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Pd-Catalyzed Sequential Arylation of 7-azaindoles: Aggregate Induced Emission of Tetra-aryl 7-azaindoles

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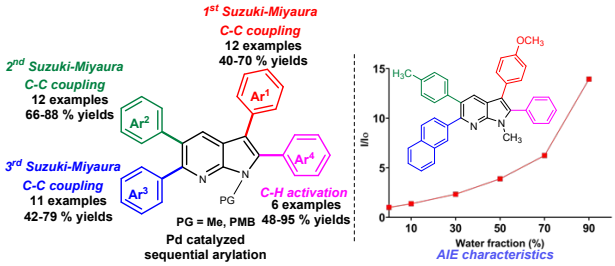


ABSTRACT

Pd-catalyzed synthesis of multi-aryl 7-azaindoles using sequential arylation of 5-bromo-6-chloro-3-iodo-1-methyl-1*H*-pyrrolo[2,3-*b*] pyridine is established. Four diverse aryl groups are installed in chemo-selective fashion providing a general method to synthesize sterically encumbered compounds and extended 7-azaindoles in 48 – 95% yield. Three selective sequential arylations at C-3, C-5 and C-6 via Suzuki-Miyaura cross-coupling followed by direct C-2 arylation using Pd catalyst and AgOTf as an additive are highlights of the present work. Interestingly the tetra-aryl 7-azaindoles showed aggregate induced emission (AIE) making it potentially useful as fluorophores in OLEDs, sensors and bio-imaging tools.

Keywords: Tetra-aryl 7-azaindoles, Sequential arylation, Sequential Suzuki-Miyaura cross-coupling, Aggregate induced emission.

1. INTRODUCTION

Sequential arylation of arenes/ hetero-arenes is widely known to furnish favourable optoelectronic[1] and medicinal properties[2] into designed molecules. Such diversity-oriented synthesis has the potential to build a vast molecular library to investigate structure-activity properties. Transition metal catalyzed arylation on arene/ heteroarene templates in a predictable manner[3] has garnered attention to obtain diverse π-conjugated organic molecules.[4]

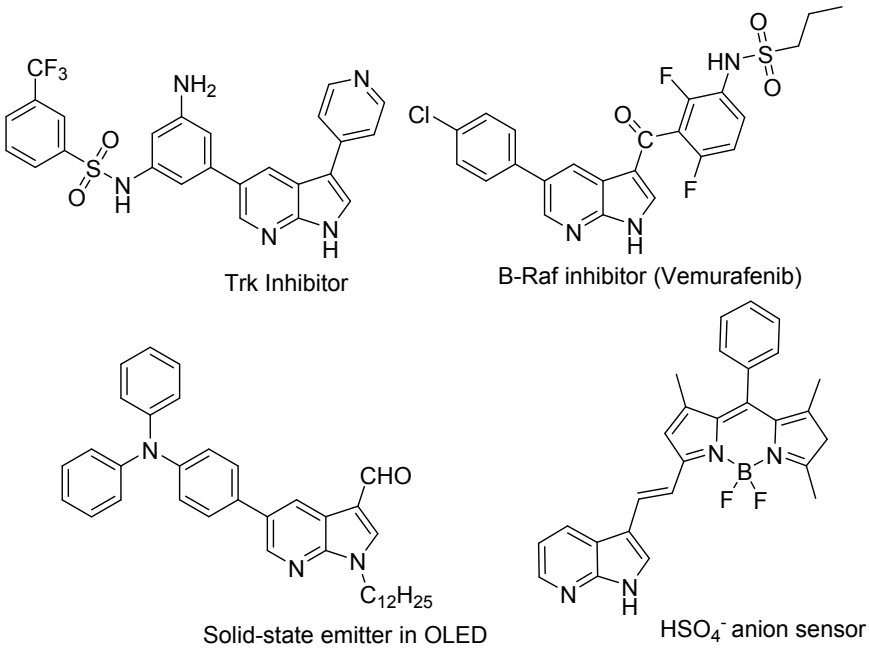
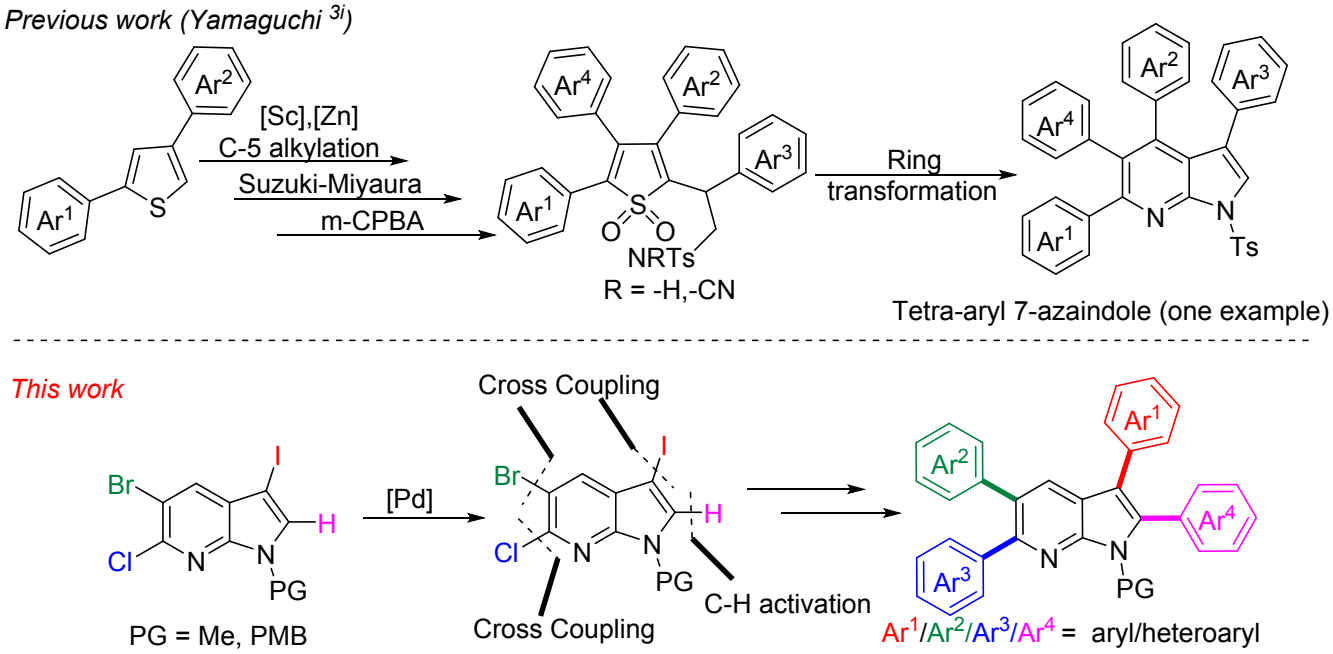


Figure 1. Biological and Material applications of substituted 7-azaindole[6,7,8]

A review in 2014 showcased various *N*-heterocycles where substitution pattern plays an astounding role in its biological activity.[5] Significant substitutions on fused pyrrole and pyridine ring has put 7-azaindoles on a list of privileged scaffolds in drug discovery (Figure 1).[6] Proton donor and acceptor functionality present on these moieties help in studying its photophysical properties.[7] Recently C-arylated 7-azaindoles have exhibited desirable applications in organic light emitting molecules and sensors (Figure 1).[8] Propeller-like organic frameworks having peripheral phenyl/aryl groups with different electronic characteristics show aggregation induced emission (AIE) phenomena attracting material chemists all over the globe.[9] In view of the above, it remains imperative to explore the synthesis of multi-aryl 7-azaindole derivatives for applications in medicinal and material sciences.

Directed metalation, halogen/magnesium exchange and sulfoxide/magnesium exchange reactions were developed by Knochel *et. al.* and recently elaborated by Snieckus *et. al.* to selectively introduce various functional groups on the 7-azaindole ring.[10] Selective mono/di-arylations at different positions of 7-azaindoles is normally achieved by de-novo approaches and metal catalyzed cross-coupling of 7-azaindoles reporting very few examples with heteroaryl substrates.[11] Das *et. al.* synthesized C-2, C-3 and C-5 tri-aryl 7-azaindoles sequentially, requiring pre-functionalization at an intermediate step.[3c] Adhering to a de-novo approach, Yamaguchi *et. al.* have synthesized tetra-aryl 7-azaindole and hepta-aryl indoles (Scheme 1). Their method required alkylation, Suzuki-Miyaura cross-coupling \and S-oxidation of synthesized C-2, C-6 di-aryl thiophenes, followed by ring transformation of substituted thiophene-S,S′-dioxides.[3i] In contrast to the previous reports we envisaged to synthesize

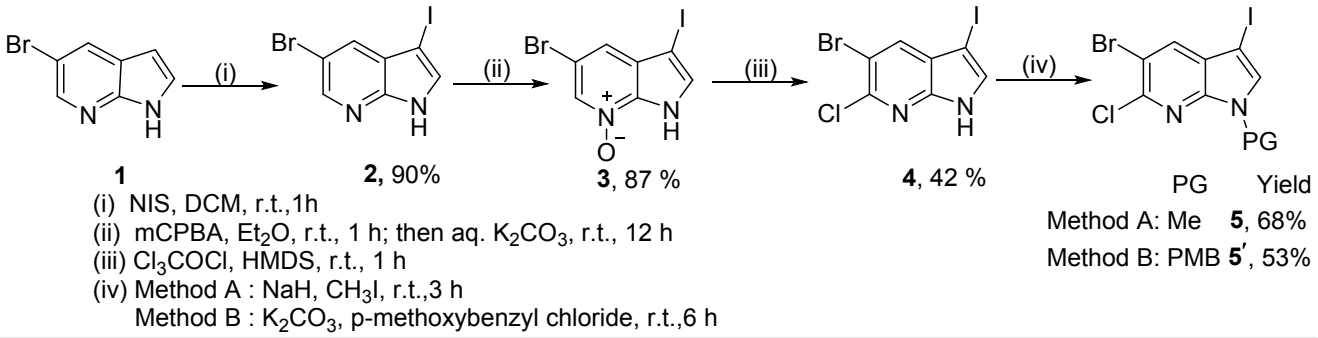


Scheme 1. Synthetic Approaches for tetra-aryl 7-azaindoles

designed tetra-aryl 7-azaindoles from tri-halogenated 7-azaindole (**5**), a common synthetic template. Such sequential routes to synthesize tetra-aryl 7-azaindoles are rare in literature. We endeavoured to synthesize structurally diverse and sterically hindered tetra-aryl derivatives via four step Pd catalyzed C-C cross-coupling protocol. Three sequential and selective Suzuki-Miyaura cross-coupling reactions with aryl/hetero-aryl substrates followed by C-2 arylations are studied. Structural features of these tetra-

aryl derivatives led us to investigate its aggregate induced emission profile of C-arylated 7-azaindoles, broadening its scope in materials research.

2. RESULTS AND DISCUSSIONS

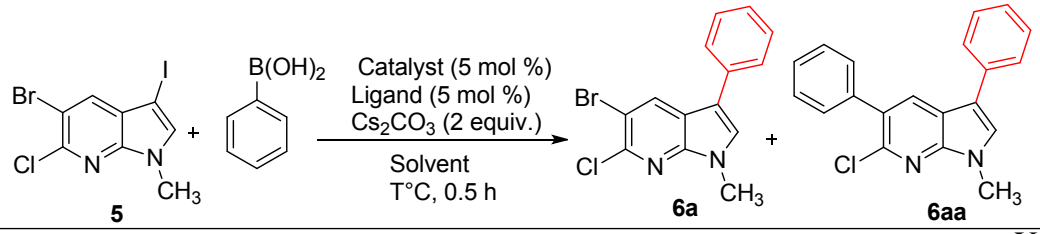


Scheme 2. Synthetic route for **5** and **5′**

The precursor 5-bromo-6-chloro-3-iodo-1-methyl-1*H*-pyrrolo[2,3-*b*]pyridine (**5/5′**) was synthesized (Scheme 2) starting from 5-bromo-7-azaindole (**1**) via iodination at C-3 position (**2**), *N*-oxidation of azine ring (**3**), chlorination at electrophilic C-6 position (**4**) and finally N-H protection by methyl (**5**) or p-methoxy benzyl (**5′**). This tri-halogenated derivative forms a template to investigate sequential Suzuki-Miyaura arylation and subsequent C-2 arylation. C-3 selective mono-arylation was first studied due to the preferential oxidative-addition towards Ar-I >Ar-Br >Ar-Cl [12]. The Suzuki-Miyaura coupling of **5** with phenyl boronic acid (1.0 equiv.) was studied using Pd_2dba_3 (5 mol%), XPhos (5 mol%) as catalytic system and base Cs_2CO_3 (2 equiv.) in toluene: ethanol (1:1) at 60°C. Stirring for 15 min the reaction yielded 42% of the desired C-3 mono-arylated product, **6a** and undesired 51% di-aryl product (**6aa**), thus revealing non-selectivity between –iodo and –bromo groups towards the Pd catalyzed oxidative addition (Table 1, entry 1). In order to make this method selective we conducted various experiments, screening different reaction parameters. SPhos was used as ligand and **6a** was isolated in 44% yield and **6aa** in 42% yield (entry 2). The reaction yielded 49% of **6a** and 9% of **6aa** at room temperature (entry 3). Changing the catalyst to $Pd(OAc)_2$ yielded higher quantity of di-aryl **6aa** (59%) as compared to **6a** (25%) at r.t. (entry 4) and $Pd(PPh_3)_4$ yielded a low 18% of **6a** and 30% of **6aa** at r.t. (entry 5). Bidentate 1,1'-bis(diphenylphosphino) ferrocene (dppf, 5 mol%) was used

as ligand instead of SPhos to obtain desired **6a** in 62% yield (entry 6), whereas, **6aa** was not synthesized.

