 7.53 (d, 2H, $J = 1.8$ Hz); 7.42 (t, 1H, $J = 1.8$ Hz), 7.60-7.56 (m, 2H); 8.01-7.96 (m, 1H), 8.14-8.09 (m, 1H), 8.34 (d, 1H, $J = 1.5$ Hz); 9.26 (d, 1H, $J = 1.5$ Hz). Anal. Calcd for $\text{C}_{19}\text{H}_{12}\text{Cl}_2\text{N}_2\text{O}_2$ (371.23): C, 61.48; H, 3.26; N, 7.55. Found: C, 61.11; H, 2.96; N, 7.13

3-Methoxycarbonyl-5-(4-formylphenyl)pyrimido[1,6-a]indole (13g). 72%; yellow solid; mp 294-295 °C; IR (KBr) ν_{max} 1710, 1602, 1526, 1457, 1432, 1365, 1300, 1261, 1235, 1216,

1164 cm^{-1} ; ^1H NMR (500 MHz, CDCl_3) δ 4.02 (s, 3H); 7.65-7.55 (m, 2H); 7.86 (d, 2H, J = 8.2 Hz); 8.09 (d, 2H, J = 8.2 Hz); 8.16-8.05 (m, 2H); 8.43 (d, 1H, J = 1.3 Hz); 9.29 (d, 1H, J = 1.3 Hz); 10.11 (s, 1H);. Anal. Calcd for $\text{C}_{20}\text{H}_{14}\text{N}_2\text{O}_3$ (330.35): C, 72.72; H, 4.27; N, 8.48. Found: C, 72.56; H, 4.45; N, 8.81.

5-(Thiophen-3-yl)-3-methoxycarbonylpyrimido[1,6-*a*]indole (13h). 89%; mp 294-295 $^{\circ}\text{C}$; IR (KBr) ν_{max} 1716, 1459, 1426, 1366, 1294, 1259, 1234, 1085 cm^{-1} ; ^1H NMR (500 MHz, CDCl_3) δ 4.01 (s, 3H); 7.59-7.48 (m, 5H); 8.11-8.03 (m, 2H); 8.42 (d, 1H, J = 1.4 Hz); 9.21 (d, 1H, J = 1.4 Hz). Anal. Calcd for $\text{C}_{17}\text{H}_{12}\text{N}_2\text{O}_2\text{S}$ (308.36): C, 66.22; H, 3.92; N, 9.00. Found: C, 65.90; H, 3.74; N, 9.05.

3-Methoxycarbonyl-5-(2-benzo[*b*]thiophenyl)pyrimido[1,6-*a*]indole (13i). 97%; orange solid; mp >300 $^{\circ}\text{C}$; IR (KBr) ν_{max} 1711, 1459, 1431, 1369, 1230, 1104 cm^{-1} ; ^1H NMR (500 MHz, CDCl_3) δ 4.00 (s, 3H); 7.45-7.30 (m, 2H); 7.65-7.50 (m, 3H); 7.92-7.82 (m, 2H); 8.10-8.04 (m, 1H); 8.28-8.23 (m, 1H); 8.63 (d, 1H, J = 1.2 Hz); 9.21 (d, 1H, J = 1.2 Hz). Anal. Calcd for $\text{C}_{21}\text{H}_{14}\text{N}_2\text{O}_2\text{S}$ (358.42): C, 70.37; H, 3.94; N, 7.82. Found: C, 70.09; H, 3.69; N, 7.53.

