JOC The Journal of Organic Chemistry

Note

Assembly of Diversely Substituted Quinolines via Aerobic Oxidative Aromatization from Simple Alcohols and Anilines

Jixing Li, Jinlong Zhang, Huameng Yang, and Gaoxi Jiang

J. Org. Chem., **Just Accepted Manuscript** • DOI: 10.1021/acs.joc.6b03064 • Publication Date (Web): 22 Feb 2017

ACS Publications

The Journal of Organic Chemistry is published by the American Chemical Society.
1155 Sixteenth Street N.W., Washington, DC 20036

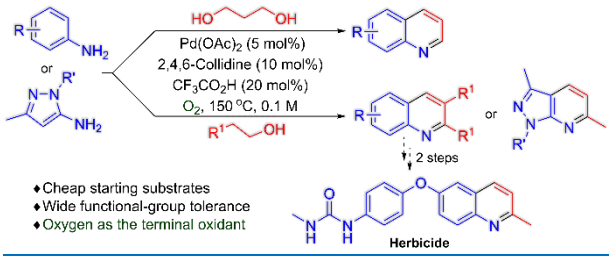
Assembly of Diversely Substituted Quinolines via Aerobic Oxidative Aromatization from Simple Alcohols and Anilines

Jixing Li,[ab] Jinlong Zhang,[a] Huameng Yang[a] and Gaoxi Jiang*[a]

a. State Key Laboratory for Oxo Synthesis and Selective Oxidation, Suzhou Research Institute of LICP, Lanzhou Institute of Chemical Physics (LICP), Chinese Academy of Sciences, Lanzhou 730000, P. R. China. E-mail: gxjiang@licp.cas.cn

b. University of Chinese Academy of Sciences, Beijing 100049, P. R. China.

gxjiang@licp.cas.cn

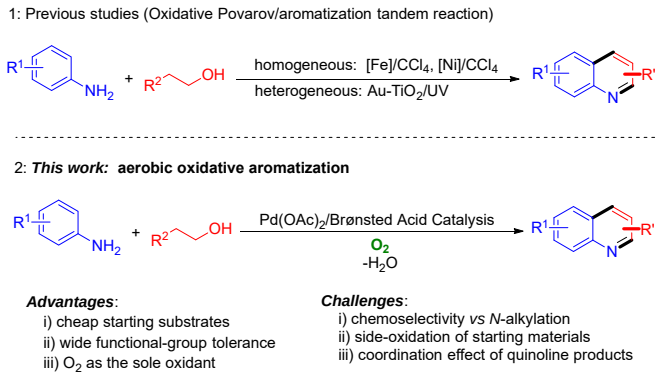


Abstract: An aerobic oxidative aromatization of simple aliphatic alcohols and anilines under the $Pd(OAc)_2$/2,4,6-Collidine/Brønsted acid catalytic system has been established, providing a direct approach for the preparation of diverse substituted quinoline derivatives in high yields with wide functional-group tolerance. Practically, the protocol can be easily scaled up to gram-scale and was utilized in the concise formal synthesis of a promising herbicide candidate.

The quinoline skeleton represents a privileged structural component that occurs ubiquitously in medicine,[1] organo,[2] and material chemistry.[3] Consequently, the development of new practical and efficient methods for the quinolines synthesis is of very importance to the pharmaceutical and chemical industries. Traditionally, different classical transformations have been developed through the condensation between carbonyl substrates with anilines in strong acidic conditions, like the Skraup reaction, Gould−Jacobs reaction, Combes reaction, and others.[4] Although modifications have been realized to improve the aforementioned condensation processes to date, a major drawback

still existed in the use of expensive raw materials, mostly limited substrate scope and low substrates utilization efficiency.[4] The further excavation of direct and efficient access from simple starting materials to quinolines is still in strong demand yet challenging.[5] Primary alcohols that can be readily obtained by industrial processes via catalytic transformation or fermentation of lignocellulosic biomass have been regarded as sustainable synthetic reagents.[6] In principle, the direct assemblage of abundantly available primary alcohols and anilines to synthesize quinolines should be regarded as one of the most ideal methodologies. This kind of transformation between arylamines and diols or aminoalcohols goes back at least to the 80's of the last century, in which cross-dehydrogenative coupling process occurred with another (over)stoichiometric amounts of alkene as the hydrogen acceptors to deliver the target products.[7] In 2012, Khusnutdinov and co-workers demonstrated the possibilities of oxidative process for the synthesis of quinolines by $FeCl_3$•$6H_2O$ or $Ni(OAc)_2 \cdot 4H_2O$ catalysis while the transformation suffered from the use of toxic CCl_4 as the oxidant[8] (Scheme 1, 1). Another heterogeneous attempt about photocatalytic process with Au-doped TiO_2 nanoparticles was reported by Swaminathan. However, the limited substrate scope prevents its further application to some extent[9] (Scheme 1, 1). Recently, surge of interest to develop practical aerobic oxidation reactions has been engaged,[10] especially the aerobic oxidation of alcohols for concise synthesis of various useful chemicals.[11] To the best of our knowledge, it is still unprecedented for synthesis of quinolines to use dioxygen (O_2) as the sole oxidant, along with simple aliphatic alcohols and anilines as starting materials. Nevertheless, the difficult challenges facing this transformation are: i) to control the definite chemoselectivity of the cyclization/aromatization cascade process from the intrinsically competitive *N*-alkylation,[12] ii) to suppress the side-oxidation of starting materials, and iii) to overcome the coordination of the

structural similar quinoline products with transition-metal that might interdict the more reactive transition-metal catalyst. Enlightened by the pioneering achievements in aerobic oxidation of alcohols,[10,11] we envisioned that a Brønsted acid catalysis might facilitate the formation of aldimine with simple anilines and promote the successive cyclization/aerobic oxidative aromatization to final quinolines. Herein, we present an aerobic oxidative aromatization of simple aliphatic alcohols and anilines enabled by a $Pd(OAc)_2$/Brønsted acid catalysis, which provides a concise and readily scalable approach for the synthesis of versatile quinolines in high yields with wide functional-group tolerance (Scheme 1, 2). The process features the use of abundantly available starting materials, environmental benign dioxygen molecule as the sole oxidant, which would make it particularly attractive.

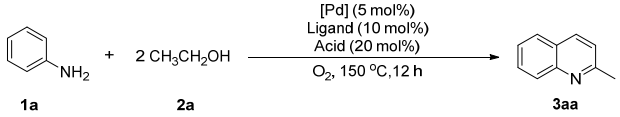


Scheme 1 Oxidative aromatization strategy for quinolines construction.

Initially, we chose the reaction of phenylamine **1a** in ethanol **2a** solvent with a concentration of 0.2 M as the model reaction to optimize the conditions at 150 °C for 12 h under O_2 atmosphere (Table 1). Only a trace amount of the desired quinoline **3aa** was detected using $Pd(PPh_3)_4$ as the catalyst without or with TsOH (entries 1-2). Pleasingly, the yield of **3aa** was increased to 20% with the addition of pyridine (entry 3). Next, the catalytic activity investigation of different palladium salts demonstrated that $Pd(OAc)_2$ is the better catalyst than others and a 33% yield was obtained (entries 3-8). After extensive screening of

the reaction conditions in terms of metal catalysts, such as Fe, Cu, Ni, and Co compounds, ligands (25 ligands) and additives, it was found that $Pd(OAc)_2$/2,4,6-Collidine/CF_3CO_2H remains the suitable catalytic system and 75% of **3aa** was obtained (entry 9, for details, please see the Electronic Supplementary Information, ESI). Lowering the concentration of **1a** from 0.2 M to 0.1 M led to a noticeable performance, providing **3aa** in 93% isolated yield (entry 10). Palladium and acid was indispensable for this reaction and a trace amount of products detected in the absence of them, respectively (entries 11-12). Also, the existence of the ligand 2,4,6-collidine was valuable for this transformation to gain excellent results and a sharp decrease of yield to 32% was obtained (entry 13). The reaction proceeded smoothly in air and resulted in 68% yield for a prolonged time (entry 14).