Table 1. Optimization table for selective Suzuki-Miyaura arylation at C-3 position of 5[a]



Entry	Catalyst	Ligand	Solvent (v:v)	T °C	Yield (%)[b] **6a : 6aa**
1	Pd_2dba_3	XPhos	Toluene : Ethanol (1:1)	60 °C	42 : 51
2	Pd_2dba_3	SPhos	Toluene : Ethanol (1:1)	60 °C	44 : 42
3	Pd_2dba_3	SPhos	Toluene : Ethanol (1:1)	r.t.	49 : 9
4	$Pd(OAc)_2$	SPhos	Toluene : Ethanol (1:1)	r.t.	25 : 59
5	$Pd(PPh_3)_4$	SPhos	Toluene : Ethanol (1:1)	r.t.	18 : 30
6	Pd_2dba_3	dppf	Toluene : Ethanol (1:1)	r.t.	62 : 0
7	Pd_2dba_3	dppf	Dioxane : Water (3:1)	r.t.	47 : 0
8	Pd_2dba_3	dppf	THF : Water (1:1)	r.t.	23 : 0
9	**Pd_2dba_3**	**dppf**	**Toluene:Ethanol (1:1)**	**60 °C**	**74 : 0**
10[c]	Pd_2dba_3	dppf	Toluene:Ethanol (1:1)	60 °C	35 : 0
11	Pd_2dba_3	dppf	Toluene : Ethanol (3:1)	60 °C	30 : 0
12[d]	Pd_2dba_3	dppf	Toluene : Ethanol (1:1)	60 °C	72 : 9
13	Pd_2dba_3	dppe	Toluene : Ethanol (1:1)	60 °C	54 : 0
14[e]	Pd_2dba_3	$P(OC_6H_5)_3$	Toluene : Ethanol (1:1)	60 °C	76 : 0
15	Pd_2dba_3	DPEPhos	Toluene : Ethanol (1:1)	60 °C	56 : 0
16	Pd_2dba_3	XantPhos	Toluene : Ethanol (1:1)	60 °C	50 : 0

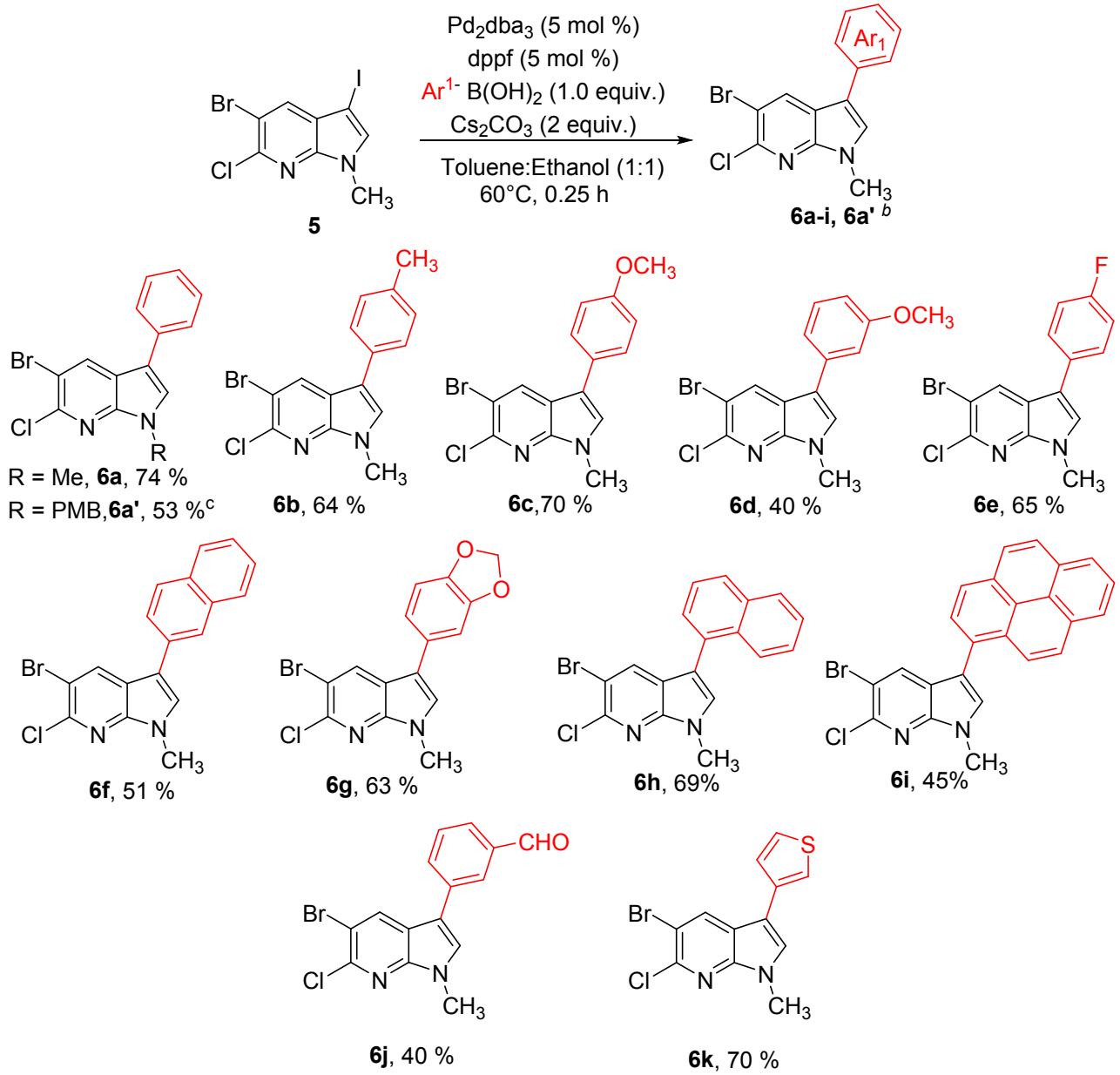
[a]Reaction conditions: **5** (0.046 g, 0.124 mmol, 1 equiv.), Phenyl boronic acid (0.015 g,0.124 mmol, 1 equiv.), Catalyst (5 mol %,0.0062 mmol), Ligand (5 mol %, 0.0062 mmol), Cs_2CO_3 (0.248 mmol,2 equiv.), Solvent (2 mL, 0.062 M), T °C, 0.25 h. [b]Isolated yields of **6a** and **6aa**.[c] Pd_2dba_3 (5 mol %), dppf (10 mol%) [d] Pd_2dba_3 (10 mol %), dppf (10 mol %). [e] Reaction time = 0.5 h.

Examining different solvent systems gave unfavourable results i.e. Dioxane: water (3:1) gave 47% of **6a** (entry 7) and THF: water (1:1) produced a low 23% yield for **6a** (entry 8). Fortunately, at 60 °C, the reaction yielded 74% of **6a** with eliminated non-selectivity (entry 9). The usage of a different Pd:L ratio also was significant as 5 mol% Pd_2dba_3 and 10 mol% dppf gave **6a** in 35% yield (entry 10). It was also observed that decreasing the ethanol in solvent mixture i.e. 3:1 toluene: ethanol decreased the yield of **6a** (entry 11). Increasing the catalyst loading and ligand to 10 mol% was of no advantage as di-aryl **6aa** was formed in 9% yield (entry 12). Further various electron poor ligands were used for optimizations. 1,2-Bis(diphenylphosphino)ethane as ligand provided **6a** in 54% yield (entry 13) and triphenyl phosphite a monodentate highly π-acidic ligand was used instead of dppf and **6a** was isolated in 76% yield (entry 14) with reaction time being 30 min. DPEPhos and XantPhos were tested as ligand in above

conditions giving **6a** in 56% and 50% yield (entry 15-16). After careful optimization reactions, Pd_2dba_3 (5 mol%), dppf (5 mol%) was chosen as the best catalytic system for C-3 SMC (Suzuki-Miyauara cross-coupling) in toluene: ethanol (1:1) stirring at 60 °C for 15 min.

Substrate scope for C-3 SMC arylation with different aryl/hetero-aryl boronic acids (Scheme 3) was explored. The phenyl group was incorporated in 74% yield (**6a**) and moderate yield of 53% for p-methoxy benzyl *N*-protected 7-azaindole (**6a′**). Electron donating 4-methyl (**6b**) and 4-methoxy

Scheme 3. Scope for C-3 selective mono-arylation of 5. [a]

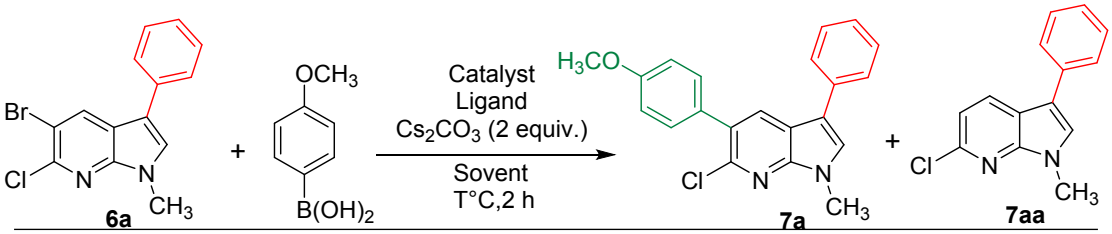


[a] Reaction conditions: **5** (0.186 g, 0.5 mmol, 1 equiv.), Ar^1-$B(OH)_2$ (0.5 mmol, 1 equiv.), Pd_2dba_3 (0.025 mmol, 5 mol%), dppf (0.025 mmol, 5 mol%), Cs_2CO_3 (1 mmol, 2 equiv.), Toluene: ethanol (1:1, 5 mL, 0.1 M), T = 60 °C, 0.25 h. [b] Isolated yields of **6a-6i, 6a′**; [c] PMB: p-methoxy benzyl, reaction was done at rt.

substituted (**6c**) phenyls were installed at C-3 in 64% and 70% yields respectively whereas meta-substituted methoxy phenyl boronic acids gave **6d** in moderate yield of 40%. Electron-withdrawing 4-fluoro substituted boronic acids coupled with **5** to form **6e** in 65% yield which shows that C-3 SMC arylation is efficient for electronically different boronic acids (**6a-c, 6e)**. Boronic acids containing bicyclic naphtyl and benzo[*d*][1,3]dioxole formed corresponding products **6f** and **6g** in 51% and 63% yields respectively and sterically hindered 1-naphthyl (**6h**) and 1-pyrene (**6i)** groups were incorporated in good yields (45-69%). In addition to it, present methodology showed efficient coupling of 3-thienyl boronic acid yielding 70% of **6j** and tolerance towards formyl functional group as exemplified by **6k.**

The C-5 arylation was next investigated for C-3 mono-aryl derivatives (Table 2). Studies commenced with SMC reaction between **6a** and 4-methoxy phenyl boronic acid (1 equiv.) using Pd_2dba_3 (5 mol%), dppf (10 mol%) and Cs_2CO_3 (2 equiv.) in toluene: ethanol mixture (1:1). The reaction was stirred at 60 °C for 2 h to yield di-aryl product (**7a**) in 37% yield but a major obstacle was proto-dehalogenation[13] at C-5 position producing **7aa** in 47% yield (Table 2, entry 1). Increasing the temperature and catalyst loading was of no advantage producing undesirable **7aa** in 59% and 39% yield respectively (entries 2-3). Solvent ratio was changed to use a less polar toluene: ethanol (3:1) giving **7a** in 20% yields and comparatively lower yield of **7aa** (13%) with conversion being 38% (entry 4). Moving forward we adopted 1,4-Dioxane: water (3:1) as solvent system favourably yielding 31% **7a** and 0% **7aa** but reactant conversion is 56% (entry 5). Further, decreasing the water fraction, an enhanced yield for **7a** (84%) was observed along with complete conversion of reactant (entry 6). 1,4-dioxane: water (8:1) was also examined as solvent but **7a** was isolated in 46% yield (entry 7). Finally, combination of 10 mol% Pd_2dba_3 with 20 mol% dppf, 2 equiv. Cs_2CO_3 stirred in 1, 4-dioxane: water (6:1) for 2h at 100 °C was found to be the preferred reaction conditions for C-5 SMC arylation. With the optimized protocol in hand, the substrate scope for C-5 SMC arylation was evaluated (Scheme 4). Boronic acids with electron donating and electron withdrawing substituents led to the formation of desired product **7a** and **7b** in 84% and 75% yields respectively where PMB protected **7a′** was synthesized in 82% yield. The electronic features of the azole ring did not deter the efficiency of cross-

Table 2. Optimization table for selective Suzuki-Miyaura arylation at C-5 position of 6a[a]



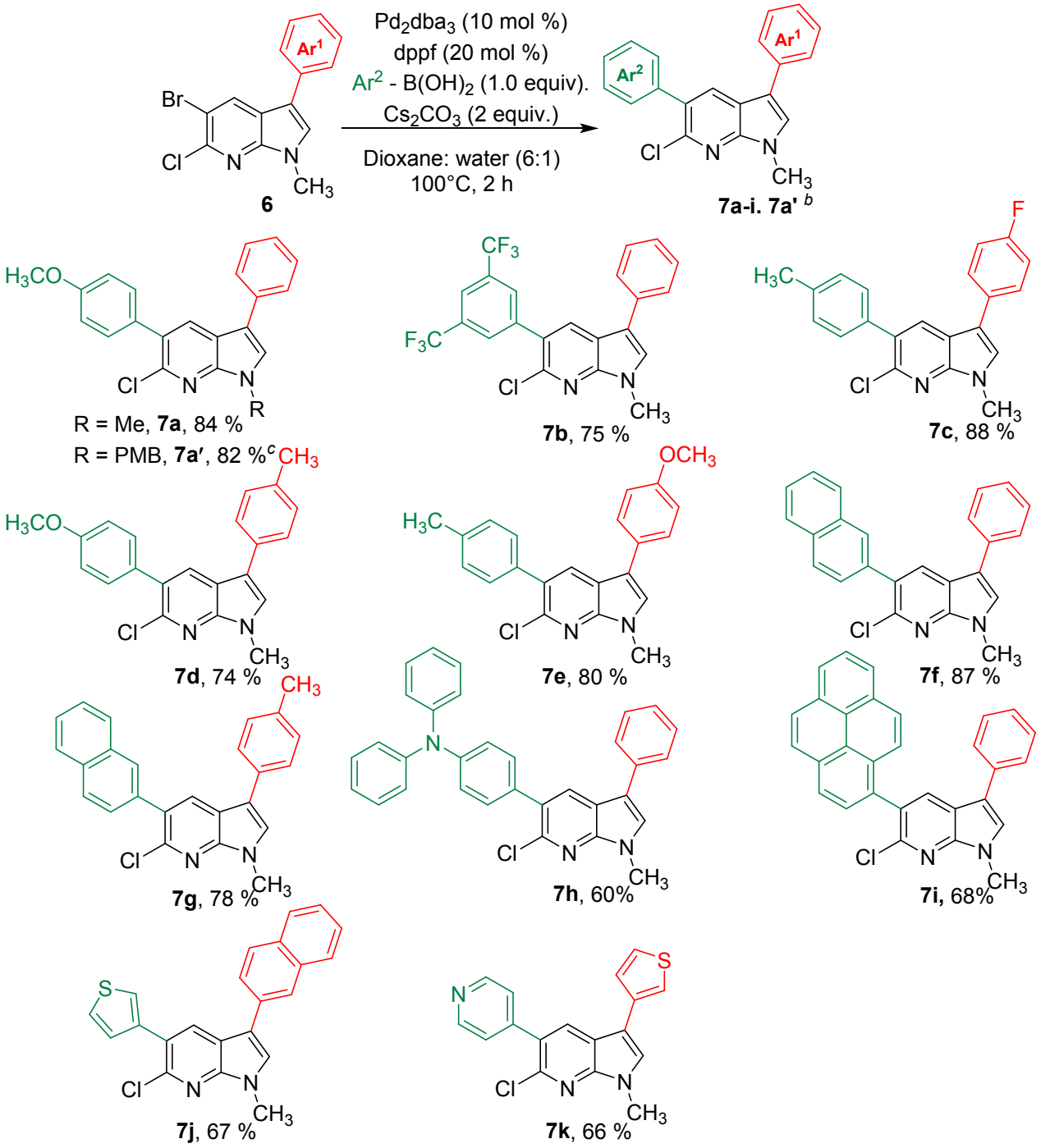
Entry	Pd_2dba_3 (mol%)	dppf (mol%)	T (°C)	Solvent (v:v)	Yield (%)[b] **7a :7aa**
1	5	10	60	Toluene :Ethanol (1:1)	37:47
2	5	10	80	Toluene :Ethanol (1:1)	33:59
3	10	20	100	Toluene :Ethanol (1:1)	20:39
4[c]	10	20	100	Toluene :Ethanol (3:1)	20:13
5[d]	10	20	100	1,4-Dioxane : Water (3:1)	31:0
6	**10**	**20**	**100**	**1,4 Dioxane:Water (6:1)**	**84:0**
7	10	20	100	1,4-Dioxane : Water (8:1)	46:0

[a]Reaction conditions: **6a** (0.05 g, .155 mmol), catalyst, ligand, 4-methoxy phenyl boronic acid (0.024 g, 0.155 mmol, 1 equiv.), Pd_2dba_3, dppf, Cs_2CO_3 (0.31 mmol, 2 equiv.), Solvent (2 mL, 0.077 M), T °C. [b]Isolated yields of **7a** and **7aa**. [c]Conv. = 38%. [d]Conv. = 56%

coupling at the C-5 position as observed for **7c-d**. Importantly introducing bicyclic naphthyl ring at C-5 gave the corresponding products **7f** and **7g** in 87% and 78% respectively. Triphenyl amine which act as excellent hole transporting agent[8e] can be incorporated at 5th position in 60% yield (**7h**). Highly conjugated and sterically hindered 1-pyrene was installed at 5th position in 68% yield (**7i**). The essential feature of this step is highlighted by the two hetero-aryl coupling reactions seen for the products **7j** and **7k**, where 3-thiophene and 4-pyridyl groups are installed in a sequential manner in 67% and 66% yields respectively.