5-(2-Benzo[b]furanyl)-3-methoxycarbonylpyrimido[1,6-a]indole (13j). 67%. mp 277-278 °C; IR (KBr) ν_{max} 1718, 1453, 1431, 1367, 1234 cm^{-1} ; ^1H NMR (500 MHz, CDCl_3) δ 4.05 (s, 3H); 7.13 (s, 1H); 7.36-7.28 (m, 2H); 7.67-7.53 (m, 4H); 8.06 (d, 1H, $J = 8.2$ Hz); 8.29 (d, 1H, $J = 8.0$ Hz); 8.87 (d, 1H, $J = 1.5$ Hz); 9.20 (d, 1H, $J = 1.5$ Hz). Anal. Calcd for $\text{C}_{21}\text{H}_{14}\text{N}_2\text{O}_3$ (342.36): C, 73.68; H, 4.12, N, 8.18. Found: C, 73.35; H, 3.86, N, 7.79.

Synthesis of derivatives 14. General procedure. To a mixture of **6** (1.0 mmol), the aryl or heteroaryl boronic acid (1.0 mmol) and K_2CO_3 (192 mg, 1.4 mmol) in toluene/MeOH (20:1) (25 mL) was added $\text{Pd}(\text{PPh}_3)_4$ (57 mg, 0.049 mmol) under argon and the mixture was heated to reflux temperature for 10 h. The reaction mixture was allowed to cool to room temperature, filtered through Celite, the Celite washed with CH_2Cl_2 and the organic phase evaporated under reduced pressure. The residue was purified by silica gel flash chromatography [CH_2Cl_2 :acetone (95:5)] to afford pure compounds **14**.

7-Methoxycarbonyl-5-phenylpyrido[3',2':4,5]pyrrolo[1,2-*c*]pyrimidine (14a). 66%; yellow solid; Mp 234-235 °C; IR (KBr) $\nu_{\max}$ 3414, 2953, 1711, 1445, 1289, 1259, 1092 cm^{-1} ; ^1H NMR (500 MHz, CDCl_3) δ 4.03 (s, 3H); 7.70-7.42 (m, 6H); 8.39 (dd, 1H, $J = 8.2, 1.5$ Hz); 8.46 (d, 1H, $J = 1.5$ Hz); 8.65 (dd, 1H, $J = 4.6, 1.5$ Hz); 9.65 (d, 1H, $J = 1.5$ Hz); ^{13}C NMR (75 MHz CDCl_3) δ 53.0; 110.6; 116.9; 121.3; 127.4; 128.7; 128.8; 128.9; 129.3; 132.1; 138.3; 140.7; 144.6; 165.1; MS (EI) m/z (relative intensity) 303 (M^+ , 100); 245 (60). Anal. Calcd for $\text{C}_{18}\text{H}_{13}\text{N}_3\text{O}_2$ (303.32): C, 71.27; H, 4.32; N, 13.84. Found: C, 71.28; H, 4.32; N, 13.85.

5-(4-Methoxyphenyl)-7-methoxycarbonylpyrido[3',2':4,5]pyrrolo[1,2-*c*]pyrimidine (14d). 52%; orange solid. Mp 236-237 °C; IR (KBr) $\nu_{\max}$ 3415, 1711, 1535, 1436, 1332, 1294, 1259 cm^{-1} ; ^1H NMR (500 MHz, CDCl_3) δ 3.91 (s, 3H); 4.01 (s, 3H), 7.11 (dd, 2H, $J = 8.8$ Hz); 7.53 (dd, 1H, $J = 8.2, 4.6$ Hz); 7.57 (d, 2H, $J = 8.8$ Hz); 8.35 (dd, 1H, $J = 8.2, 1.5$ Hz); 8.41 (d, 1H, $J = 1.5$ Hz); 8.63 (dd, 1H, $J = 4.6, 1.5$ Hz); 9.62 (d, 1H, $J = 1.5$ Hz); ^{13}C NMR (75 MHz CDCl_3) δ 52.9; 55.4; 110.5; 114.9; 117.2; 121.2; 121.4; 124.5; 128.6; 128.8; 130.1; 135.6; 138.4; 140.7; 144.6; 159.1; 165.3. Anal. Calcd for $\text{C}_{19}\text{H}_{15}\text{N}_3\text{O}_3$ (333.35): C, 68.46; H, 4.54; N, 12.61. Found: C, 68.67; H, 4.59; N, 12.50.