Table 1 Optimization of the reaction conditions.[a]



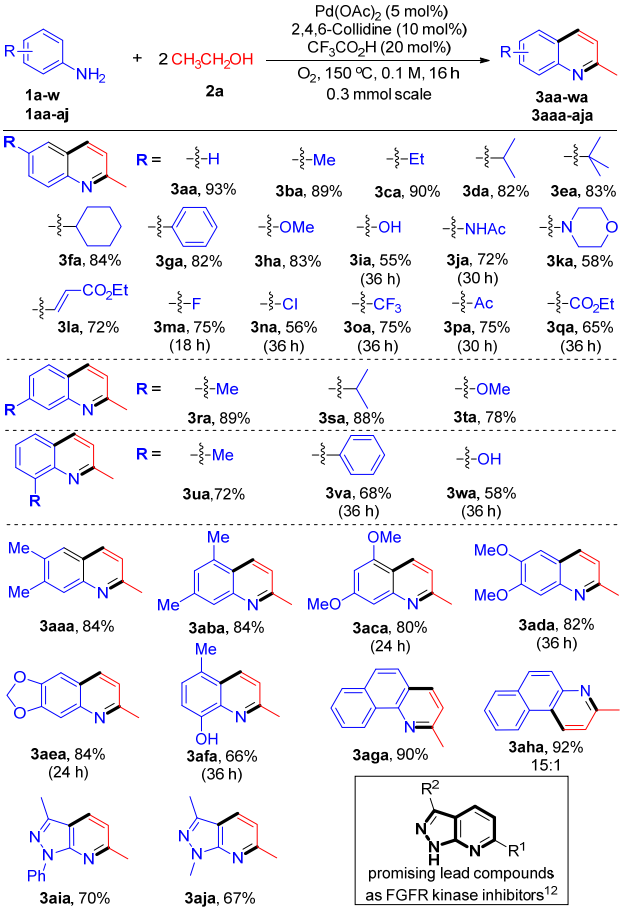
1a 2a 3aa

Entry	[Pd]-Cat.	Ligand	Acid	Yield[b]
1	$Pd(PPh_3)_4$			Trace
2	$Pd(PPh_3)_4$		TsOH	Trace
3	$Pd(PPh_3)_4$	Pyridine	TsOH	20%
4	$Pd_2(dba)_3$	Pyridine	TsOH	20%
5	$Pd(OAc)_2$	Pyridine	TsOH	33%
6	$Pd(TFA)_2$	Pyridine	TsOH	7%
7	$PdCl_2$	Pyridine	TsOH	16%
8	$[Pd(allyl)Cl]_2$	Pyridine	TsOH	20%
9	$Pd(OAc)_2$	2,4,6-Collidine	CF_3CO_2H	75%[c]
10[d]	$Pd(OAc)_2$	2,4,6-Collidine	CF_3CO_2H	93%[c]
11[d]		2,4,6-Collidine	CF_3CO_2H	trace
12[d]	$Pd(OAc)_2$	2,4,6-Collidine		trace
13[d]	$Pd(OAc)_2$		CF_3CO_2H	32%
14[de]	$Pd(OAc)_2$	2,4,6-Collidine	CF_3CO_2H	72%[c]

[a] Reaction conditions: **1a** (0.3 mmol), [Pd] (5 mol%), Ligand (10 mol%), Acid (20 mol%), ethanol **2a** (1.5 mL), O_2 (1 atm), 12 h. [b] The yield was determined by GC. [c] Yield of isolated product. [d] 3.0 mL ethanol used ([**1a**]: 0.1 M). [e] In air for 72 h.

Under the standard reaction conditions (Table 1, entry 10), we next investigated the substrate scope with respect to both anilines and aliphatic alcohols to evaluate the generality

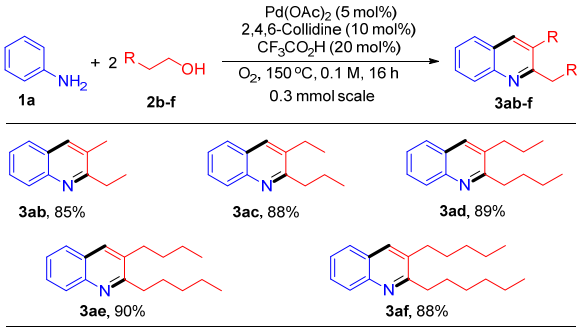
of the reaction. First, a wide range of aromatic amines were employed to react with ethanol **2a**. As shown in Scheme 2, the reactions proceeded smoothly with anilines bearing mono-substituent at ortho-, para-, or meta-position to afford the corresponding quinolines **3ba-3wa** in 55-90% yields regardless of the electronic characteristics. 8-hydroxy quinoline is a well-known ligand for abstraction of many metal ions (Cu^{2+}, Co^{2+}, Zn^{2+}, etc.).[13] Surprisingly, its 2-methyl analog **3wa** can be concisely prepared by the approach in a moderate yield. Disubstituted anilines were also compatible with this transformation and readily gave rise to **3aaa-afa** in 66-84% yields. Benzoquinolines **3aga** and **3aha** were obtained in more than 90%



Scheme 2 Scope of anilines

yields and 15:1 regioselectivity for **3aha** (1-/3-position). It is noteworthy that 1H-pyrazol-5-amines **1ai** and **1aj** be successfully converted into the corresponding 1H-pyrazolo[3,4-

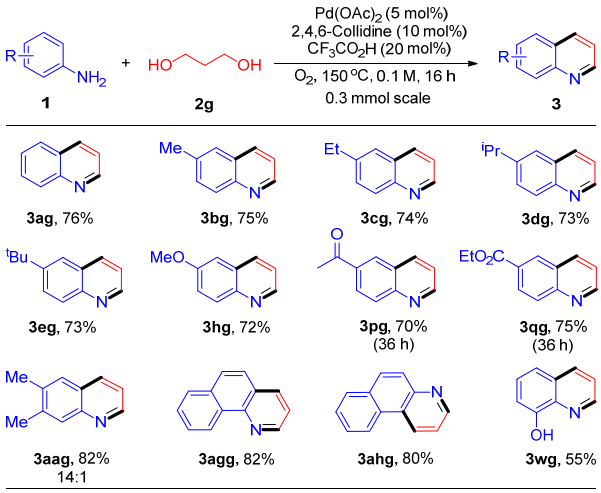
b]pyridines **3aia** and **3aja** in 70% and 67% yield, respectively. Recently, 1H-pyrazolo[3,4-*b*]pyridine derivatives were discovered to be promising lead compounds as potent and selective FGFR kinase inhibitors.[14] Undoubtedly, this protocol might streamline the synthesis of such useful compounds.



Scheme 3 Scope of primary aliphatic alcohols

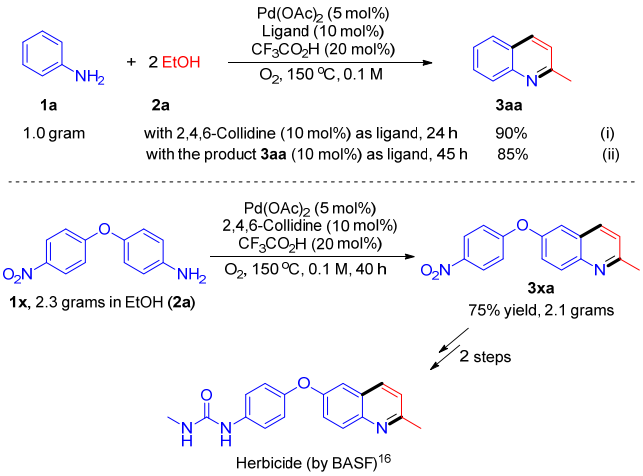
Next the scope of the aliphatic alcohols was investigated in scheme 3. The treatment of long-chain alcohols **2b-f** with **1a** to the standard reaction conditions produced 2,3-disubstituted quinolines **3ab-af** in 85-90% yields.

Significantly, the developed $Pd(OAc)_2$/2,4,6-Collidine/ CF_3COOH catalysis successfully extended to prepare another class of 2-nonsubstituted quinolines with propane-1,3-diol **2g** as the starting material.[7a] As shown in Scheme 4, alkyl and methoxyl groups worked well to afford the desired products **3bg-eg** and **3hg** in yields ranging from 72% to 75%. The use of **1q** and **1r** gave **3qg** and **3rg** in 70% and 75% yield for 36 hours, respectively. Dimethyl quinoline **3aag** was obtained in 82% with a 14:1 regioselectivity (2-/6-position). Benzoquinolines **3agg** and **3ahg** were readily produced in 82-80%. Importantly, the more challenging 2-aminophenol **1w** is also suitable for the process and laconically assembled the useful ligand 8-hydroxy quinoline **3wg**[13] in an acceptable yield.