A third SMC arylation was achieved at C-6 position of the sterically hindered azine of 3,5-substituted di-aryl 7-azaindoles (**7a-7i,7a′**). Building on the conditions of C-5 SMC arylation, different ligands were screened and solvent ratio was changed. The C-6 SMC arylation was achieved on 6-chloro-5-(4-methoxyphenyl)-1-methyl-3-phenyl-1*H*-pyrrolo[2,3-*b*]pyridine (**7a**) with 4-methyl phenyl boronic

Scheme 4. Scope for selective C-5 arylation of mono-aryl 7-azaindoles, 6[a]

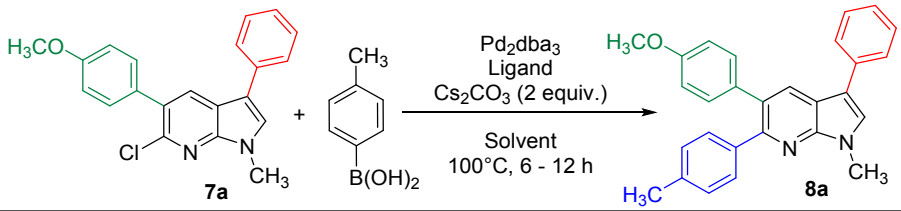


Reaction conditions: **5** (0.161 g, 0.5 mmol, 1 equiv.), Ar^2-$B(OH)_2$ (0.5 mmol, 1 equiv.), Pd_2dba_3 (0.05 mmol, 10 mol%), dppf (0.1 mmol, 20 mol%), Cs_2CO_3 (1 mmol, 2 equiv.), Dioxane: water (6:1, 5 mL), T = 100 °C, 2 h. [b]Isolated yields of **7a-7i**,**7a'**.[c] PMB = p-methoxy benzyl.

acid (1.1 equiv.) using Pd_2dba_3 (10 mol%), SPhos (20 mol%), Cs_2CO_3 (2 equiv.) in 1,4-dioxane: water (3:1 ratio, 2 mL) at 100 °C to yield 79% of **8a** (Table 3). The crystal structure of **8a** was confirmed by X-ray crystallography (see Figure S5, Table S2 in ESI).

The different aryl and hetero-aryl groups were integrated at the 6th position on the electron poor azine of 7-azaindole in moderate to good yields (Scheme 5). The presence of electron donating and electron withdrawing aryl substituent at C-5 position produced corresponding products **8a**, *N*-PMB

Table 3. Optimization table for Suzuki-Miyaura arylation at C-6 position of 7a[a]



Entry	Ligand	Solvent (v:v)	Yield (%)[b]
1[c]	dppf	1,4-Dioxane : Water (6 :1)	n.r.
2	dppf	1,4-Dioxane : Water (6 :1)	n.r.
3	XantPhos	1,4-Dioxane : Water (6 :1)	14
4	PPh_3	1,4-Dioxane : Water (6 :1)	n.r.
5	**SPhos**	**1,4-Dioxane : Water (3 :1)**	**79**

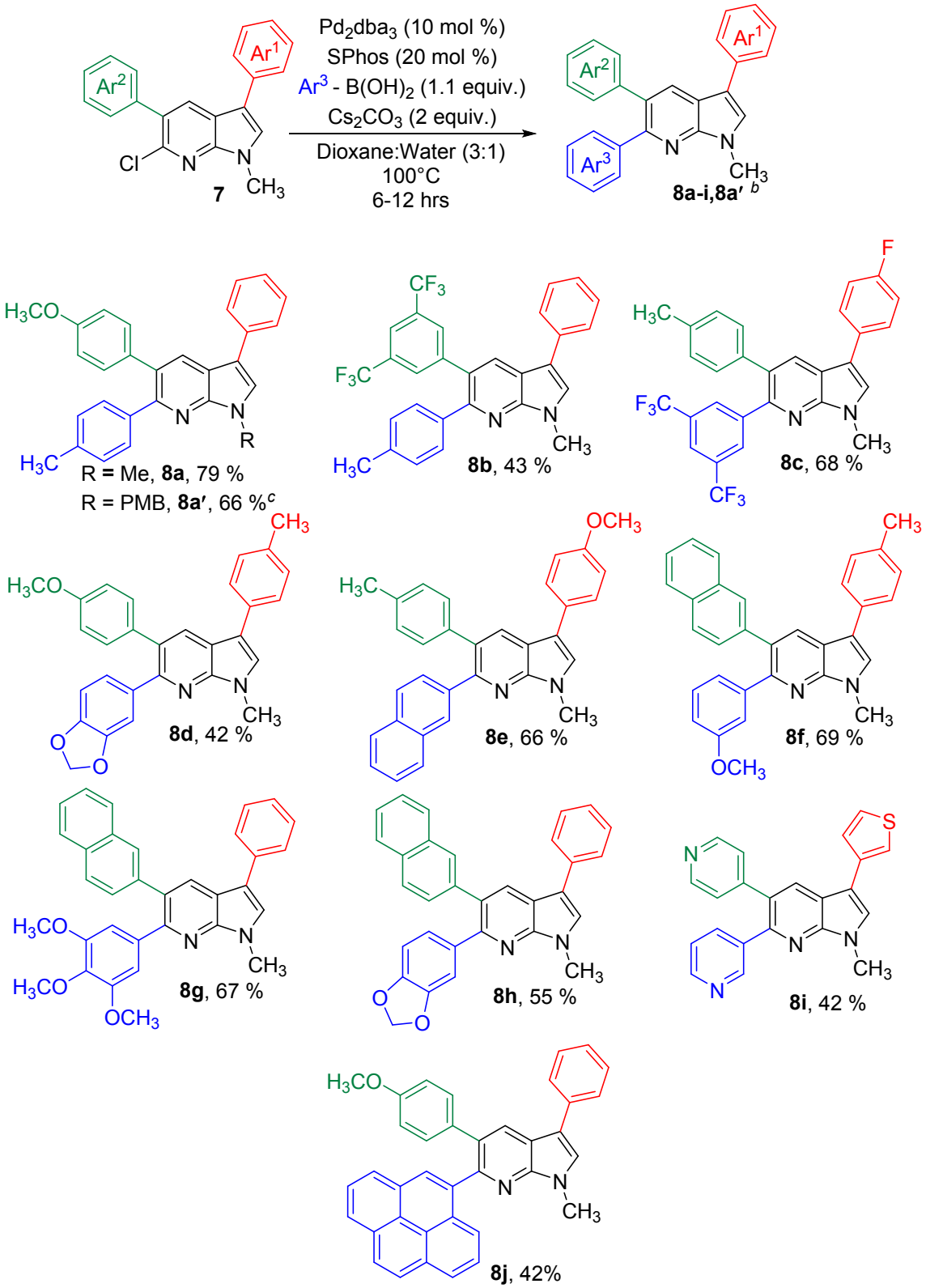
[a]Reaction conditions : **7a** (0.05g, 0.143 mmol,1 equiv.), 4-methyl Phenyl boronic acid (0.021 g, 0.157 mmol,1.1 equiv.), Pd_2dba_3 (0.0143 mmol, 10 mol%), Ligand (0.0286 mmol, 20 mol %), Cs_2CO_3 (0.286 mmol, 2 equiv.), Solvent (2 mL, 0.072 M), 100 °C, 6- 12 h. [b]Isolated yields of **8a**,[c]5 mol% Pd_2dba_3 and 10 mol% dppf.

protected **8a′** and **8b** in 79%, 66% and 43% yields respectively. The use of electron deficient 3,5-bis(trifluoromethyl) substituted phenyl boronic acid as cross-coupling partner generated **8c** in good yields (68%) but bicyclic benzo[*d*][1,3]dioxole and naphthyl boronic acids procured the desired products in 42-69% (**8d-e**). The feasibility of this reaction in substrates where C-5 position was preinstalled with a 3-naphthyl substituent was examined and noted that **8f-h** were synthesized in 55-69% yield successfully. The compound **8i**, having 3-thienyl, 4-pyridyl and 3-pyridyl groups was obtained in moderate yield showing the robustness of sequential hetero-aryl coupling using this method. Compound **8j** is formed in moderate yield of 42% showing the C6 coupling of sterically hindered 1-pyrene group.

Lastly, C-2 arylation of sterically crowded C-3, C-5, C-6 tri-aryl 7-azaindole was achieved through C-H activation. Literature provides a number of methods for arylation of indoles[14] with much emphasis on C-2 arylations[15] and role of silver salts has been elucidated.[16] $Pd(OAc)_2$ (5 mol%), 4-nitro

benzoic acid (1.5 equiv.), AgOAc (1 equiv.) was used for C-C coupling between 4-iodoanisole (2 equiv.)

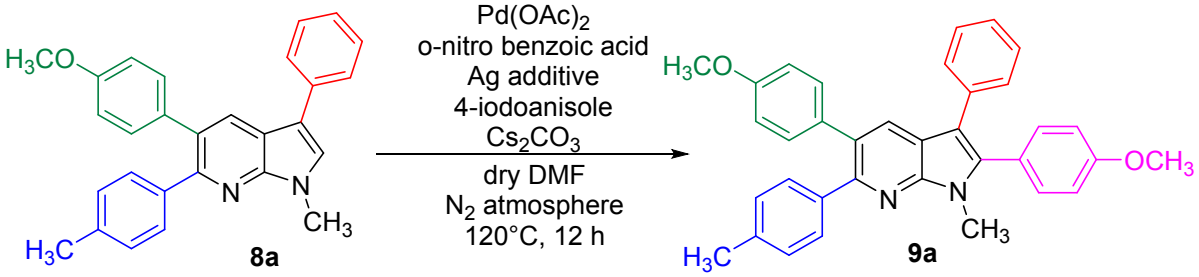
Scheme 5. Scope for synthesis of C-3, C-5, C-6 substituted tri-aryl 7-azaindoles [a]



[a]Reaction conditions: 7 (0.105 g, 0.3 mmol,1 equiv.), Ar^3-$B(OH)_2$ (0.33 mmol, 1.1 equiv.), Pd_2dba_3 (0.03 mmol, 10 mol%), SPhos (0.06 mmol, 20 mol%), Cs_2CO_3 (0.6 mmol, 2 equiv.) in 5 mL 1,4-Dioxane: Water (3:1), 100 °C, 6 -12 h. [b]Isolated yields of **8a-8i, 8a′**.[c] PMB = p-methoxy benzyl group.

and 1 equiv. of **8a**. The reaction mixture was stirred in dry DMF at 120°C under N_2 atm. but no reactant conversion took place (Table 4, entry 1). Increased catalyst load did not work (entry 2) but changing the silver salt to silver oxide gave **9a** in 14% yield, showing 66% conversion of **8a**

Table 4. Optimization table for C-2 arylation of 8a [a]



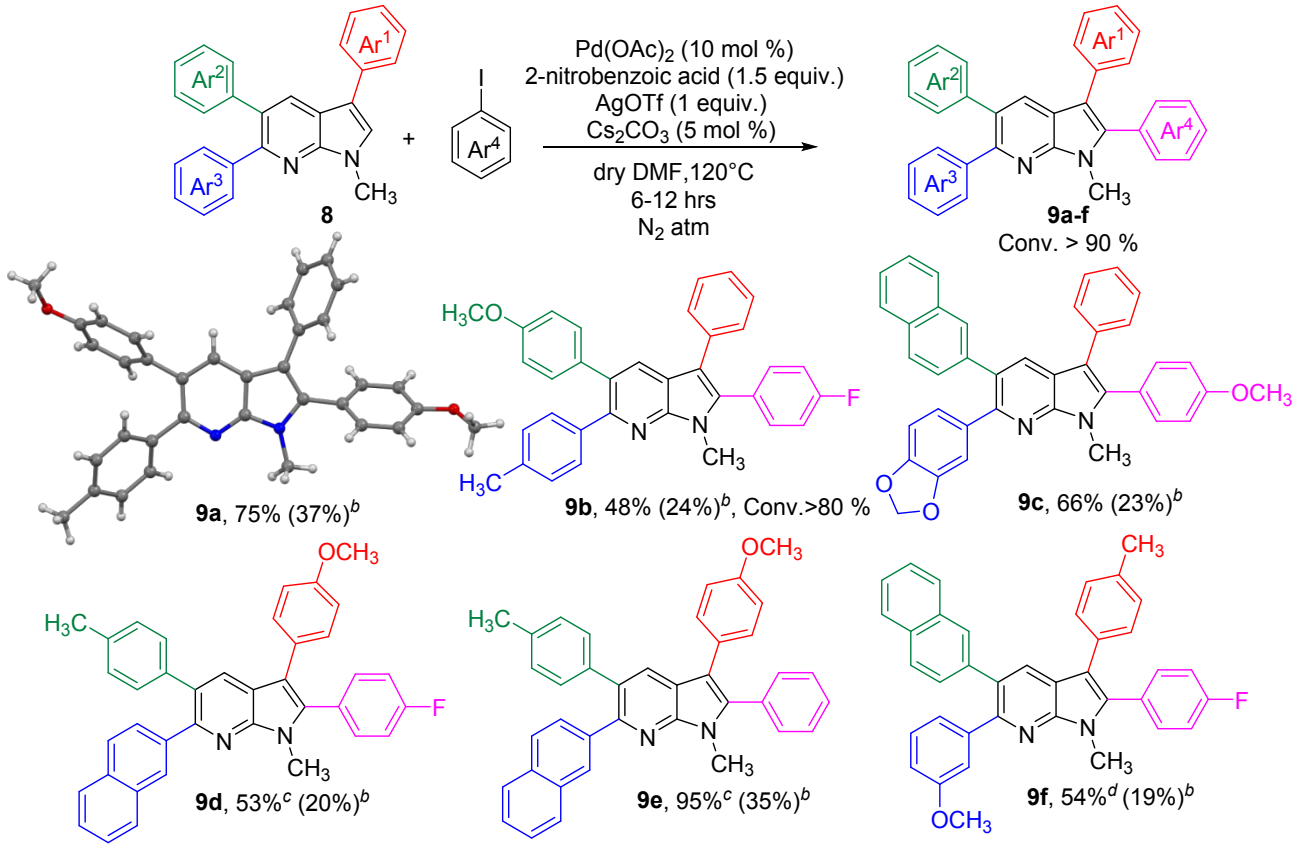
Entry	$Pd(OAc)_2$ (mol%)	Ag additive	R-Ph-COOH (R =)	Base (5 mol%)	Conv. (%)	Yield[b] (%)
1	5	AgOAc	4-NO_2	-	-	n.r
2	10	AgOAc	4-NO_2	-	-	n.r.
3[c]	10	Ag_2O	4-NO_2	-	66	14
4[d]	10	Ag_2O	4-NO_2	-	-	n.r.
5	10	Ag_2O	2-NO_2	-	61	17
6	10	AgOTf	2-NO_2	-	80	65
7	10	AgOTf	2-NO_2	Cs_2CO_3	>90	70
8[e]	10	AgOTf	2-NO_2	Cs_2CO_3	>90	21
9[f]	10	AgOTf	2-NO_2	Cs_2CO_3	>90	75

[a]Reaction conditions: **8a** (0.05 g, 0.125 mmol), 4-iodoanisole, $Pd(OAc)_2$, Ag additive (1 equiv.), nitrobenzoic acid (0.1875 mmol, 1.5 equiv.), Cs_2CO_3, DMF (2 mL, 0.062 M)), T, 12 h, N_2 atmosphere. [b]Isolated yields of **9a**. [c]32 h. [d]PPh_3 (5 mol%), 2 equiv. iodoanisole.[e]T = 80 °C. [f]1.5 equiv. iodoanisole

(entry 3) in 32 h. PPh_3 was added as ligand to increase the yield of **9a** but the substrate remained unchanged (entry 4). A comparatively more electron deficient, 2-nitro benzoic acid was used and a slight increase in the yield of the product (17%, Conversion: 61%, entry 5) was observed. Electron poor AgOTf was utilized in further experiments instead of Ag_2O to get 80% conversion of **8a** leading to an enhanced 65% yield of **9a** (entry 6). Surprisingly, addition of catalytic amount of Cs_2CO_3 further increased the yield of the **9a** to 70% and Conv. > 90% (entry 7). However, decreasing the temperature also decreased the yield (21%, entry 8) suggesting importance of temperature in C-2 arylation of **8a**. We noticed that decreasing the amount of 4-iodo anisole was advantageous to the reaction where 75% yield of **9a** is recorded along with

conversion > 90% (entry 9). The crystal structure of **9a** was confirmed by X-ray crystallography (see Figure S6, Table S3 in Supporting information).

