Supporting information for

Synthesis of Substituted 2-Cyanoarylboronic Esters

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The relative position of the boron on the aromatic ring of the cyanoarylboronic esters were unambiguously assigned using similar techniques and comparing with the data reported by Chotana *et al.* on comparable cyanoarylboronic esters: *J. Am. Chem. Soc.* **2005**, 127, 10539 – Supporting Information, pages S4-S14.

General procedure for the lithiation/*in-situ* trapping on substituted benzonitriles – synthesis of cyanoarylboronic esters:

In a 100 mL dry Schlenk-flask under N₂, 2,2,6,6-tetramethylpiperidine (2.03 mL, 12 mmol) was dissolved in dry THF (25 mL) and cooled to -10 °C before *n*-BuLi (1.6 M in hexanes, 7.5 mL, 12 mmol) was added over 2 min. The mixture was stirred for 10 min. before cooling to -78 °C. At -78 °C B(O^{*i*}Pr)₃ (3.23 mL, 14 mmol) was added over 2 min. and stirred for 5 min. at -78 °C before the benzonitrile (10 mmol) dissolved in dry THF (10 mL) was added drop wise over 5 min. The reaction was left in the coolingbath overnight, slowly reaching room temperature. At rt, the reaction was quenched with glacial acetic acid (0.8 mL, 14 mmol) followed by addition of 2,2-dimethyl-1,3-propanediol (1.56 g, 15 mmol). The mixture was stirred for 1 h. at room temperature, then transferred to a separating funnel using CH₂Cl₂ (75 mL) and the organic phase was washed with aqueous KH₂PO₄ (10 W/V%) (4 x 60 mL). The combined water phase was back extracted once with CH₂Cl₂ (15 mL) and the combined organic phase was dried over MgSO₄, and the solvents were evaporated to give the crude cyanoarylboronic ester.

Para-substituted benzonitriles (Table 1):

2-(5,5-dimethyl-1,3,2-dioxaborinan-2-yl)-4-methoxybenzonitrile (**2a**) and

3-(5,5-dimethyl-1,3,2-dioxaborinan-2-yl)-4-methoxybenzonitrile (**3a**):

Isolated as a 30:70 inseparable mixture in 96% yield and 95% purity. **2a**: $^1\text{H-NMR}$ (300 MHz, CDCl_3): 7.59 (d, 1H, $J = 8.5$ Hz), 7.35 (d, 1H, $J = 2.7$ Hz), 6.95 (dd, 1H, $J = 8.5, 2.7$ Hz), 3.85 (s, 3H), 3.81 (s, 4H). **3a**: $^1\text{H-NMR}$ (300 MHz, CDCl_3): 7.91 (d, 1H, $J = 2.2$ Hz), 7.62 (dd, 1H, $J = 8.4, 2.2$ Hz), 6.88 (d, 1H, $J = 8.4$ Hz), 3.87 (s, 3H), 3.77 (s, 4H), 1.04 (s, 6H).

2-(5,5-dimethyl-1,3,2-dioxaborinan-2-yl)-4-trifluoromethylbenzonitrile (**2b**):

Isolated as a yellow solid in 99% yield and 99% purity. $^1\text{H-NMR}$ (300 MHz, CDCl_3): 8.05 (dd, 1H, $J = 7.7, 0.5$ Hz), 7.81 (dd, 1H, $J = 8.2, 0.5$ Hz), 7.65 (dd, 1H, $J = 8.2, 7.7$ Hz), 3.84 (s, 4H), 1.06 (s, 6H). $^{13}\text{C-NMR}$ (75 MHz, CDCl_3): δ 137.8, 133.0 (q, $J_{\text{C-F}} = 31.6$ Hz), 131.0, 127.4 (q, $J_{\text{C-F}} = 4.9$ Hz), 122.5 (q, $J_{\text{C-F}} = 273.5$ Hz), 115.1, 113.4, 72.4, 31.6, 21.5. Anal. Calcd. for $\text{C}_{13}\text{H}_3\text{BF}_3\text{NO}_2$: C 55.16, H 4.63, N 4.95, found: C 55.10, H 4.81, N 5.15. Mp. (EtOAc/PE) 98-100 °C.