5-(3,5-Dichlorophenyl)-7-methoxycarbonylpyrido[3',2':4,5]pyrrolo[1,2-*c*]pyrimidine (14f). 60%; yellow solid. Mp 279-280 °C; IR (KBr) ν_{max} 3416, 3049, 1733, 1439, 1232 cm^{-1} ; ^1H NMR (500 MHz, CDCl_3) δ 4.03 (s, 3H); 7.42 (t, 1H, $J = 1.8$ Hz); 7.50 (d, 2H, $J = 1.8$ Hz); 7.57 (dd, 1H, $J = 8.2, 4.6$ Hz); 8.32 (dd, 1H, $J = 8.2, 1.5$ Hz); 8.38 (d, 1H, $J = 1.5$ Hz); 8.65 (dd, 1H, $J = 4.6, 1.5$ Hz); 9.67 (d, 1H, $J = 1.5$ Hz); ^{13}C NMR (75 MHz CDCl_3) δ 53.1; 107.6; 116.0; 121.0; 121.8; 127.0; 127.5; 128.3; 129.7; 135.3; 135.9; 137.1; 138.5; 140.8; 145.2; 164.9. Anal. Calcd for $\text{C}_{18}\text{H}_{11}\text{Cl}_2\text{N}_3\text{O}_2$ (372.21): C, 58.09; H, 2.98, N, 11.29. Found: C, 58.23; H, 2.65, N, 11.31.

7-Methoxycarbonyl-5-(4-formylphenyl)pyrido[3',2':4,5]pyrrolo[1,2-*c*]pyrimidine (14g). 65%; orange solid; mp 246-247 °C; IR (KBr) ν_{max} 1710, 1693, 1442, 1294, 1161 cm^{-1} ; ^1H NMR (500 MHz, CDCl_3) δ 4.04 (s, 3H); 7.59 (dd, 1H, $J = 8.2, 4.6$ Hz); 7.85 (d, 2H, $J = 8.2$ Hz); 8.10 (d, 2H, $J = 8.2$ Hz); 8.41 (dd, 1H, $J = 8.2, 1.5$ Hz); 8.48 (d, 1H, $J = 1.5$ Hz); 8.67 (dd, 1H, $J = 4.6, 1.5$ Hz); 9.70 (d, 1H, $J = 1.5$ Hz); 10.11 (s, 1H); ^{13}C NMR (75 MHz CDCl_3) δ 53.1; 109.1; 116.3; 120.9; 121.8; 128.5; 129.1; 129.8; 130.7; 134.9; 137.0; 138.5; 138.7; 140.9; 145.1; 164.8; 191.4. Anal. Calcd for $\text{C}_{19}\text{H}_{13}\text{N}_3\text{O}_3$ (331.33): C, 68.88; H, 3.95; N, 12.68. Found: C, 68.74; H, 3.91; N, 12.58.

5-(Thiophen-3-yl)-7-methoxycarbonylpyrido[3',2':4,5]pyrrolo[1,2-*c*]pyrimidine (14h). 40%; orange-yellowish solid; mp 258-259 °C; IR (KBr) ν_{max} 3415, 1711, 1436, 1332, 1258 cm^{-1} ; ^1H NMR (500 MHz, CDCl_3) δ 4.02 (s, 3H); 7.48 (dd, 1H, $J = 8.2, 4.6$ Hz), 7.60-7.53 (m, 3H), 8.63 (dd, 1H, $J = 8.2, 1.5$ Hz); 8.43 (d, 1H, $J = 1.5$ Hz); 8.63 (dd, 1H, $J = 4.6, 1.5$ Hz); 9.63 (d, 1H, $J = 1.5$ Hz); Anal. Calcd for $\text{C}_{16}\text{H}_{11}\text{N}_3\text{O}_2\text{S}$ (309.35): C, 62.12; H, 3.58; N, 13.58. Found: C, 62.17; H, 3.24; N, 13.97.