Scheme 6. Scope for synthesis of tetra-aryl 7-azaindoles. [a]



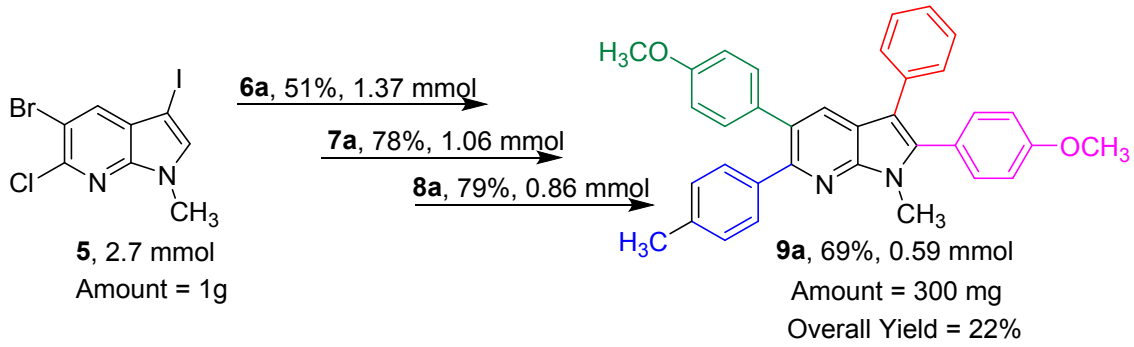
[a]Reaction conditions : **8** (0.05 g, 0.125 mmol, 1 equiv), Ar^4-I (0.1875 mmol, 1.5 equiv.), Pd $(OAc)_2$ (0.0125 mmol, 10 mol%), AgOTf (0.125 mmol, 1 equiv.), 2- nitro benzoic acid (0.1875 mmol, 1.5 equiv.), Cs_2CO_3 (0.00625 mmol, 5 mol%), DMF (2 mL, 0.062 M)), T = 120 °C, 6-12 h, N_2 atmosphere. [b] Overall Yields (4 steps). [c] Second addition of Ar^4-I (1.5 equiv.) and $Pd(OAc)_2$ (10 mol%). [d] Second addition of 1-Fluoro-4-iodobenzene (1.5 equiv).

The synthetic elaboration of methodology was done to get different tetra-arylated products (Scheme 6). Electron donating aryl iodides gave respective tetra-aryl products in good yields as seen for **9a** (75%) and sterically crowded **9c** (66%). On the contrary the electronically poor 1- fluoro-4-iodobenzene yielded corresponding product (**9b**) in 48% yield with conversion > 80%. We hoped changing the electronic character of C-3 substituted azole ring would help in increasing the efficiency for arylation at C-2 position, as observed in **9d-9f**. A second addition of $Pd(OAc)_2$ (10 mol%) and corresponding iodo-arene (1.5 equiv.) was required to drive the

reaction to completion resulting in **9d** (53%) and **9e** (95%). Compound **9f** was synthesized in 54% yield in the presence of an additional 1.5 equiv. of 1-fluoro-4-iodobenzene.

The above methodology was used for large scale synthesis of tetra-aryl 7-azaindole **9a** on > 0.5 mmol scale (Scheme 7). **6a** was produced in 51% yield from 2.7 mmol of **5**. **7a** was synthesized in 78% yield from 1.37 mmol of **7a** and **8a** was procured in 79% yield from 1.1 mmol of **7a.** Finally tetra-aryl 7-azaindole was synthesized in 69% yield from 0.85 mmol **8a** with the overall yield of **9a** being 22%.

Scheme 7: Large scale synthesis of 9a



3. OPTICAL PROPERTIES

The optical properties of synthesized multi-aryl 7-azaindoles (**6a**, **7a**, **8a**, **9a-9f**) were studied in THF using UV-Visible and fluorescence spectroscopy (Table S1, Figure S1 in Supporting information, Table 5). The UV-Vis absorption spectra of six tetra-aryl compounds (**9a-f**) used for the study exhibit absorption bands in the range of 265-279 nm due to π→π* transitions and a broad shoulder peak centred ~ 330 nm is attributed to intramolecular charge transfer (ICT) transitions in 7-azaindoles and due to donor methoxy substituted aryls and acceptor 7-azaindole core. [17]

Table 5. Spectroscopic profile for 9a-9f

Compound	$\lambda_{max\ abs\ (\pi \rightarrow \pi^*)}$ nm	$\lambda_{abs\ (shoulder\ peak)}$ nm	$\lambda_{em\ max}$ nm	Stokes shift nm	Molar absorption coefficient ($Lmol^{-1}cm^{-1}$)
9a	272	332	423	151	25,309
9b	265	333	423	158	68,554
9c	269	334	429	160	62,995
9d	279	332	457	178	90,993
9e	279	332	462	183	48,426
9f	268	331	437	169	54,873

The absorption maxima did not show much variation for the six tetra-aryl compounds but a distinct red shift in wavelength was observed in emission maxima for **9d** and **9e** where substitution by naphthalene

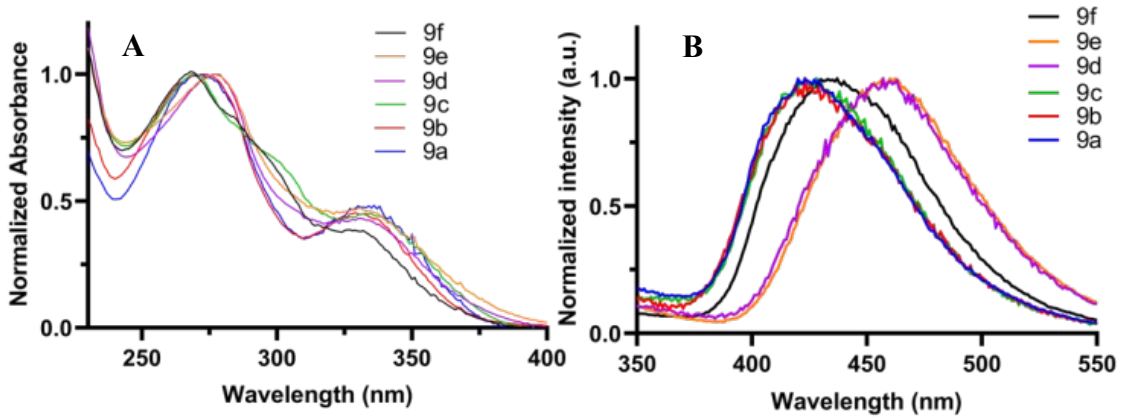


Figure 2. A) Normalized absorption spectra and B) normalized emission spectra for **9a-f**

ring at C-6 position shifted the emission wavelength to 457 (Stokes Shift, $\Delta\lambda$ = 178 nm) and 462 nm (Stokes Shift, $\Delta\lambda$ = 183 nm) respectively (Figure 2).

Intrigued by the structural diversity of the synthesized multi-aryl derivatives and considering 7-azaindole as the molecular rotor, its aggregate induced emission (AIE) characteristics in THF/water were studied as these tetra-aryl derivatives were not soluble in water. First, the effect of arylation on aggregate induced emission was studied for **6a**, **7a**, **8a** and **9a** to validate the effect of arylation on AIE properties (see Figure S1 (C) and (D) in Supporting information)**.** Mono-aryl and di-aryl 7-azaindoles showed quenching of fluorescence upon increase of water fraction whereas tri-aryl derivative, **8a** and tetra-aryl **9a** showed aggregate induced emission. The emission intensity for **8a** was observed to be very low compared to **9a** at 70% water fraction. Compounds **9a-f** showed a marked and gradual increase in fluorescence intensity which was observed as the fraction of water (v/v %) in THF/water is increased for all six tetra-aryl compounds (see Figure S1 in Supporting information). The ~13-fold increase in emission is observed for **9e** at 90% water fraction and is highest when compared to other derivatives (Figure 3). The aggregate formation was corroborated by DLS (Dynamic Light Scattering) measurements where aggregate size equals 106 nm (see Figure S2 in Supporting information). At 95%

water fraction, fluorescence intensity (I/Io) is substantially decreased (I is fluorescence intensity of **9a-9f** in pure THF and THF/water fractions and I_0 is the fluorescence intensity of **9a-9f** in pure THF).

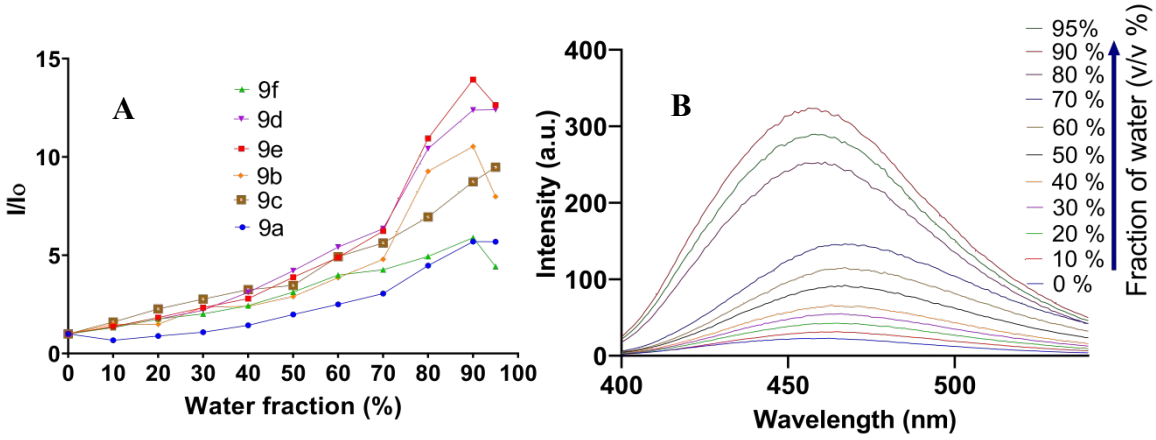


Figure 3. A) Plot of ratio of maximum fluorescence intensity (I/Io) of **9a-9f** in THF *vs.* Fraction of water. B) Variation of emission intensity with increasing water fraction in THF (Concentration: 10^{-6} M, λ_{ex} = 280 nm.).

Further, at 99% we see quenching in fluorescence emission (see Figure S1(B) and S1(D) in Supporting information). The relative quantum yield determined for **9e** in THF and THF/ Water (1:9) was found to be 0.16 and 0.31 respectively (see Figure S3 in Supporting information).

The presence of naphthalene substituent at C-6 position (**9d** and **9e**) shows an increased intensity as compared to other compounds at 90% water fraction suggesting that a highly conjugated ring at C-6 can positively affect the emissive profiles of tetra-aryl 7-azaindoles in aqueous THF. Naphthyl ring at C-5 position did not show such red shift and enhanced emission in AIE emission. Similarly, presence of electron withdrawing 4-fluoro phenyl group at C-2 position (**9b**) has shown an increase in aggregation induced fluorescence intensity as compared to its electron-donating counterpart (**9a**). AIE mechanism was understood by studying the packing of crystal structure of **9a**. The twisted conformation of aryl groups showed torsional angles as 52.4°, 55.6°, 62.2°, 40.5°. No π-π stacking was noted but edge to face weak interactions were prominent. CH···π centre intermolecular interaction between methoxy hydrogens on C-5 aryl and C-3 aryl is observed with a short distance of ~2.52 Å. Various other intermolecular interactions are noted between azine N and C-H (C-3 aryl) as well as C-H (C-5 aryl)/ O atom of methoxy on C-2 aryl (Figure 4). Such weak interactions of aryls and substituents may have

rendered the molecule rigid causing restricted rotation of aryl groups.[18] Presence of hydrogen donating substituent on the aryl ring is therefore seen to aid in the enhancement of aggregate induced emission.

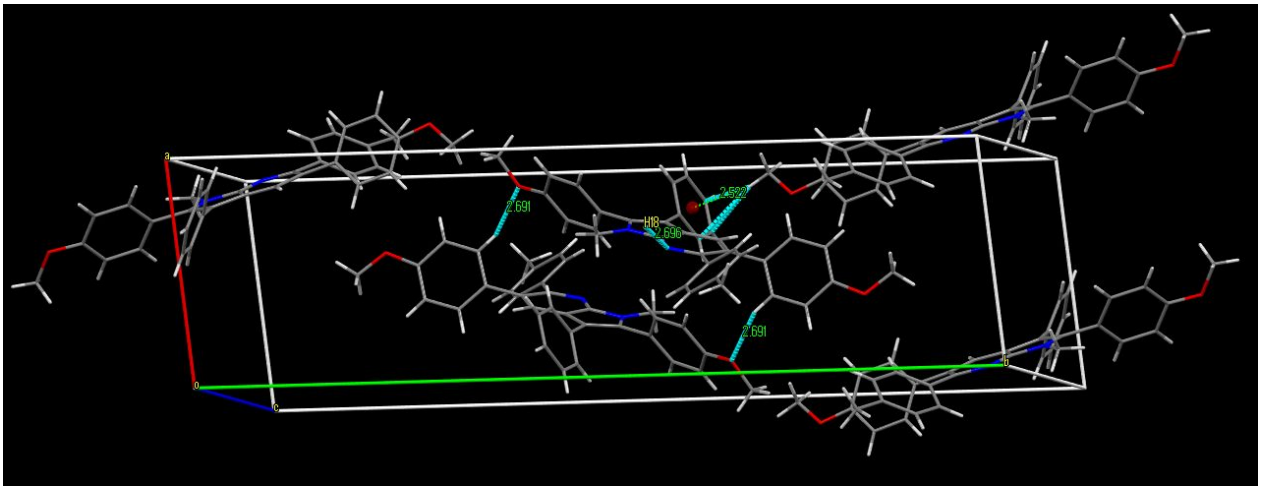


Figure 4. Crystal packing in order to show the various intermolecular interactions (shown in blue).

4. CONCLUSION

In conclusion using novel tri-halogenated 7-azaindole **5,** we strived towards sequential and selective synthesis of C-2, C-3, C-5, C-6 substituted tetra-aryl derivatives. The structural enhancements were done using three selective intermolecular Pd catalyzed Suzuki-Miyaura C-C cross-coupling on C-3, C-5, C-6 and lastly via AgOTf driven Pd catalyzed C-2 arylation. The essential feature of this sequential method is the stability of this reaction to three subsequent arylations, accommodating hetero-aryls and bulky substituents. C-H arylation on a sterically hindered C-2 positions have also been reported. The tri-aryl and tetra-aryl derivatives were synthesized in moderate to excellent yields and **9a-f** are observed to show an enhanced fluorescence emission profile in state of aggregation. This study provides access to synthesize such 7-azaindole derivatives as prospects for material sciences where such extensive conjugation to a ring provides a lever to manipulate a molecule's optoelectronic and photo-physical properties. This work is part of ongoing research in our lab on 7-azaindole derived AIEgens.