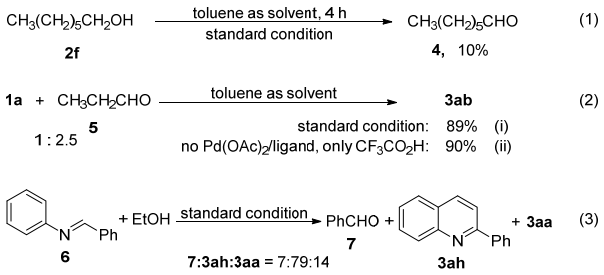
Scheme 4 Scope of anilines for the reaction with 2g

To highlight the practicability of the method, the gram-scale synthesis was conducted in scheme 5. Consequently, one gram-scale synthesis of **3aa** was executed and 90% yield obtained (Scheme 5, i). Interestingly, a slightly decreased yield of 85% was received by the direct use of the product **3aa** itself as the ligand instead of 2,4,6-collidine, intrinsically



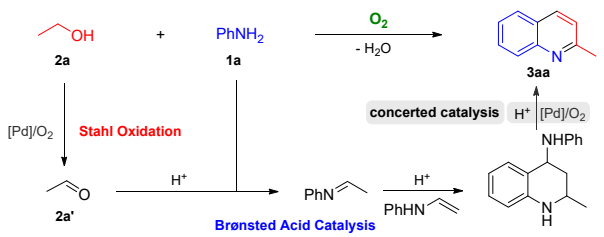
Scheme 5 Gram-scale reactions and formal synthesis of the promising herbicide candidate

obviating the difficulties in separation of the desired product **3aa** from extra pyridine-type ligand (Scheme 5, ii). Remarkably, the transformation of **1x** under the standard reaction conditions took place well in 2.3 gram-scale and effectively provided **3xa** in 75% yield. The synthetic block **3xa** is a useful motif for the concise synthesis of the herbicide candidate developed by BASF[16] (Scheme 5).



Scheme 6 Controlled reactions to verify hypothesis

Finally, several controlled reactions were performed to probe the possible reaction mechanism (Scheme 6). Aldehyde **4** can be detected in about 10% yield by treatment of alcohol **2f** to the $Pd(OAc)_2$-catalysis in toluene for 4 h (eq. 1). Quinoline **3ab** was formed effectively in 89% by the reaction of **1a** with 2.5 equiv. of propionaldehyde **5** in toluene (eq. 2, i). The similar yield was obtained only with CF_3CO_2H as catalyst (eq. 2, ii). Additionally, the subjection of imine **6** to the oxidative reaction conditions in EtOH gave rise to a mixed products of benzaldehyde **7**, **3ah**, and **3aa** in ratio of 7:79:14 (eq. 3). Aldehyde **7** should come from the hydrolysis of **6** with the simultaneous release of aniline **1a** that produced **3aa**. Based on the pioneering works on the oxidation of alcohols with oxygen[10,11] and the cyclization routes for quinoline synthesis,[8,9,15] the above observation suggested that the aldehyde synthesized in situ by Stahl oxidation was the high reactive intermediate for the aldimine formation, followed by cycloaddition with its enamine tautomer to form 2-Methyl-1,2,3,4-tetrahydroquinolin-4-yl(phenyl)amine, which resulted in the desired product via the elimination of an aniline molecule and subsequent aerobic oxidative aromatization (Scheme 7).[9b,15a,15c]



Scheme 7 Proposed reaction mechanism

In conclusion, we have realized the first example of aerobic oxidative synthesis of diverse quinolines from simple primary alcohols and anilines by a designed Pd/Brønsted acid catalysis, which streamlines efficiently the construction of quinoline and 1H-pyrazolo[3,4-*b*]pyridine derivatives with wide functional-group tolerance. Importantly, the new protocol can be easily scaled up to gram-scale and was utilized in the concise formal synthesis of a promising herbicide candidate. The use of abundantly available starting materials, environmental benign dioxygen molecule as oxidant, and cheap 2,4,6-collidine as ligand instead of traditional P-ligand should make this method particularly attractive.

Experimental Section

General Information: All non-aqueous manipulations were using standard Schlenk techniques. Reactions were monitored using thin-layer chromatography (TLC) on Silica Gel plates. Visualization of the developed plates was performed under UV light (254 nm) or $KMnO_4$ stain. Silica Gel Flash Column Chromatography was performed on SYNTHWARE 40-63μm silica gel. Unless otherwise indicated, starting catalysts and materials were obtained from Sigma Aldrich, TCI, Alfa Aesar, or Acros Co. Ltd. Moreover, commercially available reagents were used without additional purification. All NMR spectra were run at 400 MHz (^{1}H NMR) or 100 MHz (^{13}C NMR) or 377 MHz (^{19}F NMR) in $CDCl_3$ or d_6-DMSO solution. ^{1}H NMR spectra were internally referenced to TMS. ^{13}C NMR spectra were internally referenced to the residual solvent signal. High resolution mass spectra (HRMS) were recorded on Bruker MicrOTOF-Q II mass instrument (ESI).

Compounds **3aa**[17a], **3ba**[17a], **3ha**[17a], **3ma**[17a], **3na**[17a], **3oa**[17a], **3ag**[17a], **3bg**[17a], **3hg**[17a], **3ta**[17a], **3agg**[17b], **3an**[17p], **3wa**[7c], **3aca**[7c], **3ada**[7c], **3aga**[7c], **3ab**[17c], **3ac**[17c], **3ad**[17c], **3ae**[17c], **3af**[17c], **3ua**[17d], **3pa**[17e], **3aha**[17f], **3ahg**[17g], **3wg**[17h], **3ra**[8b], **3qg**[17i], **3aba**[9b], **3aca**[9b], **3pg**[17j], **3da**[17k], **3dg**[17k], **3ca**[17l], **3ea**[17m], **3aaa**[17n], **3cg**[17o],

3aag[17p] and **3eg**[17q] have previously been reported and their structure has been confirmed by comparison with the published spectral data.

General procedures for the products 3aa-wa and 3aaa-aja: Anilines 1 (0.3 mmol), $Pd(OAc)_2$ (5 mol %), 2,4,6-collidine (10 mol %) and CF_3COOH (20 mol %) was added to a flame-dried Schlenk tube which charged with a magnetic stir bar in 3.0 mL ethanol. The resulting suspension was stirred at 150℃ under O_2 for appropriate time. After celite filtration and evaporation of the solvents in vacuo, the crude product was purified by column chromatography on silica gel (petroleum/ethyl acetate=100/1) to yield products.

2-Methylquinoline (3aa): A yellow oil. Yield: 39.9 mg (93%). ^{1}H NMR (400 MHz, $CDCl_3$) δ = 8.00 (d, *J* = 8.4 Hz, 1H), 7.86 (d, *J* = 8.4 Hz, 1H), 7.66-7.54 (m, 2H), 7.36 (dd, *J* = 11.0, 4.0 Hz, 1H), 7.10 (d, *J* =8.4 Hz, 1H), 2.65 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ = 158.8, 147.8, 136.0, 129.3, 129.3, 128.5, 127.4, 127.4, 127.4, 126.4, 125.6, 125.5, 125.5, 121.9, 121.8, 25.3.

2,6-Dimethylquinoline (3ba): A light yellow oil. Yield: 43.8 mg (89%). ^{1}H NMR ($CDCl_3$, 400 MHz) δ= 8.01-8.04 (m, 2H), 7.60 (d, *J* = 8.0 Hz, 2H), 7.32 (s, 1H), 2.81 (s, 3H), 2.60 (s, 3H). ^{13}C NMR ($CDCl_3$, 100 MHz) δ = 158.0, 146.4, 135.6, 135.4, 131.7, 128.3, 126.5, 126.4, 122.0, 29.7, 25.2, 21.5.

6-Ethyl-2-methylquinoline (3ca): A light yellow oil. Yield: 46.2 mg (90%). ^{1}H NMR (400 MHz, $CDCl_3$) δ= 7.94 (t, *J* = 8.0 Hz, 2H), 7.54 (d, *J* = 8.0 Hz, 1H), 7.52 (s, 1H), 7.22 (s, 1), 2.80 (q, *J* = 8.0 Hz, 2H), 2.71 (s ,3H), 1.31(t, *J* = 8.0 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ= 158.0, 146.6, 141.6, 135.7, 130.6, 128.4, 126.5, 125.1, 125.1, 125.1, 125.0, 121.9, 121.9, 28.8, 25.3, 15.4.

6-*iso*-Propyl-2-methylquinoline (3da): A light yellow oil. Yield: 45.5 mg (82%). ^{1}H NMR ($CDCl_3$, 400 MHz) δ= 8.01 (t, *J* = 8.0 Hz, 2H), 7.63 (d, *J* = 8.0 Hz, 1H), 7.59 (s,1H), 7.28 (d, *J* = 8.0 Hz, 1H), 3.08-3.15 (m, 1H), 2.76 (s, 3H), 1.38 (d, *J* = 8.0 Hz, 6H). ^{13}C NMR ($CDCl_3$, 100 MHz) δ = 158.0, 146.7, 146.2, 135.9, 129.3, 128.4, 126.5, 123.6, 121.9, 34.0, 25.2, 23.9. HRMS (ESI) calcd. For $C_{13}H_{16}N$ [M+H]: 186.1283, found: 186.1277.