Synthesis of derivatives 15. General procedure. To a suspension of **5** (1.0 mmol) in toluene/MeOH (20:1) (5 mL) was added the corresponding heteroaryl stannane (1.0 mmol) and $\text{Pd}(\text{PPh}_3)_4$ (12 mg, 0.01 mmol) under argon. The mixture was heated to reflux temperature. The work-up of the reaction mixture is detailed below.

3-Methoxycarbonyl-5-(pyridin-2-yl)pyrimido[1,6-*a*]indole (15a). After 14 h reaction time the reaction mixture was filtered through Celite, the Celite washed with CH_2Cl_2 and the organic phase evaporated under reduced pressure. The residue was treated with Et_2O , filtered and the precipitate purified by silica gel flash chromatography in CH_2Cl_2 :acetone (9:1). Compound **15a** (23%) was isolated as a yellow solid. Mp 256-257 °C; IR (KBr) ν_{max} 3415, 1726, 1585, 1459, 1431, 1371, 1222 cm^{-1} ; ^1H NMR (500 MHz, CDCl_3) δ 3.89 (s, 3H); 7.33 (d, 1H, $J = 4.6$ Hz); 7.63-7.58 (m, 2H); 7.97-7.95 (m, 2H); 8.37-8.33 (m, 1H); 8.58-8.53 (m, 1H); 8.78 (d, 1H, $J = 4.9$ Hz); 8.86 (d, 1H, $J = 1.4$ Hz); 9.86 (d, 1H, $J = 1.4$ Hz); ^{13}C NMR (75 MHz CDCl_3) δ 52.8; 110.9; 111.4; 118.4; 121.0; 121.1; 122.9; 123.8; 125.9; 128.5; 129.2; 131.7; 135.6; 136.7; 138.4; 150.2; 153.3; 165.3; MS (EI) m/z (relative intensity) 303

(M⁺, 100); 244 (29). Anal. Calcd for C₁₈H₁₃N₃O₂ (303.32): C, 71.29; H, 4.33; N, 13.85. Found: C, 71.28; H, 4.12; N, 13.85.

3-Methoxycarbonyl-5-(phenylethynyl)pyrimido[1,6-a]indole (15d) After 14 h reaction time the reaction mixture was cooled and the resulting precipitate was filtered off and washed with EtOAc. The solid was dissolved in CH₂Cl₂ and the organic solution washed with water, dried over Na₂SO₄ and filtered. The filtrate was filtered through Celite, the Celite washed with CH₂Cl₂ and the organic phase evaporated under reduced pressure to give **15d** (27%) as an orange solid. Mp 255-256 °C; IR (KBr) ν_{max} 2190, 1724, 1636, 1457, 1436, 1366, 1232 cm⁻¹; ¹H NMR (500 MHz, CDCl₃) δ 4.04 (s, 3H); 7.46-7.34 (m, 3H); 7.68-7.50 (m, 4H); 8.10-8.02 (m, 2H); 8.48 (d, 1H, *J* = 1.5 Hz); 9.20 (d, 1H, *J* = 1.5 Hz). Anal. Calcd for C₂₁H₁₄N₂O₂ (326.36): C, 77.29; H, 4.32; N, 8.58. Found: C, 77.32; H, 4.39; N, 8.80.

Synthesis of derivatives 16. General procedure. To a suspension of **6** (1.0 mmol) in toluene/MeOH (20:1) (5 mL) was added the corresponding heteroaryl stannane (1.0 mmol) and Pd(PPh₃)₄ (12 mg, 0.01 mmol) under argon. The mixture was heated under reflux for 14 h

and then allowed to cool down to room temperature. The reaction mixture was filtered through Celite, the Celite washed with CH₂Cl₂ and the organic phase evaporated under reduced pressure. The residue was purified by silica gel flash chromatography to afford pure compounds **16**.