5. EXPERIMENTAL SECTION

General Information:

Unless otherwise noted, all reagents were purchased from commercial suppliers and used without purification. All Suzuki-Miyaura reactions were performed in round bottom flask and monitored through thin layer chromatography (TLC silica gel F_{254}, glass plates) and analysed using 254

nm UV light and Iodine, ninhydrin stains. C-2 arylation was performed in a sealed tube under N_2 atmosphere. Melting points were recorded on Büchi Melting Point B-545 instrument and are uncorrected. Organic solutions were concentrated by rotary evaporation on BUCHI-Switzerland; R-210 rotary evaporator and vacuum pump V-700. ^1H and ^{13}C NMR spectra were recorded with BRUKER 500 and Jeol 400 MHz NMR instrument. ^1H NMR and proton decoupled ^{13}C NMR spectra were recorded with a 400 MHz (^1H= 400 MHz and ^{13}C = 101 MHz) or 500 MHz (^1H = 500 MHz and ^{13}C = 126 MHz) spectrometer. Chemical shifts value of ^1H NMR were recorded in parts per million (ppm, δ) relative to tetramethylsilane (TMS, 0.00 ppm) calibrated to the residual peak as an internal standard ($CDCl_3$: δ =7.26 ppm and DMSO: δ= 2.50ppm). Data are written as: Chemical shifts as part per million (ppm, δ), multiplicity (s= singlet, d= doublet, t= triplet, q = quartet, m = multiplet), coupling constants (*J*) were reported in Hertz (Hz) and integration value. Chemical shifts value of proton decoupled $^{13}C\{^1H\}$ NMR were recorded in parts per million (ppm, δ) and calibrated to the residual peak as an internal standard ($CDCl_3$: δ = 77.0 ppm and DMSO: δ= 39.0 ppm). Mass spectra were recorded with Waters SYNAPT G2 with 2D nano ACQUITY System and Agilent LCMS with Quadropole time of flight. UV-Visible spectra were recorded in Cary 300 UV-Vis spectrophotometer and Emission spectra were recorded in Cary eclipse fluorescence spectrophotometer. Relative quantum yield for **9e** was measured using 0.1 M Quinine sulphate in H_2SO_4 as a standard. X-ray reflections were collected on Bruker D8 Quest diffractometer with CMOS detector using MoKα radiation, generated from the micro-focus sealed tube. Cell determination, data collection and data reduction were performed with the help of Bruker APEX2 (version: 2.1-b24) software. Compound **2** and **3** were synthesized by reported procedure in literature.[19, 20]

*5-Bromo-3-iodo-1H-pyrrolo[2,3-b]pyridine 7-oxide (**3**).* In a round bottom flask containing a solution of **2** (10 g, 30.97 mmol, 1 equiv.) in Diethyl ether (100 mL) was added 77% m-chloroperbenzoic acid (77.42 mmol, 13.36 g, 2.5 equiv.) portion wise. The mixture was stirred at room temperature for 1 hour as white precipitate is observed. The reaction was checked for completion using TLC and filtered. The white solid obtained was then dried and added to 200 mL distilled water and to it

saturated solution of potassium carbonate was added till the solution attained a pH of 9-10. The mixture was stirred overnight, filtered and dried. Off-white solid was obtained by filtration and washed with cold distilled water (50 mL) which was used without purification; Off-white solid (**3**, 9.13 g, 87%); m p: decompose > 250°C; ^{1}H NMR (500 MHz, DMSO-d6) δ 13.14 (br, 1H), 8.50 (s, 1H), 7.75 (s, 1H), 7.55 (s, 1H); ^{13}C{^{1}H} NMR (126 MHz, DMSO-d6) δ 138.0, 133.3, 132.7, 127.0, 122.8, 109.0, 56.5. HRMS (ESI) m/z calculated for $C_7H_5BrIN_2O$ $[M+H]^+$ 338.8630, found. 338.8641.

*Synthesis of 5-Bromo-6-chloro-3-iodo-1H-pyrrolo[2,3-b]pyridine (**4**).* **4** was synthesized by a known method in literature.[21] To a dry round bottom flask containing a magnetic bead was added 5-bromo-3-iodo-1*H*-pyrrolo[2,3-*b*]pyridine 7-oxide (3,169 mg, 0.5 mmol, 1 equiv.) in dry THF. The solution was purged with N_2 and inert atmosphere was maintained during the reaction. HMDS (1 equiv.) was added followed by slow addition of trichloroacetyl chloride (2.5 equiv.) with constant stirring on an ice bath. After addition the reaction was stirred at room temperature for 1 h and monitored using TLC. On completion THF was evaporated and mixture was extracted using ethyl acetate and washed with saturated solution of sodium bicarbonate. The organic layer was dried using anhydrous sodium sulphate and evaporated. The residue was purified using column chromatography on silica gel (Ethyl acetate: Hexanes (30: 70)) to obtain a white solid (**4**, 1,404 mg, 42%); mp : decompose > 260 ºC; ^{1}H NMR (500 MHz, DMSO-d_6) δ 12.51 (br, 1H), 8.06 (s, 1H), 7.85 (s, 1H). ^{13}C{^{1}H} NMR (126 MHz, DMSO-d_6) δ 145.9, 142.9, 134.2, 133.6, 123.6,110.2, 54.2. HRMS (ESI) m/z calculated for $C_7H_4BrClIN_2$ $[M+H]^+$ 356.8291, found 356.8300.

*Synthesis of 5-Bromo-6-chloro-3-iodo-1-methyl-1H-pyrrolo[2,3-b]pyridine (**5**).* **5** was synthesized by known methods in literature.[3e] 5-bromo-6-chloro-3-iodo-1*H*-pyrrolo[2,3-*b*]pyridine (**4**, 357 mg, 1 mmol, 1 equiv.) was taken in DMF in a round bottom flask. NaH (1 equiv.) was added to it portion wise at 0ºC - 5ºC and stirred for 30 min under N_2 atmosphere. Methyl iodide (1.1 equiv.) was then added to it and stirred for 3 hours. On completion of reaction as observed in TLC, ethyl acetate was added to the reaction mixture. The organic layer was washed with water and brine followed by drying using anhydrous sodium sulphate. Organic layer was evaporated and compound was purified using

column chromatography (Ethyl acetate: Hexanes (2: 98)) to give white product (**5**, 252 mg, 68%); mp: 174.5-175.6 °C; ^{1}H NMR ($CDCl_3$, 500 MHz) δ 7.94 (s, 1H), 7.27 (s, 1H), 3.85 (s, 3H). ^{13}C{^{1}H} NMR ($CDCl_3$, 126 MHz) δ 145.1, 144.3, 134.7, 134. 6, 123.5, 111.1, 51. 7, 31.9. HRMS (ESI) m/z calculated for $C_8H_6BrClIN_2$ $[M+H]^+$ 370.8447, found 370.8429

*Synthesis of 5-Bromo-6-chloro-3-iodo-1-(4-methoxybenzyl)-1H-pyrrolo[2,3-b]pyridine (**5′**).* ***5′*** was synthesized by known method in literature.[22] A round-bottom flask containing a magnetic bead was charged with 5-bromo-6-chloro-3-iodo-1*H*-pyrrolo [2,3-*b*]pyridine (**4**, 357 mg, 1 mmol, 1 equiv.) in DMF (10 mL), 3 equiv. of K_2CO_3 and p-methoxybenzyl chloride (1.2 equiv.). The reaction was stirred at room temperature for 6 hours under N_2 atmosphere. On completion of reaction, ethyl acetate (50 mL) was added and washed thrice with 50 mL distilled water and 50 mL brine solution. The organic layer was evaporated and purified using column chromatography (Ethyl acetate: hexanes (0.5:99.5)). The product was obtained as white solid (***5′***, 253 mg, 53%); mp: 146.0-147.3 °C, ^{1}H NMR ($CDCl_3$, 500 MHz) δ 7.92 (s, 1H), 7.20-7.19 (m, 3H), 6.85 (d, 2H, J = 8.5 Hz), 5.31 (s, 2H), 3.78 (s, 3H). ^{13}C{^{1}H} NMR (126 MHz, $CDCl_3$) δ 159.5, 144.8, 144.4, 134.6, 133.3, 129.6, 128.1, 123.5, 114.3, 111.3, 55.3, 52.5, 48.0.

*General Procedure for synthesis of **6a-6k**.* In a round bottom flask equipped with a magnetic stirrer was added **5** (1 equiv., 0.5 mmol), Ar^1-$B(OH)_2$ (1 equiv.), Pd_2dba_3 (5 mol%), dppf (5 mol%), Cs_2CO_3 (2 equiv.) in toluene: ethanol (1:1, 5 mL). The reaction mixture was stirred in an oil bath at 60 °C for 15 min and the mixture was filtered through a bed of Celite. The filtrate was then evaporated using rotatory evaporator and purified through column chromatography on silica gel using ethyl acetate: hexanes solvent mixture. The purified compounds (**6a-6k)** were obtained in 40 - 70% yields. (Note: Mass of **6i** was found by MALDI as HRMS could not yield the mass of this compound)

*5-Bromo-6-chloro-1-methyl-3-phenyl-1H-pyrrolo[2,3-b]pyridine (**6a**),* 119 mg, 74%; white solid; mp.: 109-110 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.38 (s, 1H), 7.54 (d, 2H, J = 7.7 Hz), 7.45 (t, 2H, J = 7.4 Hz), 7.35 (s, 1H), 7.32 (t, 1H, J = 7.3 Hz), 3.88 (s, 3H); ^{13}C{^{1}H} NMR (126 MHz, $CDCl_3$) δ

146.0, 143.2, 133.8, 133.4, 129.1, 127.6, 126.9, 126.7, 119.0, 114.9, 110.5, 31.7; HRMS (ESI) m/z calculated for $C_{14}H_{11}BrClN_2$ $[M+H]^+$ 320.9794, found 320.9814.

*5-Bromo-6-chloro-1-methyl-3-(p-tolyl)-1H-pyrrolo [2,3-b]pyridine (**6b**),* 107 mg, 64%; white solid; mp: 130-131°C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.36 (s, 1H), 7.43 (d, 2H, *J* = 7.8 Hz), 7.31 (s, 1H), 7.25 (d, 2H, *J* = 7.6 Hz), 3.87 (s, 3H), 2.40 (s, 3H); ^{13}C{^{1}H} NMR (126 MHz, $CDCl_3$) δ 146.0, 143.1, 136.5, 133.4, 130.8, 129.8, 127.3, 126.8, 119.0, 114.9, 110.4, 31.6, 21.2; HRMS (ESI) m/z calculated for $C_{15}H_{13}BrClN_2$ $[M+H]^+$ 334.9950, found 334.9935 .

*5-Bromo-6-chloro-3-(4-methoxyphenyl)-1-methyl-1H-pyrrolo[2,3-b]pyridine (**6c**)*, 123 mg, 70% ; white solid; mp: 134.2-136.0 °C; ^{1}H NMR ($CDCl_3$, 500 MHz) δ 8.28 (s, 1H), 7.41 (d, 2H, *J*=8.5 Hz), 7.23 (s, 1H), 6.97 (d, 2H, *J* = 8.7 Hz), 3.84 (s, 3H), 3.83 (s, 3H); ^{13}C{^{1}H} NMR ($CDCl_3$, 126 MHz) δ 158.5, 145.9, 143.0, 133.3, 128.0, 127.0, 126.2, 119.0, 114.6, 114.5, 110.2, 55.4, 31.6; HRMS (ESI) m/z calculated for $C_{15}H_{13}BrClN_2O$ $[M+H]^+$ 350.9900 found 350.9879.

*5-Bromo-6-chloro-3-(3-methoxyphenyl)-1-methyl-1H-pyrrolo[2,3-b]pyridine (**6d**)* ; 70 mg, 40%; white solid : mp: 126-127 °C; ^{1}H NMR ($CDCl_3$, 500 MHz) δ 8.36 (s, 1H), 7.37-7.34 (m, 2H), 7.11 (d, 1H, *J* = 7.7 Hz), 7.05 (d, 1H, *J* = 1.9 Hz), 6.85 (dd, 1H, *J*= 8.2 Hz, 2.2 Hz), 3.87 (s, 6H) ; ^{13}C{^{1}H} NMR ($CDCl_3$, 126 MHz) δ160.1, 146.0, 143.2, 135.1, 133.4, 130.1, 127.8, 119.4, 118.9, 114.7, 112.9, 111.7, 110.5, 55.4, 31.7; HRMS (ESI) m/z calculated for $C_{15}H_{13}BrClN_2O$ $[M+H]^+$ 350.9900, found 350.9882 .

*5-Bromo-6-chloro-3-(4-fluorophenyl)-1-methyl-1H-pyrrolo [2,3-b]pyridine (**6e**)*; 110 mg, 65%; white solid; mp: 150-151 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.32 (s, 1H), 7.54-7.46 (m, 2H), 7.31 (s, 1H), 7.16-7.12 (m, 2H, *J*= 8.2 Hz), 3.89 (s, 3H); ^{13}C{^{1}H} NMR (126 MHz, $CDCl_3$) δ 161.8 (d, 1C, *J* = 246.1 Hz), 145.9, 143.4, 133.2, 129.8 (d, 1C, *J* = 3.3 Hz), 128.5 (d, 1C, J = 7.9 Hz), 127.5, 118.9, 116.0 (d, 1C, *J* = 21.5 Hz), 114.0, 110.6, 31.6; HRMS (ESI) m/z calculated for $C_{14}H_{10}BrClFN_2$ $[M+H]^+$ 338.9700, found 338.9721.

*5-Bromo-6-chloro-1-methyl-3-(naphthalen-2-yl)-1H-pyrrolo [2,3-b]pyridine (**6f**)*; 94.7 mg, 51%; white solid; mp: 150.7-151.4 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.45 (s, 1H), 7.94 (s, 1H), 7.88

(d, 1H, *J* = 8.5 Hz), 7.85-7.83 (m, 2H), 7.63 (dd,1H, *J* = 8.4 Hz, 1.6 Hz), 7.51-7.45 (m, 2H), 7.42 (s, 1H), 3.88 (s, 3H); $^{13}C\{^{1}H\}$ NMR (126 MHz, $CDCl_3$) δ 146.1, 143.3, 133.8, 133.5, 132.2, 131.2, 128.8, 128.0, 127.8, 127.8, 126.5, 125.8,125.4, 124.9, 119.0, 114.8, 110.6, 31.7; HRMS (ESI) m/z calculated for $C_{18}H_{13}BrClN_2$ $[M+H]^+$ 370.9950, found 370.9960.

*3-(Benzo[d][1,3]dioxol-5-yl)-5-bromo-6-chloro-1-methyl-1H-pyrrolo[2,3-b]pyridine (**6g**)*; 115.1 mg 63% ; white solid; mp: 131.1-132.6 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.34 (s, 1H), 7.27 (s, 1H), 7.00 (m, 2H), 6.92-6.90 (m, 1H), 6.02 (s, 2H), 3.88 (s, 3H); $^{13}C\{^{1}H\}$ NMR (126 MHz, $CDCl_3$) δ 148.3, 146.6, 145.9, 143.3, 133.3, 127.7, 127.2, 120.4, 119.0, 114.8, 110.4, 109.00, 107.6, 101.2, 31.6; HRMS (ESI) m/z calculated for $C_{15}H_{11}BrClN_2O_2$ $[M+H]^+$ 364.9692, found 364.9706 .