6-(*tert*-Butyl)-2-methylquinoline (3ea): A light yellow oil. Yield: 49.6 mg (83%). ^{1}H NMR ($CDCl_3$, 400 MHz) δ= 8.01-8.05 (m, 2H), 7.82 (d, *J* = 8.0 Hz, 1H), 7.72 (s, 1H), 7.29 (s, 1H), 2.77

(s, 3H), 1.46 (s, 9H). ^{13}C NMR ($CDCl_3$, 100 MHz) δ = 158.2, 148.4, 146.3, 136.2, 128.3, 128.1, 126.1, 126.0, 122.5, 121.9, 112.5, 34.8, 31.2, 25.2.

6-Cyclohexyl-2-methylquinoline (3fa): A light yellow oil. Yield: 56.7 mg (84%). ^{1}H NMR ($CDCl_3$, 400 MHz) δ= 7.96 (m, dd, J_1 = 1.2 Hz, J_2 = 8.0 Hz 2H), 7.55 (t, J = 8.0 Hz, 2H), 7.22(d, J = 8.0 Hz,1H), 2.71 (s, 3H), 2.62 -2.68 (m, 1H), 1.97 (d, J = 8.0 Hz, 2H), 1.95 (d, J = 8.0 Hz, 2H), 1.38-1.51 (m,4H),1.28-1.34 (m,2H). ^{13}C NMR ($CDCl_3$, 100 MHz) δ= 158.0, 145.5, 136.1, 129.8, 128.1, 126.5, 124.0, 121.9, 44.4, 34.4, 26.9, 26.2, 25.0. HRMS (ESI) calcd. For $C_{16}H_{20}N$ [M+H]: 226.1596, found: 226.1589.

2-Methyl-6-phenylquinoline (3ga): A light yellow oil. Yield: 53.9 mg (84%). ^{1}H NMR ($CDCl_3$,400 MHz) δ= 8.14 (d, J = 8.0 Hz, 1H), 8.10 (d, J = 8.0 Hz, 1H), 7.99 (d, J = 8.0 Hz, 2H), 7.74 (d, J = 8 Hz, 2H), 7.52 (t, J = 8.0 Hz ,2H), 7.44 (m 1H),7.32(d, J = 8.0 Hz, 1H), 2.80 (s, 3H). ^{13}C NMR ($CDCl_3$, 100 MHz) δ= 159.0, 147.3, 140.4, 138.4, 136.4, 129.1, 129.1, 128.9, 127.6, 127.4, 126.7, 125.2, 122.4, 25.4. HRMS (ESI) calcd. For $C_{16}H_{14}N$ [M+H]: 220.1126, found: 220.1133.

6-Methoxy-2-methylquinoline (3ha): A light yellow oil. Yield: 43.1 mg (83%). ^{1}H NMR ($CDCl_3$, 400 MHz) δ= 7.91 (d, J = 8.0 Hz, 2H), 7.32 (dd, J_1 = 1.2 Hz, J_2 = 8.0 Hz, 1H), 7.21 (d, J = 8.0 Hz, 1H), 7.01 (d, J = 8.0 Hz, 1H), 3.89 (s, 3H), 2.69 (s, 3H). ^{13}C NMR ($CDCl_3$, 100 MHz) δ= 157.1, 156.3, 143.8, 135.1, 129.9, 127.3, 122.3, 121.9, 105.2, 55.5, 24.9.

2-Methylquinolin-6-ol (3ia): A light yellow oil. Yield: 24.0 mg (55%). ^{1}H NMR (400 MHz, DMSO-d_6) δ= 8.03 (d, J = 8.0 Hz, 1H), 7.79 (d, J = 8.0 Hz, 1H), 7.29 (t, J = 8.0 Hz, 2H), 7.12 (s, J = 1.0 Hz, 1H), 2.60 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ =156.9, 151.7, 137.7, 136.1, 126.6, 126.6, 122.7, 117.6, 109.8, 24.9. HRMS (ESI) calcd. For $C_{10}H_{10}NO$ [M+H]: 160.0762, found: 160.0756.

N-(2-methylquinolin-6-yl)acetamide (3ja): A light yellow oil. Yield: 43.2 mg (72%). ^{1}H NMR ($CDCl_3$, 400 MHz) δ= 9.22 (s, 1H), 8.31 (s, 1H), 7.88 (dd, J_1 = 1.2 Hz, J_2 = 8.0 Hz, 2H), 7.56 (d, J = 8.0 Hz, 1H), 7.30 (m, 1H), 2.66 (s, 3H), 2.17 (s, 3H). ^{13}C NMR ($CDCl_3$, 100 MHz) δ = 169.4,

157.8, 144.7, 136.2, 135.8, 128.6, 126.9, 123.4, 122.5, 116.2, 24.9, 24.4. For $C_{12}H_{13}N_2O$ [M+H]: 201.1028, found: 201.1020.

4-(2-Methylquinolin-6-yl)morpholine (3ka): A light yellow oil. Yield: 39.7 mg (58%). ^{1}H NMR (400 MHz, $CDCl_3$) δ= 7.89 (t, *J* = 8.0 Hz 2H), 7.42 (dd, J_1 = 8 Hz, J_2 = 3.6, 1H), 7.19 (s, *J* = 8.0 Hz, 1H), 6.99 (d, *J* = 8.0 Hz, 1H), 3.89 (t, *J* = 8.0 Hz, 4H), 3.24 (t, *J* = 8.0 Hz, 4H), 2.68 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ = 156.2, 148.7, 143.5, 135.1, 129.3, 127.4, 122.3, 122.0, 109.2, 66.9, 49.6, 25.0. HRMS (ESI) calcd. For $C_{14}H_{17}N_2O$ [M+H]: 229.1341, found: 229.1338.

(E)-Ethyl 3-(2-methylquinolin-6-yl)acrylate (3la): A light yellow oil. Yield: 52.1 mg (72%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.01-8.05 (m, 2H), 7.85 (t, *J* = 8.0 Hz, 3H), 7.31 (d, *J* = 8.0 Hz, 1H), 6.55 (d, *J* = 8.0 Hz, 1H), 4.31 (q, 2H), 2.76 (s,3H),1.37 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ = 166.9, 160.2, 148.6, 143.8, 136.6, 136.5, 136.4, 131.8, 129.4, 129.0, 127.2, 126.4, 119.0, 119.0, 119.0, 60.6, 29.7, 29.7, 25.5, 25.4, 25.4, 14.4. HRMS (ESI) calcd. For $C_{15}H_{16}NO_2$ [M+H]: 242.1181, found: 242.1173.

6-Fluoro-2-methylquinoline (3ma): A light yellow oil. Yield: 36.2 mg (75%). ^{1}H NMR (400 MHz, $CDCl_3$) δ= 7.97-8.05 (m, 2H), 7.47 (t, *J* = 4.0 Hz, 1H), 7.40 (d, *J* = 8.0 Hz, 1H), 7.31 (m, 1H), 2.76 (s, 3H). ^{13}C NMR (100 MHz) δ= 161.1, 158.7, 158.3, 158.3, 144.9, 135.5, 135.5, 131.0, 130.9, 127.0, 126.9, 122.7, 119.6, 119.3, 110.6, 110.4, 25.2. ^{19}F NMR ($CDCl_3$, 376 MHz): δ= -114.5 ppm.

6-Chloro-2-methylquinoline (3na): A white solid. Yield: 30.6 mg (56%). ^{1}H NMR (400 MHz, $CDCl_3$) δ= 7.99 (d, *J* = 8.0 Hz, 2H), 7.79 (s, 1H), 7.65 (d, *J* = 8.0 Hz , 1H), 7.34 (d, *J* = 8.0 Hz ,1H), 2.77 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ= 159.4, 146.2, 135.2, 131.3, 130.3, 130.2, 127.1, 126.2, 122.9, 25.3.

6-trifluoromethyl-2-methylquinoline (3oa) : A white solid (47.5 mg , 75%) .^{1}H NMR (400 MHz, $CDCl_3$) δ = 8.16 (t , J = 8.0Hz, 3H), 7.90 (d, J = 8.0 Hz, 1H), 7.43(d, J = 8.0Hz, 1H) , 2.83 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ = 161.5, 148.8, 136.8, 129.8, 125.5, 125.4, 125.2, 125.1, 123.2, 25.5. ^{19}F NMR ($CDCl_3$, 376 MHz): δ = -62.13 ppm .

1-(2-Methylquinolin-6-yl)ethanone (3pa): A white solid. Yield: 41.6 mg (75%). ^{1}H NMR (400 MHz, $CDCl_3$) δ= 8.35 (s, 1H), 8.18 (d, *J* = 8.0 Hz, 1H), 8.10 (d, *J* = 8.0 Hz, 1H), 8.01 (d, *J* = 8.0 Hz, 1H), 7.31 (d, *J* = 8.0 Hz, 1H), 2.73 (s, 3H), 2.65 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ = 169.4, 158.0, 144.7, 136.2, 135.8, 128.6, 126.9, 123.4, 122.5, 116.2, 24.9, 24.4.