2-(5,5-dimethyl-1,3,2-dioxaborinan-2-yl)-4-fluorobenzonitrile (**2c**) and

3-(5,5-dimethyl-1,3,2-dioxaborinan-2-yl)-4-fluorobenzonitrile (**3c**):

Isolated in 94% yield and 95% purity as a 40:60 inseparable mixture of isomers. **2c**: $^1\text{H-NMR}$ (300 MHz, CDCl_3): 7.70–7.63 (1H, m), 7.55 (1H, dd, $J = 8.8, 2.6$ Hz), 7.17 (1H, dt, $J = 8.8, 2.6$ Hz), 3.82 (4H, s), 1.04 (6H, s). **3c**: $^1\text{H-NMR}$ (300 MHz, CDCl_3): 8.05 (1H, dd, $J = 5.3, 2.6$ Hz), 7.70–7.63 (1H, m), 7.09, (1H, t, $J = 8.8$ Hz), 3.80 (4H, s), 1.04 (6H, s).

2-(5,5-dimethyl-1,3,2-dioxaborinan-2-yl)-4-chlorobenzonitrile (**2d**) and

3-(5,5-dimethyl-1,3,2-dioxaborinan-2-yl)-4-chlorobenzonitrile (**3d**):

Isolated as a light yellow solid in 99% yield and 95% purity as a 93:7 mixture of isomers. Analytically pure **2d** was obtained via recrystallization from EtOAc/PE. **2d**: $^1\text{H-NMR}$ (300 MHz, CDCl_3): 7.85 (d, 1H, $J = 1.7$ Hz), 7.60 (d, 1H, $J = 8.8$ Hz), 7.44 (dd, 1H, $J = 8.8, 1.7$ Hz), 3.82 (s, 4H), 1.05 (s, 6H). $^{13}\text{C-NMR}$ (75 MHz, CDCl_3): δ 138.5, 135.3, 134.8, 130.7, 118.8, 114.7, 72.4, 31.7, 21.6. Anal. Calcd. for $\text{C}_{12}\text{H}_{13}\text{BClNO}_2$: C 57.76, H 5.25, N 5.62, found: C 57.48, H 5.18, N 5.68. Mp. (EtOAc/PE): 142-144 °C.

2-(5,5-dimethyl-1,3,2-dioxaborinan-2-yl)-4-bromobenzonitrile (**2e**) and

3-(5,5-dimethyl-1,3,2-dioxaborinan-2-yl)-4-bromobenzonitrile (**3e**):

Isolated as a light yellow solid in 98% yield and 99% purity as a 90:10 mixture of isomers. Analytically pure **2e** was obtained via recrystallization from EtOAc/PE. **2e**: $^1\text{H-NMR}$ (300 MHz,

CDCl₃): 8.01 (d, 1H, *J* = 2.0 Hz), 7.61 (dd, 1H, *J* = 8.1, 2.0 Hz), 7.51 (d, 1H, *J* = 8.4 Hz), 3.82 (s, 4H), 1.04 (s, 6H). ¹³C-NMR (75 MHz, CDCl₃): 138.1, 134.7, 133.6, 127.1, 118.8, 115.1, 72.6, 31.9, 21.9. Anal. Calcd. For C₁₂H₁₃BBBrNO₂: C 49.03, H 4.46, N 4.76, found: C 49.28 H 4.60 N 4.77. Mp.(EtOAc/PE) 141-143 °C.

Meta-substituted benzonitriles (Table 2):

2-(5,5-dimethyl-1,3,2-dioxaborinan-2-yl)-3-methoxybenzonitrile (**6a**):

Isolated as a yellow solid in 93% yield and 99% purity. ¹H-NMR (300 MHz, CDCl₃): δ 7.37 (dd, 1H, *J*= 8.2, 7.6 Hz), 7.21 (dd, 1H, *J*= 7.6, 0.7 Hz), 7.02 (d, 1H, *J*= 8.2, 0.7), 3.83 (s, 4H), 3.82 (s, 3H), 1.12 (s, 6H). ¹³C-NMR (75 MHz, CDCl₃): δ 161.6, 130.5, 124.3, 119.0, 115.8, 113.9, 72.5, 55.7, 31.8, 21.7. Anal. calcd. for C₁₃H₁₆BNO₃: C 63.71, H 6.58, N 5.72, found: C 63.86, H 6.32, N 5.68. Mp.(EtOAc/PE) 98-100 °C.