*5-Bromo-6-chloro-1-methyl-3-(naphthalen-1-yl)-1H-pyrrolo[2,3-b]pyridine (**6h**)*; 128 mg, 69%; white solid; mp: 145.4-147.1 °C ; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.97 (s, 1H), 7.93 (t, 2H, *J* = 8.9 Hz), 7.87 (d, 1H, *J* = 8.1 Hz), 7.54-7.47 (m, 3H), 7.45-7.42 (m, 1H), 7.34 (s, 1H), 3.94 (s, 3H); $^{13}C\{^{1}H\}$ NMR (126 MHz, $CDCl_3$) δ 145.6, 143.4, 134.0, 133.7, 132.1, 131.0, 129.6, 128.6, 127.9, 127.8, 126.3, 126.1, 125.7, 125.6, 120.9, 113.3, 110.4, 31.7; HRMS (ESI) m/z calculated for $C_{18}H_{13}BrClN_2$ $[M+H]^+$ 370.9951, found 370.9971 .

*5-Bromo-6-chloro-1-methyl-3-(pyren-1-yl)-1H-pyrrolo[2,3-b]pyridine (**6i**)*; 100.6 mg, 45%; white solid; mp: 227.3-228.4 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.21-8.18 (m, 3H), 8.17 (s, 1H), 8.09 (s, 2H), 8.04-7.98 (m, 4H), 7.44 (s, 1H), 3.98 (s, 3H); $^{13}C\{^{1}H\}$ NMR (126 MHz, $CDCl_3$) δ 145.8, 143.5, 133.8, 131.5, 131.0, 130.7, 129.9, 129.2, 128.4, 128.1, 127.7, 127.6, 127.4, 126.2, 125.3, 125.2, 125.0, 125.0, 124.9, 124.9, 121.0, 113.8, 110.6, 31.8. Exact mass calculated for $C_{24}H_{14}BrClN_2$ 444.0029, found. 444.0056.

*5-Bromo-6-chloro-1-methyl-3-(thiophen-3-yl)-1H-pyrrolo[2,3-b]pyridine (**6j**)*; 114.6 mg, 70%; white solid; mp; 152.8-153.7 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.32 (s, 1H), 7.42 (dd, 1H, *J* = 4.8 Hz, 2.9 Hz), 7.34 (d, 1H, *J* = 1.7 Hz), 7.33 (s, 1H), 7.29 (d, 1H, *J* = 4.9 Hz), 3.86 (s, 3H); $^{13}C\{^{1}H\}$ NMR (126 MHz, $CDCl_3$) δ 145.8, 143.3, 134.1, 133., 127.5, 126.4, 126.3, 119.1, 118.9, 110.4, 110.3, 31.6; HRMS (ESI) m/z calculated for $C_{12}H_9BrClN_2S$ $[M+H]^+$ 326.9358, found 326.9334.

*3-(5-Bromo-6-chloro-1-methyl-1H-pyrrolo [2,3-b]pyridin-3-yl)benzaldehyde (**6k**)*; 69.9 mg, 40%; white solid; mp: 169.8-170.9 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 10.11 (s, 1H), 8.39 (d, 1H, *J* = 2.0 Hz), 8.08 (s, 1H), 8.05 (d, 1H, *J* = 2.0 Hz), 7.87 (d, 1H, *J* = 7.6 Hz), 7.84 (d, 1H, *J* = 7.7 Hz), 7.66 (t, 1H, *J* = 7.6 Hz), 3.91 (s, 3H); ^{13}C{^{1}H} NMR (126 MHz, $CDCl_3$) δ 192.1, 145.0, 144.1, 136.9, 134.7, 133.0, 129.8, 129.6, 128.6, 128.4, 126.4, 120.00, 113.0, 109.7, 29.0; HRMS (ESI) m/z calculated for $C_{15}H_{11}BrClN_2O$ $[M+H]^+$ 348.9743, found 348.9756.

*Synthesis of 5-Bromo-6-chloro-1-(4-methoxybenzyl)-3-phenyl-1H-pyrrolo[2,3-b]pyridine (**6a′**)* In a round bottom flask equipped with a magnetic stirrer was added **5′** (1 equiv., 0.5 mmol), Ar^1-$B(OH)_2$ (1 equiv.), Pd_2dba_3 (5 mol%), dppf (5 mol%), Cs_2CO_3 (2 equiv.) in Toluene: Ethanol (1:1, 5mL) . The reaction mixture was stirred at room temperature for 15 min and the mixture was filtered through bed of celite. The filtrate was then evaporated using rotatory evaporator and purified through column chromatography (Ethyl acetate: Hexanes (0.5: 99.5)) to give white solid (**6a′**, 113.2 mg, 53%); mp: 116.6-117.5 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.39 (s, 1H), 7.50 (d, 2H, *J* = 7.7 Hz), 7.41 (t, 2H, *J* = 7.5 Hz), 7.29-7.27 (m, 2H), 7.25-7.22 (m, 2H), 6.86 (d, 2H, *J* = 8.3 Hz), 5.37 (s, 2H), 3.78 (s, 3H); ^{13}C{^{1}H} NMR (126 MHz, $CDCl_3$) δ 159.5, 145.9, 143.4, 133.8, 133.5, 129.4, 129.0, 128.6, 126.9, 126.7, 126.1, 119.0, 115.5, 114.3, 110.7, 55.3, 47.8; HRMS (ESI) m/z calculated for $C_{21}H_{17}BrClN_2O$ $[M+H]^+$ 427.0213, found. 427.0224

*General Procedure for synthesis of **7a-7i**.* In a round bottom flask equipped with a magnetic stirrer was added **6** (1 equiv., 0.5 mmol), Ar^2-$B(OH)_2$ (1.0 equiv.), Pd_2dba_3 (10 mol%), dppf (20 mol%), Cs_2CO_3 (2 equiv.) in Dioxane: Water (6:1, 5mL). The reaction mixture was stirred in an oil bath at 100 °C for 2 h. The reaction was cooled down to room temperature and ethyl acetate was added to it. The organic layer was washed with water followed by brine solution and dried with anhydrous sodium sulphate. The organic layer was then evaporated using rotatory evaporator and purified through column chromatography (Ethyl acetate: Hexanes). The purified compounds (**7a-7i)** were obtained in 66 – 84 %.

*6-Chloro-5-(4-methoxyphenyl)-1-methyl-3-phenyl-1H-pyrrolo[2,3-b]pyridine (**7a**)*, Compound was prepared from **6a;**146.6 mg, 84%; white solid; mp: 128.2-128.7 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ

8.14 (s, 1H), 7.59 (d, 2H, *J* = 7.6 Hz), 7.44-7.40 (m, 4H), 7.38 (s, 1H), 7.28 (t, 1H, *J* = 7.3 Hz), 6.99 (d, 2H, *J* = 8.4 Hz), 3.95 (s, 3H), 3.87 (s, 3H); $^{13}C\{^{1}H\}$ NMR (126 MHz, $CDCl_3$) δ 159.1, 146.6, 143.6, 134.4, 131.7, 131.4, 131.1, 129.0, 128.7, 126.9, 126.8, 126.4, 117.7, 115.4, 113.6, 55.3, 31.6; HRMS (ESI) m/z calculated for $C_{21}H_{18}ClN_2O$ $[M+H]^+$ 349.1107, found 349.1125.

*5-(3,5-Bis(trifluoromethyl)phenyl)-6-chloro-1-methyl-3-phenyl-1H-pyrrolo[2,3-b]pyridine (**7b**)*; Compound was synthesized from **6a**; 170.7 mg, 75%; white solid; mp: 148.0-149.0 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.13 (s, 1H), 7.94 (s, 2H), 7.92 (s, 1H), 7.58 (d, 2H,*J* = 7.8 Hz), 7.47-7.43 (m, 3H), 7.31 (t, 1H, *J* = 7.4 Hz), 3.97 (s, 3H); $^{13}C\{^{1}H\}$ NMR (126 MHz, $CDCl_3$) δ 147.2, 142.7, 141.4, 133.9, 131.6 (q, 2C, *J* = 33.4 Hz), 131.2, 130.3 (d, 2C, *J* = 2.2 Hz), 129.1, 127.5, 127.0, 126.8, 126.0, 123.3 (d, 2C, *J* = 272.8 Hz), 121.5-121.4 (m, 1C), 117.8, 115.9, 31.7; HRMS (ESI) m/z calculated for $C_{22}H_{14}ClF_6N_2$ $[M+H]^+$ 455.0749, found 455.0737.

*6-Chloro-3-(4-fluorophenyl)-1-methyl-5-(p-tolyl)-1H-pyrrolo[2,3-b]pyridine (**7c**)*; Compound was synthesized from **6e**; 154.3 mg, 88%; yellow semi-solid; ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.07 (s, 1H), 7.54-7.51 (m, 2H), 7.37 (d, 2H, *J* = 8.0 Hz), 7.32 (s, 1H), 7.26 (d, 2H, *J* = 7.9 Hz), 7.10 (t, 2H, *J* = 8.7 Hz), 3.94 (s, 3H), 2.42 (s, 3H); $^{13}C\{^{1}H\}$ NMR (126 MHz, $CDCl_3$) δ 161.65 (d, 1C, *J* = 245.7 Hz), 146.57, 143.60, 137.45, 136.35, 131.19, 130.43 (d, 1C, *J* = 3.2 Hz), 129.9, 129.0, 128.9, 128.4 (d, 1C, *J* = 7.7 Hz), 126.6, 117.6, 115.9 (d, 1C, *J* = 21.3 Hz), 114.5, 31.6, 21.3; HRMS (ESI) m/z calculated for $C_{21}H_{17}ClFN_2$ $[M+H]^+$ 351.1064, found 351.1084.

*6-Chloro-5-(4-methoxyphenyl)-1-methyl-3-(p-tolyl)-1H-pyrrolo[2,3-b]pyridine (**7d**)*; Compound was synthesized from **6b**; 134.6 mg, 74%; white solid; mp: 119.1-120.3 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.11 (s,1H), 7.48 (d, 2H, *J* = 7.9 Hz), 7.41 (d, 2H, *J* = 8.6 Hz), 7.33 (s, 1H), 7.22 (d, 2H, *J*=7.8 Hz), 6.98 (d, 2H, *J* = 8.6 Hz), 3.92 (s, 3H), 3.86 (s, 3H), 2.38 (s, 3H); $^{13}C\{^{1}H\}$ NMR (126 MHz, $CDCl_3$) δ 159.1, 146.6, 143.5, 136.1, 131.7, 131.4, 131.2, 129.7, 128.5, 126.8, 126.5, 117.7, 115.3, 113.6, 55.4, 31.6, 21.2; HRMS (ESI) m/z calculated for $C_{22}H_{20}ClN_2O$ $[M+H]^+$ 363.1264, found 363.1259 .

*6-Chloro-3-(4-methoxyphenyl)-1-methyl-5-(p-tolyl)-1H-pyrrolo[2,3-b]pyridine (**7e**)*; Compound was synthesized from **6c**; 145.3 mg, 80%; white solid; mp; 113.6-113.8 °C; ^{1}H NMR (500 MHz,

$CDCl_3$) δ 8.09 (s, 1H), 7.49 (d, 2H, *J* = 8.6 Hz), 7.38 (d, 2H, *J* = 7.8 Hz), 7.28-7.25 (m, 3H), 6.95 (d, 2H, *J* = 8.6 Hz), 3.92 (s, 3H), 3.83 (s, 3H), 2.42 (s, 3H); $^{13}C\{^1H\}$ NMR (126 MHz, $CDCl_3$) δ 158.4, 146.6, 143.3, 137.3, 136.5, 131.4, 129. 9, 128.9, 128.7, 128.1, 126.9, 126.2, 117.7, 115.1, 114.5, 55.4, 31.6, 21.3; HRMS (ESI) m/z calculated for $C_{22}H_{20}ClN_2O$ $[M+H]^+$ 363.1264 found 363.1253 .

*6-Chloro-1-methyl-5-(naphthalen-2-yl)-3-phenyl-1H-pyrrolo[2,3-b]pyridine (**7f**)*; Compound was synthesized from **6a**; 160.7 mg, 87%; white solid; mp 210.4-211.6 °C; ^1H NMR (500 MHz, $CDCl_3$) δ 8.25 (s,1H), 7.92-7.88 (m, 4H), 7.65 (d, 1H, *J* = 8.5 Hz), 7.61 (d, 2H, *J* = 7.7 Hz), 7.52 (dd, 2H, *J* = 5.9 Hz. 3.0 Hz), 7.44-7.41 (m, 3H), 7.28 (t,1H, *J* = 7.3 Hz), 3.97 (s, 3H); $^{13}C\{^1H\}$ NMR (126 MHz, $CDCl_3$)δ 146.8, 143.5, 136.9, 134.4, 133.2, 132.6, 131.7, 129.0, 128.8, 128.2, 128.1, 127.7, 127.5, 126.9, 126.9, 126.5, 126.3, 126.3, 117.7, 115.6, 31.6; HRMS (ESI) m/z calculated for $C_{24}H_{18}ClN_2$ $[M+H]^+$ 369.1158, found 369.1152 .

*6-Chloro-1-methyl-5-(naphthalen-2-yl)-3-(p-tolyl)-1H-pyrrolo[2,3-b]pyridine (**7g**)*; Compound was synthesized from **6b**; 149.4 mg, 78%; white solid; mp: 165.1-166.6 °C; ^1H NMR (500 MHz, $CDCl_3$) δ 8.23 (s, 1H), 7.92-7.88 (m, 4H), 7.65 (dd, 1H, *J* = 8.5 Hz, 1.4 Hz), 7.51-7.49 (m, 4H), 7.37 (s, 1H), 7.23 (d, 2H, *J* = 7.9 Hz), 3.96 (s, 3H), 2.37 (s, 3H); $^{13}C\{^1H\}$ NMR (126 MHz, $CDCl_3$) δ 146.8, 143.4, 136.9, 136.2, 133.2, 132.6, 131.8, 131.4, 129.7, 128.8, 128.2, 128.1, 127.8, 127.5, 126.8, 126.6, 126.3, 126.3, 117.8, 115.5, 31.7, 21.2; HRMS (ESI) m/z calculated for $C_{25}H_{20}ClN_2$ $[M+H]^+$ 383.1315, found 383.1324 .

*4-(6-Chloro-1-methyl-3-phenyl-1H-pyrrolo[2,3-b]pyridin-5-yl)-N,N-diphenylaniline (**7h**)*; Compound was synthesized from 100 mg (0.311 mmol) of **6a**; 90 mg, 60%; light yellow solid; mp: 175.4-177.6 °C ; ^1H NMR (500 MHz, $CDCl_3$) δ 8.16 (s, 1H), 7.59 (d, 1H, *J* = 7.3 Hz), 7.42 (t, 2H, *J* = 7.7 Hz), 7.36 (s, 1H), 7.34 (d, 2H, *J* = 8.5 Hz), 7.28 (t, 4H, *J* = 7.8 Hz), 7.16 (d, 4H, *J* = 7.7 Hz), 7.12 (d, 2H, *J* = 8.5 Hz), 7.04 (t, 2H, *J* = 7.3 Hz), 3.93 (s, 3H); $^{13}C\{^1H\}$ NMR (126 MHz, $CDCl_3$) δ 147.7, 147.2, 146.6, 143.5, 134.4, 133.0, 131.4, 130.8, 129.3, 129.0, 128.7, 126.9, 126.8, 126.4, 124.7, 123.1, 122.7, 117.7, 115.4, 31.6; HRMS (ESI) m/z calculated for $C_{32}H_{25}ClN_3$ $[M+H]^+$ 486.1737, found 486.1751.