Ethyl 2-methylquinoline-6-carboxylate (3qa): A white solid. Yield: 41.9 mg (65%). ^{1}H NMR (400 MHz, $CDCl_3$) δ= 8.51 (s, 1H), 8.25 (d, *J* = 8.0 Hz, 1H), 8.11 (d, *J* = 8.0 Hz, 1H), 8.02 (d, *J* = 8.0 Hz, 1H), 7.31 (d, *J* = 8.0 Hz, 1H), 4.42 (q, 2H), 2.74 (s, 3H), 1.42 (t, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ = 197.4, 161.8, 149.8, 137.5, 134.1, 129.6, 129.1, 127.8, 125.6, 122.9, 26.7, 25.6. HRMS (ESI) calcd. For $C_{13}H_{14}NO_2$ [M+H]: 216.1025, found: 216.1018.

2,7-Dimethylquinoline (3ra): A yellow oil. Yield: 41.9 mg (89%). ^{1}H NMR (400 MHz, $CDCl_3$) δ= 7.93 (d, *J* = 8.0 Hz, 2H), 7.50 (d, *J* = 8.0 Hz, 2H), 7.22 (d, *J* = 8.0 Hz, 1H), 2.72 (s, 3H) , 2.50 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ = 158.0, 135.7, 135.4, 131.7, 128.1, 126.5, 126.4, 122.0, 25.1, 21.5.

7-Isopropyl-2-methylquinoline (3sa): A yellow oil. Yield: 48.8 mg (88%). ^{1}H NMR ($CDCl_3$, 400 MHz) δ= 7.97 (d, *J* = 8.0 Hz,1H), 7.87 (s, 1H), 7.67 (d, *J* = 8.0 Hz, 1H), 7.37 (d, *J* = 8.0 Hz, 1H), 7.19 (d, *J* = 8.0 Hz, 1H), 3.09 (m, 1H), 2.71 (s, 3H), 1.34 (d, *J* = 8.0 Hz, 6H). ^{13}C NMR ($CDCl_3$, 100 MHz) δ = 158.8, 150.6, 148.0, 136.0, 127.2, 125.8, 124.9, 124.7, 121.3, 34.3, 25.2, 23.8, 23.8. HRMS (ESI) calcd. For $C_{13}H_{16}N$ [M+H]: 186.1283, found: 186.1276.

7-Methoxy-2-methylquinoline (3ta): A yellow oil. Yield: 40.5 mg (78%). ^{1}H NMR ($CDCl_3$, 400 MHz) δ= 7.93 (d, *J* =8.0 Hz, 1H), 7.62 (d, *J* = 8.0 Hz, 1H), 7.37 (s, 1H), 7.11-7.14 (m, 2H), 3.92 (s, 3H), 2.70 (s, 3H). ^{13}C NMR ($CDCl_3$, 100 MHz) δ = 160.8, 159.2, 149. 5, 135.9, 128.5, 121.6, 119.8, 118.7, 106.7, 55.5, 25.2.

2,8-dimethylquinoline (**3ua**): A yellow oil. Yield: 33.9 mg (72%). ^{1}H NMR ($CDCl_3$, 400 MHz) δ= 8.04 (d, *J* = 8.0 Hz, 1H), 7.66 (d, *J* = 8.0 Hz, 1H), 7.58 (d, *J* = 8.0 Hz, 1H), 7.41(t , *J* = 8.0 Hz, 1H), 7.31 (d, *J* = 8.0 Hz, 1H), 2.87 (s, 3H), 2.82 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ = 157.9, 147.0, 136.5, 136.2, 129.5, 126.4, 125.5, 125.3, 121.6, 25.7, 18.0.

2-Methyl-8-phenylquinoline (3va): A yellow oil. Yield: 44.7 mg (68%). ^{1}H NMR ($CDCl_3$, 400 MHz) δ= 8.14 (d, *J* = 8.0 Hz, 1H), 7.88 (d, *J* = 8.0 Hz, 2H), 7.80- 7.85 (m, 2H), 7.56-7.63 (m, 3H), 7.50 (d, *J* = 8.0 Hz, 1H), 7.36 (d, *J* = 8.0 Hz 1H), 2.77 (s, 3H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ= 158.8, 145.5, 139.9, 139.6, 136.3, 131.1, 130.3, 127.8, 127.3, 127.1, 127.0, 125.4, 121.8, 25.8. HRMS (ESI) calcd. For $C_{16}H_{14}N$ [M+H]: 220.1126, found: 220.1133.

2-methylquinolin-8-ol (3wa) : A white solid (27.7 mg , 58%) . ^{1}H NMR ($CDCl_3$,400 MHz): δ = 8.07 (d, J = 8.0Hz,1H), 7.42 (t, J = 8.0 Hz, 1H), 7.33 (t, J = 8.0 Hz, 2H), 7.19 (d, J = 8.0 Hz, 1H),2.77 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ = 156.9, 151. 7, 137.7, 136.1, 126.6, 126.6, 122.7, 117.6, 109.8, 24.9. ppm. HRMS (ESI) calcd. For $C_{10}H_{10}NO$ [M+H]: 160.0762 , found: 160.0755 .

2,6,7-Trimethylquinoline (3aaa): A yellow oil. Yield: 27.7 mg (84%). ^{1}H NMR ($CDCl_3$,400 MHz) δ= 7.92 (d, *J* = 8.0 Hz, 1H), 7.81 (s, 1H), 7.50 (s, 1H), 7.19 (d, *J* = 8.0 Hz, 1H), 2.73 (s, 3H), 2.47 (s, 3H), 2.43 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ = 157.9, 147.0, 139.5, 135.3, 135.1, 128.0, 126.7, 125.0, 121.1, 25.2, 20.4, 19.9.

2,5,7-Trimethylquinoline (3aba): A yellow oil. Yield: 27.7 mg (84%).The title compound was prepared according to the general procedure as a yellow oil (27.7 mg, 84%). ^{1}H NMR ($CDCl_3$, 400 MHz) δ= 8.10 (d, *J* = 8.0 Hz, 1H), 7.65 (s, 1H), 7.19 (d, *J* = 8.0 Hz, 1H) 7.12 (s,1H), 2.70 (s, 3H), 2.59 (s, 3H), 2.48 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ = 158.3, 148.4, 139.2, 133.9, 132.4, 128.5, 128.5, 125.9, 123.8, 120.7, 25.1, 21.8, 18.5.

5,7-Dimethoxy-2-methylquinoline (3aca): A yellow oil. Yield: 48.7 mg (80%). ^{1}H NMR ($CDCl_3$, 400 MHz) δ= 8.32 (d, *J* = 8.0 Hz, 1H), 7.12 (d, *J* = 8.0 Hz, 1H), 7.01 (s, 1H), 6.47(s, 1H), 3.95 (d, 6H), 2.71 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ = 161.3, 159.5, 156.0, 150.0, 130.9, 118.8, 114.7, 99.1, 97.3, 55.7, 55.5, 25.1.

6,7-Dimethoxy-2-methylquinoline (3ada): A yellow oil. Yield: 49.9 mg (82%). ^{1}H NMR ($CDCl_3$, 400 MHz) δ= 7.82 (d, *J* = 8.0 Hz, 1H), 7.32 (s, 1H), 7.08 (d, *J* = 8.0 Hz, 1H), 6.94 (s, 1H), 3.96 (d, 3H), 3.93 (s, 3H), 2.63 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ = 156.5, 152.2, 149.0, 144.6, 134.5, 121.7, 120.1, 107.4, 105.0, 56.0, 55.9, 24.9.

6-Methyl-[1,3]dioxolo[4,5-g]quinoline (3aea): A white solid. Yield: 47.1 mg (84%). ^{1}H NMR ($CDCl_3$, 400 MHz) δ= 7.87 (d, *J* = 8.0 Hz, 1H), 7.35 (s, 1H), 7.15 (d, *J* = 8.0 Hz, 1H), 7.03 (s, 1H), 6.10 (s, 2H), 2.70 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ = 156.5, 150.6, 145.9, 135.1, 123.1, 120.2, 105.3, 102.7, 101.5, 101.3, 29.7, 24.9. HRMS (ESI) calcd. For $C_{11}H_{10}NO_2$ [M+H]: 188.0712, found: 188.0718.

2,6-Dimethylquinolin-8-ol (3afa): A white solid. Yield: 34.3 mg (66%). ^{1}H NMR ($CDCl_3$, 400 MHz) δ= 8.18 (d, *J* = 8.0 Hz, 1H), 7.35 (d, *J* = 8.0 Hz, 1H), 7.22 (d, *J* = 8.0 Hz, 1H), 7.08 (d, *J* = 8.0 Hz, 1H) , 2.76 (s, 3H), 2.60 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ = 156.3, 145.0, 137.9, 133.1, 126.5, 125.7, 124.1, 122.2, 109.1, 24.8, 17.8. HRMS (ESI) calcd. For $C_{11}H_{12}NO$ [M+H]: 174.0919, found: 174.0926.