2-(5,5-dimethyl-1,3,2-dioxaborinan-2-yl)-5-trifluoromethylbenzonitrile (**7b**):

Isolated as a yellow solid in 98% yield and 99% purity. ¹H-NMR (300 MHz, CDCl₃): δ 8.03 (d, 1H, *J*= 8.2 Hz), 7.92 (d, *J*= 1.7 Hz), 7.78 (dd, *J*= 8.2, 1.7 Hz), 3.85 (s, 4H), 1.06 (s, 6H). ¹³C-NMR (75 MHz, CDCl₃): δ 135.7, 132.6 (q, *J*_{C-F}= 33.7 Hz), 129.9 (q, *J*_{C-F}= 4.2 Hz), 127.7 (q, *J*_{C-F}= 4.2 Hz), 122.9 (q, *J*_{C-F}= 272.4 Hz), 118.1, 117.3, 72.5, 31.9, 21.8. Anal Calcd. for C₁₃H₃BF₃NO₂ C 55.16, H 4.63, N 4.95, found: C 54.98, H 4.69, N 4.99. Mp. (EtOAc/PE) 86-88 °C.

2-(5,5-dimethyl-1,3,2-dioxaborinan-2-yl)-3-fluorobenzonitrile (**6c**):

Isolated as a light yellow solid in 96% yield and 95% purity. Analytically pure **6c** was obtained via recrystallization from EtOAc/PE. ¹H-NMR (300 MHz, CDCl₃): 7.48-7.40 (m, 2H), 7.26-7.19 (m, 1H), 3.84 (s, 4H), 1.10 (s, 6H). ¹³C-NMR (75 MHz, CDCl₃): δ 164.8 (d, *J*_{C-F}= 249 Hz), 131.6 (d, *J*_{C-F}= 9 Hz), 129.0 (d, *J*_{C-F}= 4 Hz), 119.6 (d, *J*_{C-F}= 25 Hz), 118.2 (d, *J*_{C-F}= 4 Hz), 117.3 (d, *J*_{C-F}= 11 Hz), 72.6, 31.8, 21.7. Anal. Calcd. for C₁₂H₁₃BFNO₂: C 61.85, H 5.62, N 6.01, found: C 61.64, H 5.43, 5.87. Mp. (EtOAc/PE) 73-76 °C.

2-(5,5-dimethyl-1,3,2-dioxaborinan-2-yl)-3-chlorobenzonitrile (**6d**):

Judged from GC-MS and ¹H-NMR of a reaction aliquot, **5d** is fully converted to **6d**. However, this compound is not stable and could not be isolated and characterized as a single entity. ¹H-NMR (300 MHz, CDCl₃): 7.54-7.49 (m, 2H), 7.35 (dd, *J* = 8.4, 7.4 Hz), 3.85 (s, 3H), 1.14 (s, 6H).

2-(5,5-dimethyl-1,3,2-dioxaborinan-2-yl)-3-bromobenzonitrile (**6e**):

Isolated as a light brown solid in 96% yield and 95% purity. Analytically pure **6e** was obtained via recrystallization from EtOAc/PE. $^1\text{H-NMR}$ (300 MHz, CDCl_3): 7.69 (dd, 1H, $J = 8.0, 1.1$ Hz), 7.56 (dd, 1H, $J = 7.7, 1.1$ Hz), 7.26 (dd, 1H, $J = 8.0, 7.7$ Hz), 3.85 (s, 4H), 1.14 (s, 6H). $^{13}\text{C-NMR}$ (75 MHz, CDCl_3): 135.7, 130.7, 130.2, 126.1, 118.1, 116.6, 72.6, 31.9, 22.0. Anal. Calcd. For $\text{C}_{12}\text{H}_{13}\text{BBrNO}_2$: C 49.03, H 4.46, N 4.76, found: C 49.30 H 4.59 N 4.83. Mp.(EtOAc/PE) 109-112 °C.

Ortho-substituted benzonitriles (Table 3):2-(5,5-dimethyl-1,3,2-dioxaborinan-2-yl)-6-methoxybenzonitrile (**9a**):

Isolated as a yellow solid in 96% yield and 99% purity. $^1\text{H-NMR}$ (300 MHz, CDCl_3): 7.37 (dd, 1H, $J = 8.2, 7.6$ Hz), 7.21 (dd, 1H, $J = 7.6, 0.7$ Hz), 7.02 (d, 1H, $J = 8.2, 0.7$), 3.83 (s, 4H), 3.82 (s, 3H), 1.12 (s, 6H). $^{13}\text{C-NMR}$ (75 MHz, CDCl_3): 161.6, 130.5, 124.3, 119.0, 115.8, 113.9, 72.5, 55.7, 31.8, 21.7. Anal. calcd. for $\text{C}_{13}\text{H}_{16}\text{BNO}_3$: C 63.71, H 6.58, N 5.72, found: C 63.86, H 6.32, N 5.68. Mp.(EtOAc/PE) 98-100 °C.