6-Chloro-1-methyl-3-phenyl-5-(pyren-1-yl)-1H-pyrrolo[2,3-b]pyridine ***(7i)***; Compound synthesized from **6a**; 150 mg, 68%, light brown solid; mp: 198.3-200.1 °C ; ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.32 (s, 1H), 8.24 (d, 1H, *J* = 7.8 Hz), 8.20 (d, 1H, *J* = 7.6 Hz), 8.15 (d, 1H, *J* = 7.5 Hz), 8.11 (s, 2H), 8.01-7.97 (m, 3H), 7.78 (d, 2H, *J* = 9.2 Hz), 7.59 (d, 2H, *J* = 7.4 Hz), 7.45 (s, 1H), 7.36 (t, 2H, 7.7 Hz), 7.22 (t, 1H, *J* = 7.4 Hz), 4.02 (s, 3H); ^{13}C{^{1}H} NMR (126 MHz, $CDCl_3$) δ 147.3, 144.8, 134.3, 134.2, 132.6, 131.4, 131.2, 130.9, 129.7, 129.0, 128.3, 127.9, 127.8, 127.6, 127.4, 127.0, 126.9, 126.5, 126.1, 125.4, 125.2, 125.1, 124.8, 124.5, 117.5, 115.5, 31.7; HRMS (ESI) m/z calculated for $C_{30}H_{20}ClN_2$ $[M+H]^+$ 443.1315, found 443.1329

6-Chloro-1-methyl-3-(naphthalen-2-yl)-5-(thiophen-3-yl)-1H-pyrrolo[2,3-b]pyridine ***(7j)***; Compound was synthesized from **6f**; 125.6 mg, 67%; white solid ; mp: 113.9-115.5 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.30 (s, 1H), 8.02 (s, 1H), 7.89 (d, 1H, *J* = 8.4 Hz), 7.86-7.83 (m, 2H), 7.71 (d, 1H, *J* = 8.2 Hz), 7.50-7.44 (m, 4H), 7.41-7.40 (m,1H), 7.36-7.35 (m, 1H), 3.95 (s, 3H); ^{13}C{^{1}H} NMR (126 MHz, $CDCl_3$) δ 146.7, 143.5, 139.3, 133.9, 132.2, 131.8, 131.3, 129.4, 128.7, 127.8, 127.8, 127.4, 126.4, 125.6, 125.1, 124.8, 124.2, 124.1, 117.7, 115.4, 31.7; HRMS (ESI) m/z calculated for $C_{22}H_{16}ClN_2S$ $[M+H]^+$ 375.0722, found 375.0702 .

6-Chloro-1-methyl-5-(pyridin-4-yl)-3-(thiophen-3-yl)-1H-pyrrolo[2,3-b]pyridine ***(7k)***; Compound was synthesized from **6h**; 107.6 mg, 66%; yellow solid; mp: 206.9-207.6 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ) δ 8.69 (d, 2H, *J* = 5.8 Hz), 8.08 (s, 1H), 7.45-7.43 (m, 2H), 7.42 (dd,1H, *J* = 5.0 Hz, 3.0 Hz), 7.40 (s,1H), 7.38 (dd, 1H, *J* = 2.9 Hz, 1.3 Hz), 7.33 (dd, 1H, *J* = 4.9 Hz, 1.3 Hz), 3.93 (s, 3H); ^{13}C{^{1}H} NMR (101 MHz,) δ 149.7, 147.1, 146.8, 142.6, 134.4, 131.2, 127.3, 126.5 126.4, 126.3, 124.9, 119.2, 117.8, 111.2, 31.7; HRMS (ESI) m/z calculated for $C_{17}H_{13}ClN_3S$ $[M+H]^+$ 326.0518, found 326.0501 .

6-Chloro-1-(4-methoxybenzyl)-5-(4-methoxyphenyl)-3-phenyl-1H-pyrrolo[2,3-b]pyridine ***(7a′)***; Compound was synthesized from **6a′**; 186 mg, 82%; white solid; mp: 136.4-137.0 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.14 (s, 1H), 7.55 (d, 2H, *J* = 7.4 Hz), 7.42 (d, 2H, *J* = 7.3 Hz), 7.37 (t, 2H, *J* = 7.0 Hz), 7.31 (s, 1H), 7.28-7.24 (m, 3H), 6.99 (d, 2H, *J* = 7.2 Hz), 6.87 (d, 2H, *J* = 7.4 Hz), 5.43 (s, 2H) 3.86 (s,

3H), 3.78 (s, 3H); $^{13}C\{^{1}H\}$ NMR (126 MHz, $CDCl_3$) δ 159.4, 159.2, 146.4, 143.7, 134.4, 131.8, 131.5, 131.1, 129.4, 129.1,129.0, 128.9, 126.9, 126.4, 125.4, 117.7, 115.9, 114.3, 113.6, 55.35, 55.31, 47.7; HRMS (ESI) m/z calculated for $C_{28}H_{24}ClN_2O_2$ $[M+H]^+$ 455.1526 found 455.1523.

*General Procedure for synthesis of (**8a-8j**)*. In a sealed tube equipped with a magnetic stirrer was added **7** (1 equiv., 0.3 mmol), Ar^3-$B(OH)_2$ (1.1 equiv.), Pd_2dba_3 (10 mol%), SPhos (20 mol%), Cs_2CO_3 (2 equiv.) in Dioxane:Water (3:1, 5mL). The reaction mixture was stirred at 100 °C for 6-12 h in an oil bath. The reaction was cooled down to room temperature and ethyl acetate was added to it. The organic layer was washed with water followed by brine solution and dried with anhydrous sodium sulphate. The organic layer was then evaporated using rotatory evaporator and purified through column chromatography on silica gel (Ethyl acetate: Hexanes). The purified compounds (**8a-8j)** were obtained in 42-79 % yields.

*5-(4-Methoxyphenyl)-1-methyl-3-phenyl-6-(p-tolyl)-1H-pyrrolo[2,3-b]pyridine (**8a**)*; Compound synthesized from **7a**; 91 mg, 79%; white solid; mp: 167.5 -168.0 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ. 8.18 (d, 1H, *J* = 1.4 Hz), 7.66 (d, 2H, *J* = 8.0 Hz), 7.44-7.41(m, 3H), 7.35 (dd, 2H, *J* = 8.0 Hz, 1.7 Hz), 7.27 (t, 1H, *J* = 7.4 Hz), 7.15-7.14 (m, 2H), 7.06 (d, 2H, *J* = 7.7 Hz), 6.82 (d, 2H, *J* = 8.4 Hz), 3.97 (s, 3H), 3.80 (s, 3H), 2.32 (s, 3H); $^{13}C\{^{1}H\}$ NMR (126 MHz, $CDCl_3$) δ 158.3, 151.5, 147.7, 138.4, 136.9, 135.1, 134.3, 131.2, 130.4, 130.2, 129.0, 128.9, 128.5, 126.8, 126.0, 117.1, 114.8, 113.6, 55.3, 31.4, 21.3; HRMS (ESI) m/z calculated for $C_{28}H_{25}N_2O$ $[M+H]^+$ 405.1967, found 405.1945.

*5-(3,5-Bis(trifluoromethyl)phenyl)-1-methyl-3-phenyl-6-(p-tolyl)-1H-pyrrolo[2,3-b]pyridine (**8b**)*; Compound was synthesized from **7b**; 65.8 mg, 43%; white solid; mp: 212.4 - 213.2 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.20 (s, 1H), 7.72 (s, 1H), 7.66-7.63 (m, 4H), 7.49-7.45 (m, 3H), 7.31 (t, 1H, *J* = 7.4 Hz), 7.22 (d, 2H, *J* = 8.0 Hz), 7.09 (d, 2H, *J* = 7.8 Hz), 4.00 (s, 3H), 2.33 (s, 3H); $^{13}C\{^{1}H\}$ NMR (126 MHz, $CDCl_3$) δ 151.8, 148.2, 144.0, 137.8, 137.1, 134.6, 131.3 (q, 2C, *J* = 33.1 Hz), 130.3 (d, 2C, *J* = 2.7Hz), 130.1, 130.00, 129.1, 128.8, 127.5, 127.0, 126.4, 126.4, 123.3 (q, 2C, *J* = 272.8 Hz) 120.0-119.9 (m, 1C), 117.4, 115.4, 31.4, 21.1; HRMS (ESI) m/z calculated for $C_{29}H_{21}F_6N_2$ $[M+H]^+$ 511.1609, found 511.1602.

*6-(3,5-Bis(trifluoromethyl)phenyl)-3-(4-fluorophenyl)-1-methyl-5-(p-tolyl)-1H-pyrrolo[2,3-b]pyridine(**8c**)*; Compound synthesized from **7c;** 107.6 mg, 68%; yellow solid; mp: 174.8-175.9 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.18 (s, 1H), 7.90 (s, 2H), 7.72 (s, 1H), 7.61-7.58 (m, 2H), 7.45 (s, 1H), 7.15-7.12 (m, 4H), 7.07 (d, 2H, *J* = 8.0 Hz), 4.01 (s, 3H), 2.36 (s, 3H); ^{13}C{^{1}H} NMR (126 MHz, $CDCl_3$) δ 161.6 (d, 1C, *J* = 245.5 Hz), 147.8, 147.7, 143.0, 137.4, 137.1, 130.8 (q, 2C, *J* = 33.1 Hz), 130.7, 130.5 (d, 2C, *J* = 3.0 Hz), 130.3, 130.0, 129.8, 129.3, 128.4 (d, 2C, *J* = 7.8 Hz), 127.9 , 123.4 (q, 2C, *J* = 272.6 Hz), 120.7-120.6 (m, 1C), 118.2, 115.9 (d, 2C, *J* = 21.4 Hz), 114.3, 31.4, 21.0; HRMS (ESI) m/z calculated for $C_{29}H_{20}F_7N_2$ $[M+H]^+$ 529.1514, found 529.1515.

*6-(Benzo[d][1,3]dioxol-5-yl)-5-(4-methoxyphenyl)-1-methyl-3-(p-tolyl)-1H-pyrrolo[2,3-b]pyridine (**8d**)*; Compound synthesized from **7d**; 56.3 mg, 42%; white solid; mp: 127.1-127.7 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.14 (s, 1H), 7.54 (d, 2H, *J* = 7.7 Hz), 7.38 (s, 1H), 7.24 (d, 2H, *J* = 7.4 Hz), 7.15 (d, 2H, *J* = 8.3 Hz), 7.03 (s, 1H), 6.86 (d, 1H, *J* = 8.6 Hz), 6.83 (d, 2H, *J* = 8.4 Hz), 6.67 (d, 1H, *J* = 8.0 Hz), 5.93 (s, 2H), 3.96 (s, 3H), 3.81 (s, 3H), 2.38 (s, 3H); ^{13}C{^{1}H} NMR (126 MHz, $CDCl_3$) δ 158.3, 150.8, 147.5, 147.2, 146.8, 135.7, 135.5, 134.2, 132.1, 131.1, 130.5, 129.6, 128.8, 126.8, 126.6, 124.5, 117.3, 114.9, 113.8, 110.8, 107.7, 100.9, 55.3, 31.3, 21.2; HRMS (ESI) m/z calculated for $C_{29}H_{25}N_2O_3$ $[M+H]^+$ 449.1865, found 449.1843.

*3-(4-Methoxyphenyl)-1-methyl-6-(naphthalen-2-yl)-5-(p-tolyl)-1H-pyrrolo[2,3-b]pyridine (**8e**)*; Compound synthesized from **7e**; 90 mg, 66%; white solid; mp: 197.2-198.9 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.20 (s, 1H), 8.04 (s, 1H), 7.76 (s, 2H), 7.66 (d, 1H, *J* = 8.4 Hz), 7.59 (d, 2H, *J* = 8.2 Hz), 7.50 (d, 1H, *J* = 8.3 Hz), 7.43-7.42 (m, 2H), 7.36 (s, 1H), 7.14 (d, 2H, *J* = 7.4 Hz), 7.03 (d, 2H, *J* = 7.6 Hz), 6.99 (d, 2H, *J* = 8.3 Hz), 4.00 (s, 3H), 3.84 (s, 3H), 2.31 (s, 3H); ^{13}C{^{1}H} NMR (126 MHz, $CDCl_3$) δ 158.2, 151.1, 147.8, 139.0, 138. 8, 136.1, 133.3, 132.6, 130.5, 130.1, 129.6, 129.5, 128.9, 128.5, 128.4, 128.0, 127.6, 127.5, 127.0, 126.5, 125.9, 125.7, 117.5, 114.7, 114.4, 55.4, 31.4, 21.1; HRMS (ESI) m/z calculated for $C_{32}H_{27}N_2O$ $[M+H]^+$ 455.2123, found 455.2120.

*6-(3-Methoxyphenyl)-1-methyl-5-(naphthalen-2-yl)-3-(p-tolyl)-1H-pyrrolo[2,3-b]pyridine (**8f**)*; Compound synthesized from **7g**; 94.2 mg, 69%; white solid; mp: 176.4-177.6 °C; ^{1}H NMR (500 MHz,

$CDCl_3$) δ 8.31 (s, 1H), 7.85 (s, 1H), 7.80 (t, 2H, *J* = 6.1 Hz), 7.65 (d,1H, *J* = 8.4 Hz), 7.57 (d, 2H, *J* = 7.8 Hz), 7.48-7.45 (m, 2H),7.43 (s, 1H), 7.25 (d, 2H, *J*= 7.0 Hz), 7.21 (d, 1H,*J*=8.4 Hz), 7.10-7.07 (m, 2H), 7.01 (d, 1H, *J* = 7.5 Hz), 6.77-6.76 (m, 1H), 4.01 (s, 3H), 3.57 (s, 3H), 2.39 (s, 3H); $^{13}C\{^1H\}$ NMR (126 MHz, $CDCl_3$)δ 159.1, 151.1, 147.8, 142.4, 139.6, 135.9, 133.5, 132.0, 132.0, 130.9, 129.7, 129.2, 128.9, 128.8, 128.3, 127.9, 127.6, 127.2, 126.9, 126.8, 126.1, 125. 8, 123.2, 117.5, 115.6, 115.0, 113.6, 55.1, 31.4, 21.2; HRMS (ESI) m/z calculated for $C_{32}H_{27}N_2O$ $[M+H]^+$ 455.2123, found 455.2124.

*1-Methyl-5-(naphthalen-2-yl)-3-phenyl-6-(3,4,5-trimethoxyphenyl)-1H-pyrrolo[2,3-b]pyridine **(8g)**;* Compound synthesized from **7f**; 100.3 mg, 67%; white solid; mp: 197.0-198.0 °C; ^1H NMR (500 MHz, $CDCl_3$) δ 8.34 (s, 1H), 7.86 (s, 1H), 7.79 (m, 2H), 7.69-7.67 (m, 3H), 7.46-7.42 (m, 5H), 7.28 (t, 1H, *J* = 7.3 Hz), 7.23 (d, 1H, *J* = 7.4 Hz), 6.73 (s, 2H), 4.03 (s, 3H), 3.80 (s, 3H), 3.49 (s,6H); $^{13}C\{^1H\}$ NMR (126 MHz, $CDCl_3$)δ 152.6, 151.0, 147.8, 139.7, 137.5, 136.2, 134.9, 133.5, 132.0, 130.9, 129.4,129.0, 128.8, 128.2, 128.8, 127.8, 127.6, 127.4, 127.2, 126.9, 126.2, 125.9, 117.4, 115.1, 107.9, 60.9, 55.8, 31.5; HRMS (ESI) m/z calculated for $C_{33}H_{29}N_2O_3$ $[M+H]^+$ 501.2178, found 501.2151.