2-Methylbenzo[h]quinoline (3aga): A white solid. Yield: 52.1 mg (90%). ^{1}H NMR ($CDCl_3$, 400 MHz) δ= 9.38 (d, *J* = 8.0 Hz,1H), 8.03 (d, *J* = 8.0 Hz, 1H), 7.90 (d, *J* = 8.0 Hz, 1H), 7.63-7.77(m , 4H), 7.38 (d, *J* = 8.0 Hz, 1H), 2.82 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ = 157.8, 146.0, 136.1, 136.0, 135.8, 133.7, 131.4, 127.9, 127.7, 127.0, 126.8, 126.7, 125.2, 25.5.

2-Methylbenzo[g]quinoline (3aha): A white solid. Yield: 53.3 mg (90%). ^{1}H NMR ($CDCl_3$, 400 MHz) δ= 8.80 (d, *J* = 8.0 Hz, 1H), 8.57 (d, *J* = 8.0 Hz, 1H), 7.98 (s, 2H), 7.94(d, *J* = 8.0 Hz, 1H), 7.61-7.69 (m, 2H), 7.42 (d, *J* = 8.0 Hz, 1H), 2.82 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ = 158.4, 147.7, 131.3, 130.9, 130.7, 129.7, 128.6, 127.8, 127.0, 126.8, 126.8, 25.0.

3,6-Dimethyl-1-phenyl-1H-indazole (3aia): A white solid. Yield: 46.6 mg (70%). ^{1}H NMR ($CDCl_3$, 400 MHz) δ= 8.44 (d, *J* = 8.0 Hz, 1H), 8.25 (d, *J* = 8.0 Hz, 2H), 7.54 (t, *J* = 8.0 Hz, 2H), 7.31 (t, *J* = 8.0 Hz, 1H), 6.93 (d, *J* = 8.0 Hz, 1H), 2.79 (s, 3H), 2.74 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ = 151.1, 149.2, 149.0, 148.9, 143.1, 142.6, 139.5, 129.1, 129.0, 129.0, 125.5, 121.3, 121.2, 118.4, 116.6, 29.7, 19.1, 15.5. HRMS (ESI) calcd. For $C_{15}H_{15}N_2$ [M+H]: 224.1188, found: 224.1180.

1,3,6-Trimethyl-1H-pyrazolo[3,4-b]pyridine (3aja): A light yellow solid. Yield: 31.4 mg (66%). ^{1}H NMR ($CDCl_3$, 400 MHz) δ= 8.31 (d, *J* = 8.0 Hz, 1H), 6.77 (d, *J* = 8.0 Hz, 2H), 4.03 (s, 3H), 2.65 (d, 6H). ^{13}C NMR (100 MHz, $CDCl_3$) δ = 151.3, 148.7, 148.6, 148.5, 143.0, 140.4, 117.0, 114.8, 33.5, 19.0, 15.1. HRMS (ESI) calcd. For $C_9H_{12}N_3$ [M+H]: 162.1031, found: 162.1024.

General procedures for the products 3ab-f: Anilines **1a** (0.3 mmol), $Pd(OAc)_2$ (5 mol%), 2,4,6-Collidine (10 mol%) and CF_3COOH (20 mol%) was added to a flame-dried Schlenk tube which charged with a magnetic stir bar in 3 mL solvent. The resulting suspension was stirred at 150 ºC under O_2 for appropriate time. Then the reaction was quenched with 10 mL of distilled water and extracted with EtOAc (10×3 mL), then dried over with Na_2SO_4. The organic liquid was then removed in vacuo and the resulting mixture was purified by column chromatography on silica gel (petroleum/ethyl acetate=100/1) to yield products.

2-ethyl-3-methylquinoline (3ab) : A yellow oil (42.1 mg, 85%) . ^{1}H NMR ($CDCl_3$, 400 MHz) δ = 8.07 (d, *J* = 8.0 Hz, 1H), 7.87(s, 1H), 7.74 (d, *J*= 8.0 Hz, 1H), 7.66 (m, 1H), 7.45(t, *J* = 8.0Hz, 1H) , 3.04 (t, *J* = 8.0 Hz, 2H), 2.52 (s, 3H), 1.42 (q, 3H) ppm.

3-Ethyl-2-propylquinoline (3ac): A yellow oil. Yield: 52.5 mg (88%). ^{1}H NMR ($CDCl_3$, 400 MHz) δ= 8.07 (d, *J* = 8.0 Hz, 1H), 7.87 (s, 1H), 7.75 (d, *J* = 8.0 Hz, 1H), 7.64 (t, *J* = 8.0 Hz, 1H), 7.47 (t, *J* = 8.0 Hz, 1H), 3.01 (t, *J* = 8.0 Hz, 2H), 2.88 (t, *J* = 8.0 Hz, 2H), 1.74-1.84 (m, 2H), 1.03 (t, *J* = 8.0 Hz, 3H), 1.09 (t, *J* = 8.0 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ = 162.0, 146.4, 135.4, 133.9, 128.7, 128.4, 127.4, 126.9, 125.6, 37.8, 25.2, 23.0, 14.5, 14.4.

2-Butyl-3-propylquinoline (3ad): A yellow oil. Yield: 60.6 mg (90%). ^{1}H NMR ($CDCl_3$, 400 MHz) δ= 8.07 (d, *J* = 8.0 Hz, 1H), 7.90 (s, 1H), 7.77 (d, *J* = 8.0 Hz, 1H), 7.66 (t, *J* = 8.0 Hz, 1H), 7.50 (d, *J* = 8.0 Hz, 1H), 3.02 (t, *J* = 8.0 Hz, 2H), 2.80 (t, *J* = 8.0 Hz, 2H), 1.74-1.84 (m, 4H), 1.52-1.57 (m, 2H), 1.03 (t, *J* = 8.0 Hz, 3H), 1.09 (t, *J* = 8.0 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ = 162.3, 146.5, 134.9, 133.9, 128.4, 128.3, 127.2, 126.9, 125.5, 35.7, 34.4, 31.9, 23.6, 23.1, 14.10, 14.07.

3-Butyl-2-pentylquinoline (3ae): A yellow oil. Yield: 68.9 mg (90%). ^{1}H NMR ($CDCl_3$, 400 MHz) δ= 8.07 (d, *J* = 8.0 Hz, 1H), 7.89 (s, 1H), 7.76 (d, *J* = 8.0 Hz, 1H), 7.65 (t, *J* = 8.0 Hz, 1H), 7.49 (t , *J* = 8.0 Hz, 1H), 3.03 (t, *J* = 8.0 Hz, 2H), 2.94 (t, *J* = 8.0 Hz, 2H), 1.84- 1.87 (m, 2H), 1.75-1.17 (m,

2H), 1.41-1.52 (m, 6H), 0.97-1.05 (m, 6H). ^{13}C NMR (100 MHz, $CDCl_3$) δ = 162.3, 146.50, 134.9, 133.9, 128.4, 128.3, 127.2, 126.9, 125.5, 35.7, 34.4, 31.9, 31.4, 30.2, 23.6, 23.1, 14.10, 14.07.

2-Hexyl-3-pentylquinoline (3af): A yellow oil. Yield: 74.7 mg (88%). ^{1}H NMR ($CDCl_3$, 400 MHz) δ= 8.06 (d, *J* = 8.0 Hz, 1H), 7.88 (s, 1H), 7.76 (d, *J* = 8.0 Hz, 1H), 7.65 (t, *J* = 8.0 Hz, 1H), 7.49 (t, *J* = 8.0 Hz, 1H), 3.02 (t, *J* = 8.0 Hz, 2H), 2.82 (t, *J* = 8.0 Hz, 2H), 1.74-1.85 (m, 4H), 1.31-1.52 (m, 16H). ^{13}C NMR (100 MHz, $CDCl_3$) δ = 162.3, 146.5, 134.8, 134.2, 128.4, 128.3, 127.2, 126.9, 125.5, 36.0, 32.4, 31.8, 30.2, 29.8, 29.7, 29.2, 22.7, 22.6, 14.11, 14.06.

General procedures for the products 3ag-3wg: Anilines **1** (0.3 mmol), $Pd(OAc)_2$ (5 mol%), 2,4,6-Collidine (10 mol%) and CF_3COOH (20 mol%) was added to a flame-dried Schlenk tube which charged with a magnetic stir bar in 3.0 mL propan-1,3-diol. The resulting suspension was stirred at 150 ºC under O_2 for appropriate time. Then the reaction was quenched with 10 mL of distilled water and extracted with EtOAc (10×3 mL), then dried over with Na_2SO_4. The organic liquid was then removed in vacuo and the resulting mixture was purified by column chromatography on silica gel (petroleum/ethyl acetate=100/1) to yield products.