2-(5,5-dimethyl-1,3,2-dioxaborinan-2-yl)-6-trifluoromethylbenzonitrile (**9b**):

Isolated as a yellow solid in 99% yield and 99% purity. $^1\text{H-NMR}$ (300 MHz, CDCl_3): 8.05 (dd, 1H, $J = 7.7, 0.5$ Hz), 7.81 (dd, 1H, $J = 8.2, 0.5$ Hz), 7.65 (dd, 1H, $J = 8.2, 7.7$ Hz), 3.84 (s, 4H), 1.06 (s, 6H). $^{13}\text{C-NMR}$ (75 MHz, CDCl_3): 137.8, 133.0 (q, $J_{\text{C-F}} = 31.6$ Hz), 131.0, 127.4 (q, $J_{\text{C-F}} = 4.9$ Hz), 122.5 (q, $J_{\text{C-F}} = 273.5$ Hz), 115.1, 113.4, 72.4, 31.6, 21.5. Anal Calcd. for $\text{C}_{13}\text{H}_3\text{BF}_3\text{NO}_2$: C 55.16, H 4.63, N 4.95, found: C 55.10, H 4.81, N 5.15. Mp. (EtOAc/PE) 98-100 °C.

2-(5,5-dimethyl-1,3,2-dioxaborinan-2-yl)-6-fluorobenzonitrile (**9c**) and3-(5,5-dimethyl-1,3,2-dioxaborinan-2-yl)-2-fluorobenzonitrile (**10c**):

Isolated in 99% yield and 99% purity as a 40:60 inseparable mixture of isomeres. **9c**: $^1\text{H-NMR}$ (300 MHz, CDCl_3): 7.68–7.60 (1H, m), 7.53 (1H, td, $J = 7.9, 5.3$ Hz) 7.24–7.17 (1H, m), 3.82 (4H, s), 1.04 (6H, s). **10c**: $^1\text{H-NMR}$ (300 MHz, CDCl_3): 7.97–7.91 (1H, m), 7.68–7.60 (1H, m), 7.24–7.17 (1H, m), 3.79 (4H, s), 1.04 (6H, s).

2-chloro-6-(5,5-dimethyl-1,3,2-dioxaborinan-2-yl)benzonitrile (**9d**):

Isolated as a light yellow solid in 95% yield and >99% purity as a 95:5 mixture of **9d** and **10d**. Analytically pure **9d** was obtained via recrystallization from EtOAc/PE. **9d**: $^1\text{H-NMR}$ (300 MHz, CDCl_3): 7.77 (dd, 1H, $J = 7.3, 1.4$ Hz), 7.55 (dd, 1H, $J = 8.1, 1.4$ Hz), 7.47 (dd, 1H, $J = 8.1, 7.3$ Hz), 3.83 (4H, s), 1.05 (6H, s). $^{13}\text{C-NMR}$ (75 MHz, CDCl_3): 138.0, 133.0, 132.3, 131.4,

116.8, 116.1, 72.4, 31.6, 21.6. Anal. Calcd for $C_{12}H_{13}BClNO_2$: C 57.76, H 5.25, N 5.62, found: C 57.52, H 5.45, N 5.45. Mp(EtOAc/PE) 84-85 °C.

2-Bromo-6-(5,5-dimethyl-1,3,2-dioxaborinan-2-yl)benzonitrile (**9e**):

Isolated as a yellow solid in 97% yield and 99% purity as a 98:2 mixture of **9e** and **10e**. Analytically pure **9d** was obtained via recrystallization from EtOAc/PE. 1H -NMR (300 MHz, $CDCl_3$): 7.79 (dd, 1H, $J = 7.3, 1.4$ Hz), 7.69 (dd, 1H, $J = 8.0, 1.4$ Hz), 7.37 (dd, 1H, $J = 8.0, 7.3$ Hz), 3.81 (s, 4H), 1.04 (s, 6H). ^{13}C -NMR (75 MHz, $CDCl_3$): 134.3, 133.3, 132.2, 126.7, 118.8, 117.1, 72.4, 31.7, 21.7. Anal. Calcd. For $C_{12}H_{13}BBrNO_2$: C 49.03, H 4.46, N 4.76, found: C 49.02 H 4.61 N 4.71. Mp.(EtOAc/PE) 77-79 °C.