*6-(Benzo[d][1,3]dioxol-5-yl)-1-methyl-5-(naphthalen-2-yl)-3-phenyl-1H-pyrrolo[2,3-b] pyridine **(8h)***, Compound was synthesized from **7f**; 75.2 mg, 55%; white solid; mp: 186.8 -187.5 °C; ^1H NMR (500 MHz, $CDCl_3$) δ 8.29 (s, 1H), 7.86 (s, 1H), 7.81-7.80 (m, 2H), 7.67-7.66 (m, 3H), 7.49-7.41 (m, 5H), 7.27 (t, 1H, *J* = 7.3 Hz), 7.23 (d, 1H, *J* = 9.8 Hz), 7.12 (s, 1H), 6.86 (d, 1H, *J* = 8.0 Hz), 6.59 (d, 1H, *J* = 8.1 Hz), 5.90 (s, 2H), 4.00 (s, 3H); $^{13}C\{^1H\}$ NMR (126 MHz, $CDCl_3$) δ 151.0, 147.8, 147.3, 147.0, 139.7, 135.3, 135.0, 133.6, 132.1, 131.0, 129.2, 129.0, 128.9, 128.2, 127.9, 127.7, 127.3, 127.0, 126.9, 126.13, 126.07, 125. 8, 124.7, 117.3, 115.1, 110.8, 107.7, 100.9, 31.4; HRMS (ESI) m/z calculated for $C_{31}H_{23}N_2O_2$ $[M+H]^+$ 455.1759, found 455.175.

*1-Methyl-6-(pyridin-3-yl)-5-(pyridin-4-yl)-3-(thiophen-3-yl)-1H-pyrrolo[2,3-b]pyridine **(8i)***; Compound was synthesized from **7i**; 46.2 mg, 42%; yellow solid; mp: decompose; ^1H NMR (500 MHz, DMSO-d_6) δ 8.53-8.50 (m, 4H), 8.43 (s, 1H), 8.11 (s, 1H), 7.94-7.93 (m, 1H), 7.75-7.74 (m, 1H), 7.65 (dd, 1H, *J* = 4.9 Hz, 2.8 Hz), 7.60 (dd, 1H, *J* = 4.9 Hz, 1.0 Hz), 7.36 (dd, 1H, *J* = 7.7 Hz, 4.9 Hz), 7.31

(d, 2H, *J* = 5.6 Hz), 3.92 (s, 3H); $^{13}C\{^{1}H\}$ NMR (126 MHz, DMSO-d_6) δ 150.9, 149.9, 148.9, 148.7, 147.8, 147.7, 137.7, 136.4, 134.9, 130.8, 130.0, 127.0, 126.9, 126. 9, 125.8, 123.5, 119.2, 117.3, 110.2, 31.6; HRMS (ESI) m/z calculated for $C_{22}H_{17}N_4S$ $[M+H]^+$ 369.1174, found 369.1159 .

5-(4-Methoxyphenyl)-1-methyl-3-phenyl-6-(pyren-4-yl)-1H-pyrrolo[2,3-b]pyridine ***(8j)****;* Compound synthesized from 150 mg (0.43 mmol) **7a**; 93 mg; 42%; off white solid; mp: 253.3-255.1 °C ; ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.38 (s, 1H), 8.16 (d, 1H, *J* = 7.5 Hz), 8.12 (d, 1H, *J* = 7.4 Hz), 8.09-8.02 (m, 4H), 7.98 (d, 1H, *J* = 7.6 Hz), 7.94 (d, 1H, *J* = 9.3 Hz), 7.85 (d, 1H, *J* = 7.8 Hz), 7.74 (d, 2H, *J* = 7.1 Hz), 7.51 (s, 1H), 7.48 (t, 2H, *J* = 7.7 Hz), 7.32 (t, 1H, J = 7.4 Hz), 7.02 (d, 2H, *J* = 8.7 Hz), 6.50 (d, 2H, *J* = 8.7 Hz), 3.98 (s, 3H), 3.58 (s, 3H); $^{13}C\{^{1}H\}$ NMR (126 MHz, $CDCl_3$) δ 158.0, 151.6, 147.5, 136.8, 135.1, 133.4, 131.3, 131.1, 131.0, 130.8, 130.7, 129.9, 129.6, 129.0, 128.8, 127.51, 127.3, 127.2, 127.2, 127.0, 126.2, 125.8, 124.9, 124.85, 124.82, 124.3 117.8, 115.0, 113.3, 55.0, 31.6; HRMS (ESI) m/z calculated for $C_{37}H_{27}N_2O$ $[M+H]^+$ 515.2123, found 515.2148 .

1-(4-Methoxybenzyl)-5-(4-methoxyphenyl)-3-phenyl-6-(p-tolyl)-1H-pyrrolo[2,3-b]pyridine ***(8a')***; Compound was synthesized from **7a'** (0.5 mmol); 168 mg, 66%; mp: 91.0 - 92.3 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.18 (s, 1H), 7.62 (d, 2H, *J* = 7.2 Hz), 7.41-7.38 (m, 3H), 7.36 (d, 2H, *J* = 8.0 Hz), 7.32 (d, 2H, *J* = 8.5 Hz), 7.24 (s, 1H), 7.16 (d, 2H, *J* = 8.6 Hz), 7.07 (d, 2H, *J* = 7.9 Hz), 6.87 (d, 2H, *J* = 8.6 Hz), 6.83 (d, 2H, *J* = 8.6 Hz), 5.51 (s, 2H), 3.81 (s, 3H), 3.79 (s, 3H), 2.33 (s, 3H); $^{13}C\{^{1}H\}$ NMR (126 MHz, $CDCl_3$) δ159.2, 158.3, 151.4, 147.6, 138.5, 136.9, 135.1, 134.4, 131.2, 130.4, 130.3, 129.9, 129.5, 129.3, 128. 9, 128.5, 126.8, 126.0, 125.4, 117.1, 115.4, 114.1, 113.6, 55.3, 55.3, 47.4, 21.3; HRMS (ESI) m/z calculated for $C_{35}H_{31}N_2O_2$ $[M+H]^+$ 511.2385, found 511.2362.

General Procedure for synthesis of ***9a-9f****.* In reaction vial was taken **8** (0.125 mmol, 1 equiv.) and to it was added aryl iodide (0.1875 mmol, 1.5 equiv.), $Pd(OAc)_2$ (10 mol%), o-nitrobenzoic acid (1.5 equiv.), silver triflate (1 equiv.), Cs_2CO_3 (5 mol%) in DMF (2 mL). The reaction was stirred in an oil bath at at 120 °C in N_2 atmosphere for 6-12 h. On completion of reaction the mixture was bought to room temperature and to it was added ethyl acetate (15 mL). The organic layer was washed thrice with

water (50 mL) and 50 mL brine. The organic extract was dried over anhydrous sodium sulphate and evaporated. The crude mixture was evaporated and purified by column chromatography on silica gel using ethyl acetate and hexane mixture. The product (**9a-9f)** was obtained in 48-95 % yields.

2,5-Bis(4-methoxyphenyl)-1-methyl-3-phenyl-6-(p-tolyl)-1H-pyrrolo[2,3-b]pyridine ***(9a)***, Compound was synthesized from **8a**; 48 mg, 75%; white solid; mp: 242.0 - 243.0 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.01 (s, 1H), 7.36 (d, 2H, *J* = 7.8 Hz), 7.32 - 7.29 (m, 4H), 7.28 - 7.23 (m, 2H), 7.18 - 7.13 (m, 3H), 7.06 (d, 2H, *J* = 7.8 Hz), 6.94 (d, 2H,*J* = 8.4 Hz), 6.80 (d, 2H, *J* = 8.4 Hz), 3.84 (s, 6H), 3.79 (s, 3H), 2.32(s, 3H); ^{13}C{^{1}H} NMR (101 MHz,) δ 159.2, 158.4, 151.4, 147.6, 138.5, 137.0, 135.1, 134.4, 131.3, 130.5, 130.3, 130.0, 129.6, 129.3, 129.0, 128.6, 126.9, 126.1, 125.5, 117.2, 115.4, 114.2, 113. 7, 55.4, 55.3, 47.5, 21.3; HRMS (ESI) m/z calculated for $C_{35}H_{31}N_2O_2$ $[M+H]^+$ 511.2385, found 511.2358

2-(4-Fluorophenyl)-5-(4-methoxyphenyl)-1-methyl-3-phenyl-6-(p-tolyl)-1H-pyrrolo[2,3-b]pyridine ***(9b)***, Compound was synthesized from **8a**; 30 mg, 48%, white solid; mp: 219.7-220.2 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.02 (s, 1H), 7.37-7.35 (m, 4H), 7.29-7.26 (m, 4H), 7.21-7.18 (m, 1H), 7.14-7.10 (m, 4H), 7.07 (d, 2H, *J* = 7.9 Hz), 6.81 (d, 2H, *J* = 8.5 Hz), 3.83 (s, 3H), 3.80 (s, 3H), 2.33 (s, 3H); ^{13}C{^{1}H} NMR (126 MHz, $CDCl_3$) δ 162.8 (d, 1C, *J* = 249.2 Hz) 158.3, 151.6, 147.8, 138.5, 137.3, 136.9, 134.40, 134.3, 132.74, 132.67, 131.2, 130.2, 129.8, 129.55, 129.51, 128.5 (d, 2C, *J* = 5.0 Hz), 127.5 (d, 1C, *J* = 3.5 Hz), 125.9, 118.31, 115.8 (d, 2C, *J* = 21.6 Hz), 113.6, 113.2, 55.3, 29.7, 21.3; HRMS (ESI) m/z calculated for $C_{34}H_{28}FN_2O$ $[M+H]^+$ 499.2185, found 499.2168.

6-(Benzo[d][1,3]dioxol-5-yl)-2-(4-methoxyphenyl)-1-methyl-5-(naphthalen-2-yl)-3-phenyl-1H-pyrrolo[2,3-b]pyridine ***(9c)***, Compound was synthesized from **8h**; 46.4 mg, 66%; white solid; mp: 242.3 - 243.5 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.13 (s, 1H), 7.84 (s, 1H), 7.81-7.79 (m, 2H), 7.66 (d, 1H, *J* = 8.2 Hz), 7.45-7.44 (m, 2H), 7.33-7.26 (m, 6H), 7.23 (d, 1H, *J* = 7.0 Hz), 7.17 (t, 1H, *J* = 6.6 Hz), 7.13 (s, 1H), 6.95 (d, 2H, *J* = 8.1 Hz), 6.87 (d, 1H, *J* = 7.8 Hz), 6.59 (d, 1H, *J* = 7.9 Hz), 5.90 (s, 2H), 3.86 (s, 3H), 3.84 (s, 3H); ^{13}C{^{1}H} NMR(126 MHz, $CDCl_3$) δ 159.7, 150.7, 147. 9, 147.3, 146.9,

139. 8, 138.7, 135.5, 134.7, 133.6, 132.2, 132.0, 130.2, 129.5, 129.4, 128.9, 128.5, 128.1, 127.9, 127.7, 127.3, 126.1, 125.8, 125.7, 124.8, 123.5, 118.6, 114.1, 112.8, 110.8, 107.8, 100.9, 55.3, 29.8; HRMS (ESI) m/z calculated for $C_{38}H_{29}N_2O_3$ $[M+H]^+$ 561.2178, found 561.2156.

*3-(4-Methoxyphenyl)-1-methyl-6-(naphthalen-2-yl)-2-phenyl-5-(p-tolyl)-1H-pyrrolo[2,3-b]pyridine (**9d**)*, Compound was synthesized from **8e**; 36.2 mg, 53%; White solid; mp: 175.4-176.5 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.07-8.05 (m, 2H), 7.77-7.76 (m, 2H), 7.67(d, 1H, *J* = 8.5 Hz), 7.51 (d, 1H, *J* = 8.4 Hz), 7.44-7.43 (m, 2H), 7.39-7.36 (m, 2H), 7.25-7.22 (m, 2H), 7.14-7.11 (m, 4H), 7.03 (d, 2H, *J* = 7.7 Hz),6.84 (d, 2H, *J* = 8.5 Hz), 3.87 (s, 3H), 3.80 (s, 3H), 2.31 (s, 3H); ^{13}C{^{1}H} NMR (126 MHz, $CDCl_3$) δ 162.8 (d, 1C, *J* = 248.5 Hz),157.9, 151.2, 147.9, 139.0, 138.7, 137.2, 136.1, 133.3, 132.74, 132.68, 132.6, 130.6, 130.1, 130.0 (d, 2C, *J* = 5.0 Hz), 129.6, 128.9, 128.5, 128.4, 127.6 (d, 1C, *J* = 4.2 Hz), 127.5, 127.0, 126.6, 125.9, 125.7, 118.7, 115.8 (d, 2C, *J* = 21.8 Hz), 114.0, 113.0, 55.2, 29.8, 21.2; HRMS (ESI) m/z calculated for $C_{38}H_{30}FN_2O$ $[M+H]^+$ 549.2342, found 549.2328.

*3-(4-Methoxyphenyl)-1-methyl-6-(naphthalen-2-yl)-2-phenyl-5-(p-tolyl)-1H-pyrrolo[2,3-b]pyridine (**9e**)*; Compound was synthesized from **8e**; 62.6 mg, 95%; white solid; mp: 177.8-178.4 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.07-8.05 (m, 2H), 7.77-7.76 (m, 2H), 7.67(d, 1H, *J* = 8.5 Hz), 7.52 (d, 1H, *J* = 8.4 Hz), 7.44-7.41 (m, 7H), 7.25-7.24 (m, 2H), 7.15-7.13 (d, 2H, *J* = 7.9 Hz), 7.03 (d, 2H, *J* = 7.7 Hz),6.84 (d, 2H, *J* = 8.5 Hz), 3.89 (s, 3H), 3.79 (s, 3H), 2.31 (s, 3H); ^{13}C{^{1}H} NMR (126 MHz, $CDCl_3$) δ 157.8, 151.0, 148.0, 139.1, 138.8, 138.3, 136.0, 133.3, 132.6, 131.6, 130.9, 130.6, 130.1, 130.0, 129.9, 129.6, 128.9, 128.6, 128.5, 128.4, 128.3, 127.5, 126.9, 126.8, 125.8, 125. 7, 118.8, 113.9, 112.7, 55.2, 29.9, 21.1; HRMS (ESI) m/z calculated for $C_{38}H_{31}N_2O$ $[M+H]^+$ 531.2436, found 531.2432 .

*3-(4-Methoxyphenyl)-1-methyl-6-(naphthalen-2-yl)-2-phenyl-5-(p-tolyl)-1H-pyrrolo[2,3-b]pyridine (**9f**)*; Compound was synthesized from **8f**; 37 mg, 54%; white solid; mp: 212.5 - 213.5 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.15 (s, 1H), 7.83 (s, 1H), 7.79-7.78 (m, 2H), 7.64 (d, 1H, *J* = 8.4 Hz), 7.47-7.43 (m, 2H), 7.38 (dd, 2H, *J* = 8.3 Hz, 5.6 Hz), 7.21-7.19 (m, 3H), 7.14-7.07 (m, 6H), 7.03 (d, 1H, *J* = 7.6 Hz), 6.77 (dd, 1H, *J* = 7.9 Hz, 1.7 Hz), 3.87 (s, 3H), 3.57 (s, 3H), 2.32 (s, 3H); ^{13}C{^{1}H} NMR (126 MHz, $CDCl_3$) δ 162. 8 (d, 1C, *J* = 248.4 Hz), 159.1, 151.3, 147.9, 142.5, 139.6, 137.5,

135.7, 133.5, 132.8, 132.7, 132.0, 131.2, 130.4, 129. 8, 129.4, 129.3, 128.9 (d, 2C, J = 12.3 Hz), 128.2, 127.9, 127.6, 127.5 (d, 1C, J = 3.4 Hz), 127.2, 126.1, 125.8, 123.2, 118.7, 115.8 (d, 2C, J = 33.1 Hz), 115.7, 113.5, 113.4, 55.1, 29.8, 21.2; HRMS (ESI) m/z calculated for $C_{38}H_{30}FN_2O$ $[M+H]^+$ 549.2342, found 549.2343.

6. ASSOCIATED CONTENTS

Supporting Information

Spectral data of **6a**, **7a**, **8a**, **9a-f**; DLS measurement; quantum yield of **9e**; Crystal structure and data of **8a** and **9a**; ^1H and ^{13}C NMR of isolated compounds, mass spectra of isolated compounds.

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