7-Methoxycarbonyl-5-(pyridin-2-yl)pyrido[3',2':4,5]pyrrolo[1,2-c]pyrimidine (16a).

Chromatography in CH₂Cl₂:acetone (95:5) afforded **16a** (42%) as a yellow solid. Mp 257-258 °C; IR (KBr) ν_{max} 3450, 1715, 1575, 1459, 1431, 1370, 1225 cm⁻¹; ¹H NMR (500 MHz, CDCl₃) δ 4.03 (s, 3H); 7.26 (ddd, 1H, *J* = 7.9, 4.9, 1.3 Hz); 7.57 (dd, 1H, *J* = 8.2, 4.6 Hz); 7.77 (d, 1H, *J* = 7.9 Hz); 7.85 (td, 1H, *J* = 7.9, 1.8 Hz); 8.63 (dd, 1H, *J* = 4.6, 1.5 Hz); 8.72 (dd, 1H, *J* = 8.2, 1.5 Hz); 8.81 (d, 1H, *J* = 4.9 Hz); 8.94 (d, 1H, *J* = 1.6 Hz); 9.69 (d, 1H, *J* = 1.6 Hz). Anal. Calcd for C₁₇H₁₂N₄O₂ (304.31): C, 67.10; H, 3.97; N, 18.41. Found: C, 67.18; H, 3.77; N, 18.36.

5-(2-Methylthiopyrimidin-4-yl)-7-methoxycarbonylpyrido[3',2':4,5]pyrrolo[1,2-c]pyrimidine (16c). Chromatography in CH₂Cl₂:acetone (95:5) afforded **16c** (63%) as a yellow solid. Mp 235-236 °C; IR (KBr) ν_{max} 3453, 1712, 1556, 1437, 1365, 1336, 1181 cm⁻¹; ¹H NMR (500 MHz, CDCl₃) δ 2.73 (s, 3H); 4.04 (s, 3H); 7.41 (d, 1H, *J* = 5.4 Hz); 7.60 (dd, 1H, *J* = 8.2, 4.4 Hz); 8.57 (d, 1H, *J* = 5.4 Hz); 8.72-8.62 (m, 2H); 9.23 (d, 1H, *J* = 1.5 Hz); 9.73 (d, 1H, *J* = 1.5 Hz); ¹³C NMR (75 MHz CDCl₃) δ 14.4; 53.2; 105.7; 113.0; 118.3; 120.8; 122.4; 129.9; 133.7; 138.5; 138.8; 141.4; 145.1; 157.3; 160.2; 164.7; 173.2; MS (EI) *m/z* (relative

intensity) 351 (M^+ , 100); 291 (75); 246 (41). Anal. Calcd for $C_{17}H_{13}N_5O_2S$ (351.39): C, 58.11; H, 3.73; N, 19.93. Found: C, 58.14; H, 3.71; N, 19.94.

7-Methoxycarbonyl-5-(phenylethynyl)pyrido[3',2':4,5]pyrrolo[1,2-c]pyrimidine (16d).

Chromatography in CH_2Cl_2 :acetone (98:2) afforded **16d** (38%) as a orange solid. Mp 218-220 °C; IR (KBr) ν_{max} 3422, 2923, 2197, 1717, 1458, 1434, 1365, 1290, 1233 cm^{-1} ; 1H NMR (500 MHz, $CDCl_3$) δ 4.03 (s, 3H); 7.50-7.38 (m, 3H); 7.69-7.53 (m, 3H); 8.35 (dd, 1H, $J = 7.9, 1.6$ Hz); 8.47 (s, 1H); 8.61 (dd, 1H, $J = 4.7, 1.6$ Hz); 9.59 (s, 1H). Anal. Calcd for $C_{20}H_{13}N_3O_2$ (327.35): C, 73.39; H, 4.00; N, 12.84. Found: C, 73.35; H, 4.12; N, 12.81.