Quinoline (3ag): A yellow oil. Yield: 29.4 mg (76%). ^{1}H NMR ($CDCl_3$, 400 MHz) δ= 8.74 (s, 1H), 8.00 (d, *J* = 8.0 Hz, 1H), 7.84 (d, *J* = 8.0 Hz, 1H), 7.48-7.55 (m, 2H), 7.30 (t, *J* = 8.0 Hz, 1H), 7.10 (t, *J* = 8.0 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ = 150.2, 148.1, 135.8, 129.3, 128.1, 127.7, 126.3, 120.9

6-Methylquinoline (3bg): A yellow oil. Yield: (32.6 mg (75%). ^{1}H NMR ($CDCl_3$, 400 MHz) δ= 8.94 (s, 1H), 8.05 (d, *J* = 8.0 Hz, 1H), 8.00 (d, *J* = 8.0 Hz, 1H), 7.51- 7.57(m, 2H), 7.34-7.37 (m, 1H), 2.54 (s, 3H).

6-Ethylquinoline (3cg): A yellow oil. Yield: 34.9 mg (73%). ^{1}H NMR ($CDCl_3$, 400 MHz) δ= 8.85 (s, 1H), 8.09 (d, *J* = 8.0 Hz, 1H), 8.03 (d, *J* = 8.0 Hz, 1H), 7.58-7.65 (m, 2H), 7.34-7.38 (m, 1H), 2.94 (q, 2H), 1.34 (t, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ = 149.6, 147.1, 142.6, 135.6, 130.7, 129.2, 128.4, 125.3, 121.0, 28.9, 15.4.

6-*iso*-Propylquinoline (3dg): A yellow oil. Yield: 37.4 mg (73%). ^{1}H NMR ($CDCl_3$, 400 MHz) δ= 8.89 (s, 1H), 8.15 (d, *J* = 8.0 Hz, 1H), 8.09 (d, *J* = 8.0 Hz, 1H), 7.58-7.66 (m, 2H), 7.37-7.43 (m, 1H), 3.11-3.31 (m, 1H), 1.39 (d, 6H).

6-(*tert*-Butyl)quinoline (3eg): A yellow oil. Yield: 40.5 mg (73%). ^{1}H NMR ($CDCl_3$, 400 MHz) δ= 8.85 (d, *J* = 8.0 Hz, 1H), 8.11 (d, *J* = 8.0 Hz, 1H), 8.05 (d, *J* = 8.0 Hz, 1H), 7.80-7.82 (m, 1H), 7.72 (d, *J* = 8.0 Hz, 1H), 7.34-7.37 (m, 1H), 1.42(s, 9H).

6-Methoxyquinoline (3hg): A yellow oil. Yield: 34.3 mg (72%). ^{1}H NMR ($CDCl_3$, 400 MHz) δ= 8.78 (d, *J* = 8.0 Hz, 1H), 8.02-8.07 (m, 2H), 7.35- 7.41 (m, 2H), 7.08 (d, *J* = 8.0 Hz, 1H), 3.94 (s, 3H).

1-(Quinolin-6-yl)ethanone (3pg): A white solid. Yield: 35.9 mg (70%). ^{1}H NMR ($CDCl_3$, 400 MHz) δ= 9.01 (d, *J* = 8.0 Hz, 1H), 8.45 (s, 1H), 8.25-8.30 (m, 2H), 8.16 (d, *J* = 8.0 Hz, 1H), 7.47-7.50 (m, 1H), 2.74 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ = 197.4, 152.6, 150.1, 137.6, 134.9, 130.1, 129.9, 127.7, 127.5, 122.0, 26.8.

Ethyl quinoline-6-carboxylate (3qg): A yellow solid. Yield: 45.2 mg (75%). ^{1}H NMR ($CDCl_3$, 400 MHz) δ= 9.00 (d, *J* = 8.0 Hz, 1H), 8.59 (s, 2H), 8.25-8.32 (m, 2H), 8.14 (d, *J* = 8.0 Hz, 1H), 7.46-7.49 (m, 1H), 4.45 (q, 2H), 1.45 (t, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ =166.1, 152.4, 150.0, 137.3, 130.9, 129.7, 129.0, 127.4, 121.8, 61.4, 14.4.

6,7-Dimethylquinoline (3aag): A yellow solid. Yield: 38.6 mg (82%). ^{1}H NMR ($CDCl_3$, 400 MHz) δ= 8.93-8.95 (m, 1H), 8.05 (d, *J* = 8.0 Hz, 1H), 7.56 (s, 1H), 8.14 (d, *J* = 8.0 Hz, 1H), 7.30-7.33 (m, 1H), 2.50 (t, 3H), 2.45 (s, 3H).

Benzo[h]quinoline (3agg): A yellow solid. Yield: 44 mg (82%). ^{1}H NMR ($CDCl_3$, 400 MHz) δ= 9.35 (d, *J* = 8.0 Hz, 1H), 9.00-9.02 (m, 1H), 8.07-8.10 (m, 1H), 7.99 (d, *J* = 8.0 Hz, 1H), 7.75-7.79 (m, 2H), 7.68-7.72 (m, 1H), 7.61 (d, *J* = 8.0 Hz, 1H), 7.44-7.47 (m, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ = 148.8, 146.6, 135.8, 133.6, 131.5, 128.2, 127.9, 127.8, 127.1, 126.4, 125.4, 124.4, 121.8.

Benzo[f]quinolone (3ahg): A yellow solid. Yield: 43 mg (80%). ^{1}H NMR ($CDCl_3$, 400 MHz) δ= 8.99-9.03 (m ,1H), 8.94 (d, *J* = 8.0 Hz, 1H), 6.62 (d, *J* = 8.0 Hz, 1H), 7.94-8.05 (m, 3H), 7.65-7.73 (m, 2H), 7.55-7.58 (m, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ = 149.7, 148.2, 131.7, 130.9, 130.7, 129.6, 128.7, 128.2, 127.3, 127.1, 125.4, 122.6, 121.3.

Quinolin-8-ol (3wg): A white solid. Yield: 23.9 mg (55%). ^{1}H NMR ($CDCl_3$, 400 MHz) δ= 8.84-8.86 (m, 1H), 8.15-8.18 (m, 1H), 7.51 (t, *J* = 8.0 Hz, 1H), 7.42-7.45 (m, 1H), 7.38-7.35 (m, 1H), 7.27-7.29 (m, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ = 152.4, 148.0, 138.3, 136.2, 128.6, 127.8, 121.8, 118.0, 110.4.

2-Methyl-6-(4-nitrophenoxy)quinoline (3xa): 2.3 g aniline in this gram-scale synthesis. A light yellow solid. Yield: 2.1 g (75%). ^{1}H NMR ($CDCl_3$, 400 MHz) δ= 8.23 (d, *J* = 8.0 Hz, 2H), 8.11 (d, *J* = 8.0 Hz, 1H), 8.02 (t, *J* = 8.0 Hz, 1H), 7.46 (d, *J* = 8.0 Hz, 2H), 7.35 (d, *J* = 8.0 Hz, 1H), 7.09 (d, *J* = 8.0 Hz, 2H), 2.78 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ = 163.0, 158.9, 152.0, 145.5, 142.9, 135.8, 135.6, 131.4, 127.2, 126.1, 125.9, 123.8, 122.8, 117.8, 117.6, 25.3. HRMS (ESI) calcd. For $C_{16}H_{13}N_2O_3$ [M+H]: 281.0926, found: 281.0915.

2-Phenylquinoline (3ah): A light yellow solid. ^{1}H NMR ($CDCl_3$, 400 MHz) δ= 8.18-8.23 (m, 4H), 7.88 (d, *J* = 8.0 Hz, 1H), 7.83 (d, *J* = 8.0 Hz, 1H), 7.74 (t, *J* = 8.0 Hz, 1H), 7.46-7.63 (m, 4H). ^{13}C NMR (100 MHz, $CDCl_3$) δ = 157.4, 148.3, 139.7, 136.8, 129.8, 129.7, 129.3, 128.9, 127.6, 127.5, 127.2, 126.3, 119.0.

Acknowledgment: Financial support from the Hundred Talent Program of Chinese Academy of Sciences (CAS), the National Natural Science Foundation of China (21602231) and the Natural Science Foundation of Jiangsu (Grant No. BK20151235 and BK20160396) are gratefully acknowledged.

Supporting Information: Copy of ^{1}H and ^{13}C NMR spectra of all compounds were presented on supporting information.