Synthesis of phenanthridine (Scheme 1):

2-(4'-Chloro-2'-fluorophenyl)-5-trifluoromethylbenzonitrile (**11**):

A 50 mL schlenk-flask was charged with 2-(5,5-Dimethyl-[1,3,2]dioxaborinan-2-yl)-5-(trifluoromethyl)benzonitrile (**7b**) (1.42 g, 5.0 mmol), 2-bromo-4-chloro-1-fluoro-benzene (1.26 g, 6.0 mmol), $Pd(OAc)_2$ (56 mg, 0.25 mmol), PPh_3 (197 mg, 0.75 mmol), and $K_3PO_4 \cdot nH_2O$ (2.12 g, 10 mmol). The flask was evacuated and filled with N_2 , dioxane (25 mL) was added and the reaction was stirred at 80 °C for 16 hours. The mixture was cooled to rt. before water (25 mL) was added and the mixture was extracted with EtOAc (3 x 20 mL). The combined organic phase was dried ($MgSO_4$) and evaporated to give the crude product which was purified by flash chromatography (EtOAc/PE 1:10) to give 1.09 g (67%) **11** as a white solid. Mp.(EtOAc/PE) 63-64 °C. 1H -NMR (300 MHz, $CDCl_3$): 8.02 (s, 1H), 7.89 (d, 1H, $J = 8.06$ Hz), 7.62 (d, 1H, $J = 8.06$ Hz), 7.40-7.30 (m, 1H), 7.30-7.24 (m, 2H). ^{13}C -NMR (75 MHz, $CDCl_3$): 158.9 (d, $J_{C-F} = 250$ Hz), 141.7, 136.7 (d, $J_{C-F} = 10$ Hz), 131.5 (d, $J_{C-F} = 2$ Hz), 131.1 (d, $J_{C-F} = 34$ Hz), 130.1 (q, $J_{C-F} = 4$ Hz), 129.2 (q, $J_{C-F} = 4$ Hz), 125.1 (d, $J_{C-F} = 4$ Hz), 122.9 (d, $J_{C-F} = 15$ Hz), 122.6 (q, $J_{C-F} = 270$ Hz), 117.2, 116.9, 116.3, 113.6. Anal. Calcd for $C_{14}H_6ClF_4N$: C 56.12, H 2.02, N 4.67, found: C 55.92, H 2.22, N 4.61.

3-Chloro-6-morpholin-4-yl-8-trifluoromethylphenanthridine (**12**):

In a dry 20 mL schlenk-flask under N_2 , morpholine (131 mg, 1.5 mmol) was dissolved in dry THF (3 mL) and cooled to -10 °C. n -BuLi (1.6 M in hexanes, 1.45 mmol) was added and stirred at -10 °C for 5 min. The mixture was cooled to -78 °C before **11** (299 mg, 1.0 mmol) dissolved in THF (2 mL) was added drop wise over 5 min. Stirring was continued for 20 min. before the mixture was allowed to reach rt. Stirred for additional 10 min before quenching with sat. NH_4Cl (aq) (10 mL). The water phase was extracted with EtOAc (3 x 10 mL), dried over $MgSO_4$, and evaporated to give the crude product which was purified by flash chromatography

to give 271 mg (74%) **12** as a white solid. Mp.(EtOAc/PE) 152-154 °C. ^1H -NMR (300 MHz, CDCl_3): 8.59 (d, 1H, J = 8.8 Hz), 8.43 (s, 1H), 8.34 (d, 1H, J = 8.8 Hz), 7.98 (m, 2H), 7.49 (dd, 1H, J = 8.8, 2.3 Hz), 4.00 (t, 4H, J = 4.5 Hz), 3.52 (t, 4H, J = 4.5 Hz). ^{13}C -NMR (75 MHz, CDCl_3): 159.9, 144.8, 136.5, 135.3, 128.4 (q, $J_{\text{C-F}}$ = 33 Hz), 127.7, 126.1 (q, $J_{\text{C-F}}$ = 3 Hz), 125.4, 123.7 (q, $J_{\text{C-F}}$ = 272 Hz), 123.6 (q, $J_{\text{C-F}}$ = 4 Hz), 123.4, 123.2, 120.2, 119.7, 66.7, 51.6. Anal. Calcd. for $\text{C}_{18}\text{H}_{14}\text{ClF}_3\text{N}_2\text{O}$: C 58.95, H 3.85, N 7.64, found: C 58.66 H 3.80, N 7.50.

S7

2b

S8

2d

S9

2e

S10

6a

S11

7b

S12

6c

6e

S13

5.0

0.0

S14

9a

S15

9b

S16

9d

S17

9e

S18

11

8.50

8.00

7.50

7.00

6.50

S19

12