References

[1] (a) Candeias, N. R.; Branco, L.-C.; Gois, P. M. P.; Afonso, C. A. M.; Trindade, A.-F. *Chem. Rev.* **2009**, *109*, 2703-2802; (b) Elguero, J.; Silva, A. M. S.; Tome, A. C. In *Modern*

Heterocyclic Chemistry; Alvarez-Builla, J.; Vaquero, J. J.; Eds. Barluenga, J. Wiley-VCH: Weinheim, 2011; Vol. 2, pp 635; (c) Andries, K.; Verhasselt, P.; Guillemont, J.; et al. *Science* **2005**, *307*, 223-227; (d) Bax, B. D.; Chan, P. F.; Eggleston, D. S.; et al. *Nature* **2010**, *466*, 935-940; (e) Vandekerckhove, S.; D'hooghe, M. *Bioorg. Med. Chem.* **2015**, *23*, 5098-5119.

[2] (a) Zhang, Y.; Sigman, M. S. *J. Am. Chem. Soc.* **2007**, *129*, 3076-3077; (b) Jiang, H.; He, J.; Liu, T.; Yu, J.-Q. *J. Am. Chem. Soc.* **2016**, *138*, 2055-2059; (c) Chen, G.; Gong, W.; Zhuang, Z.; Andrä, M. S.; Chen, Y.-Q.; Hong, X.; Yang, Y.-F.; Liu, T.; Houk, K. N.; Yu, J.-Q. *Science* **2016**, *353*, 1023-1027; (d) Volla, C. M. R.; Atodiresei, I.; Rueping, M. *Chem. Rev.* **2014**, *114*, 2390-2431.

[3] (a) Fabian, J.; Nakazumi, H.; Matsuoka, M. *Chem. Rev.* **1992**, *92*, 1197-1226; (b) Mishra, A.; Behera, R. I. K.; Behera, P. K.; Mishra, B. K.; Behera, G. B. *Chem. Rev.* **2000**, *100*, 1973-2012.

[4] (a) Kouznetsov, V. V.; Méndez, L. Y. V.; Gómez, C. M. M. *Curr. Org. Chem.* **2005**, *9*, 141-161; (b) Yamashkin, S. A.; Oreshkina, E. A. *Chem. Heterocycl. Compd.* **2006**, *42*, 701-718; (c) Madapa, S.; Tusi, Z.; Batra, S. *Curr. Org. Chem.* **2008**, *12*, 1116-1183; (d) Marco-Contelles, J.; Pérez-Mayoral, E.; Samadi, A.; Carreiras, M. C.; Soriano, E. *Chem. Rev*. **2009**, *109*, 2652-2671; (e) Eftekhari-Sis, B.; Zirak, M. *Chem. Rev.* **2015**, *115*, 151-264.

[5] (a) Mastalir, M.; Glatz, M.; Pittenauer, E.; Allmaier, G.; Kirchner, K. *J. Am. Chem. Soc.* **2016**, *138*, 15543-15546; (b) Li, C.; Li, J.; An, Y.; Peng, J.; Wu, W.; Jiang, H. *J. Org. Chem.* **2016**, *81*, 12189-12196.

[6] Barta, K.; Ford, P. C. *Acc. Chem. Res.* **2014**, *47*, 1503-1512.

[7] For review, see: (a) Khusnutdinov, R. I.; Bayguzina, A. R.; Dzhemilev, U. M. *J. Organomet. Chem.* **2014**, *768*, 75-114; for selected examples, see: (b) Tsuji, Y.; Huh, K.-T.; Watanabe, Y. *J. Org. Chem.* **1987**, *52*, 1673-1680; (c) Zhang, Z.; Tan, J.; Wang, Z. *Org. Lett.* **2008**, *10*, 173-175; (d) Aramoto, H.; Obora, Y.; Ishii, Y. *J. Org. Chem.* **2009**, *74*, 628-633; (e) Mura, M. G.; Rajamäki, S.; Luca, L. D.; Cini, E.; Porcheddu, A. *Adv. Synth. Catal.* **2015**, *357*, 576-582.

[8] (a) Khusnutdinov, R. I.; Baygusina, A. R.; Aminov, R. I., Dzhemilev, U. M. *Russ. J. Org. Chem.* **2012**, 48, 690-693; (b) Khusnutdinov, R. I. *Russ. Chem. Bull.* **2013**, *62,*133-137; (c) Khusnutdinov, R. I.; Bayguzina, A. R.; Aminov, R. I.; Dzhemilev, U. M. *Russ. J. Gen. Chem.* **2015**, *85*, 2725-2727; (d) Khusnutdinov, R.; Bayguzina, A.; Aminov, R.; Dzhemilev, U. *J. Heterocyclic Chem.* **2016**, *53*, 1022-1029; and references cited therein.

[9] (a) Selvam, K.; Swaminathan, M. *Catal. Commun.* **2011**, *12*, 389-393; (b) Selvam, K.; Swaminathan, M. *Tetrahedron Lett.* **2010**, *51*, 4911-4914.

[10] (a) Punniyamurthy, T.; Velusamy, S.; Iqbal, J. *Chem. Rev.* **2005**, *105*, 2329-2364; (b) Stahl, S. S. *Science* **2005**, *309*, 1824-1826; (c) Frei, H. *Science* **2006**, *313*, 309-310; (d) Que, Jr. L.; Tolman, W. B. *Nature* **2008**, *455*, 333-340.

[11] (a) Mallat, T.; Baiker, A. *Chem. Rev.* **2004**, *104*, 3037-3058; (b) Chen, B.; Wang, L.; Gao, S. *ACS Catal.* **2015**, *5*, 5851–5876; (c) McCann, S. D.; Stahl, S. S. *Acc. Chem. Res.* **2015**, *48*, 1756-1766.

[12] Guillena, G.; Ramón, D. J; Yus, M. *Chem. Rev.* **2010**, *110*, 1611-1641.

[13] Kroschwitz, J. I. Ed. Encyclopedia of Polymer Science and Engineering, Wiley, New York, **1985**, 2nd ed. 3, 363.

[14] Zhao, B.; Li, Y.; Xu, P.; Dai, Y.; Luo, C.; Sun, Y.; Ai, J.; Geng, M.; Duan, W. *ACS Med. Chem. Lett.* **2016**, *7*, 629-634.

[15] (a) Forrest, T. P.; Dauphinee, G. A.; Miles, W. F. *Can. J. Chem.* **1969**, *47*, 2121-2122; (b) Guo, Q.; Wang, W.; Teng, W.; Chen, L.; Wang, Y.; Shen, B. *Synthetic Commun.* **2012**, *42*, 2574-2584; (c) Kouznetsov, V. V.; Gómez, G. M. M.; Ruíz, F. A. R.; Olmo, E. *Tetrahedron Lett.* **2012**, *53*, 3115-3118; (d) Guo, Q.; Liao, L.; Teng, W.; Ren, S.; Wang, X.; Lin, Y.; Meng, F. *Catalysis Today* **2016**, *263*, 117-122.

[16] Hagen, H.; Ziegler, H.; Wuerzer, B. **1982**, EP0144052.

[17] (a) Yi, X.; Xi, C. *Org. Lett.* **2015**, *17*, 5836-5839; (b) Iosub, A. V.; Stahl, S. S. *Org. Lett.* **2015**, *17*, 4404-4407; (c) He, L.; Cao, Y. *Angew. Chem. Int. Ed.* **2011**, *50*, 10216-10220; (d) Chakraborty, S.; Jones, W. D. *J. Am. Chem. Soc.* **2014**, *136*, 8564-8567; (e) Manjappa, K. B. *Tetrahedron Lett.* **2013**, *54*, 1368-1370; (f) Monrad, R. N.; Madsen, R. *Org. Biomol. Chem.* **2011**, *9*, 610-615; (g) Mamane, V. *Tetrahedron* **2008**, *64*, 10699-10705; (h) Nome, F. *J. Org. Chem.* **2009**, *74*, 1042-1053; (i) Fagnou, K. *Chem. Sci.* **2012**, *3*, 244-248; (j) Cho, C. S.; Shim. S. C. *J. Heterocyclic Chem.* **2002**, *39*, 291-294; (k) Li, L.; Wang, C. Y.; Biscoe. M. R. *Nat. Chem.* **2013**, *5*, 607-612; (l) Ganesabaskaran, S.; Rengasamy, R.; Paramasivan, P. *Tetrahedron Lett.* **2006**, *47*, 1783-1785; (m) Georg, F.; Andreas, Z. *Chem-Eur. J.* **2009**, 15, 4857-4864; (n) Osborne, A. G. *Tetrahedron* **1983**, 39, 2831-2842; (o) Schofield. L. *J. Am. Chem. Soc.* **1953**, *75*, 2256-2268; (p) Markgraf, J. H.; Blatchly, R. A. *J. Org. Chem.* **1979**, *44*, 3261-3263; (q) Michael, H.; Friedrich, V. *J. Chem. Soc. Perkin Transactions 1: Organic and Bio-Organic Chemistry* (1972-1999), **1980**, 1933-1939.