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Development of an efficient, one-pot, multicomponent protocol for synthesis of 8-hydroxy-4-phenyl-1,2-dihydroquinoline derivatives

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Abstract

A one-pot quick and efficient multicomponent reaction has been developed for the synthesis of a new series of functionalized 8-hydroxy-4-phenyl-1,-2-dihydroquinoline derivatives using 30 mol% ammonium acetate in ethanol as solvent. This economical protocol run smoothly to give variety of quinoline derivatives in 55% to 98% yield from inexpensive reagents and catalyst in mild reaction conditions. Various spectroscopic techniques like FTIR, ^{1}H NMR and ^{13}C NMR, MALDI-TOF-MS, and EI-MS were used to study and confirm their structure.

1 | INTRODUCTION

Multicomponent reactions attracted a great attention in recent years due to their simplicity, atom economy, and greater efficiency due to reduced number of intermediate purification steps that increase the yield of target products. These reactions are very useful for the generation of a variety of heterocyclic compounds in one-pot through one step or by many successive steps protocol from simple and inexpensive starting materials.[1–18] Quinoline derivatives are heterocyclic compounds that are used as selective and potent drugs against many diseases. They show excellent antiviral activity against dengue Zika and avian influenza virus[19–21] and now in current year even against COVID-19.[22–24] Modification of quinoline moiety through substitution can improve its physical and chemical properties and also pharmacological behavior. Due to its wide range of pharmaceutical applications, it is very popular compound to design new drugs for treatment of multiple diseases like cancer, dengue fever, malaria, tuberculosis, fungal infections, AIDS, Alzheimer's disease, and diabetes.[25–56] 8-Hydroxy quinoline is a vital part of various natural and pharmaceutically active compounds exhibiting a wide range of biological activities.[57–59] On account of their vital role as medicinal agents[60–64] (Figure 1), 8-hydroxyquinolines have become important synthetic targets for chemists. No doubt a diverse range of synthetic protocols including both catalytic and noncatalytic have been developed for construction of new compounds with virtually boundless combinations of functionality having quinoline and 8-hydroxy quinoline scaffold.[8,65–72] L-proline as catalyst was reported for the synthesis of quinoline derivatives from anilines but reaction time was 8 to 12 hours[66] so we use ammonium acetate as catalyst in one-pot protocol which reduced the reaction time to 20 to 120 minutes. Ammonium acetate is used as catalyst as well as reagent in synthesis of a wide range of heterocyclic compounds.[73,74] In this article, we report a quick and efficient three component reaction of malononitrile, 2-aminophenol, and functionalized aldehydes for the synthesis of 8-hydroxy-4-phenyl-1,2-dihydroquinoline derivatives catalyzed by ammonium acetate μ.

2 | RESULTS AND DISCUSSION

Our research work started with screening of catalyst for model reaction of benzaldehyde (**1a**) malononitrile (**2**) and 2-aminophenol (**3**) (Scheme 1) in the absence and

FIGURE 1 8-hydroxy quinoline derivatives with potential pharmacological applications [Colour figure can be viewed at wileyonlinelibrary.com]
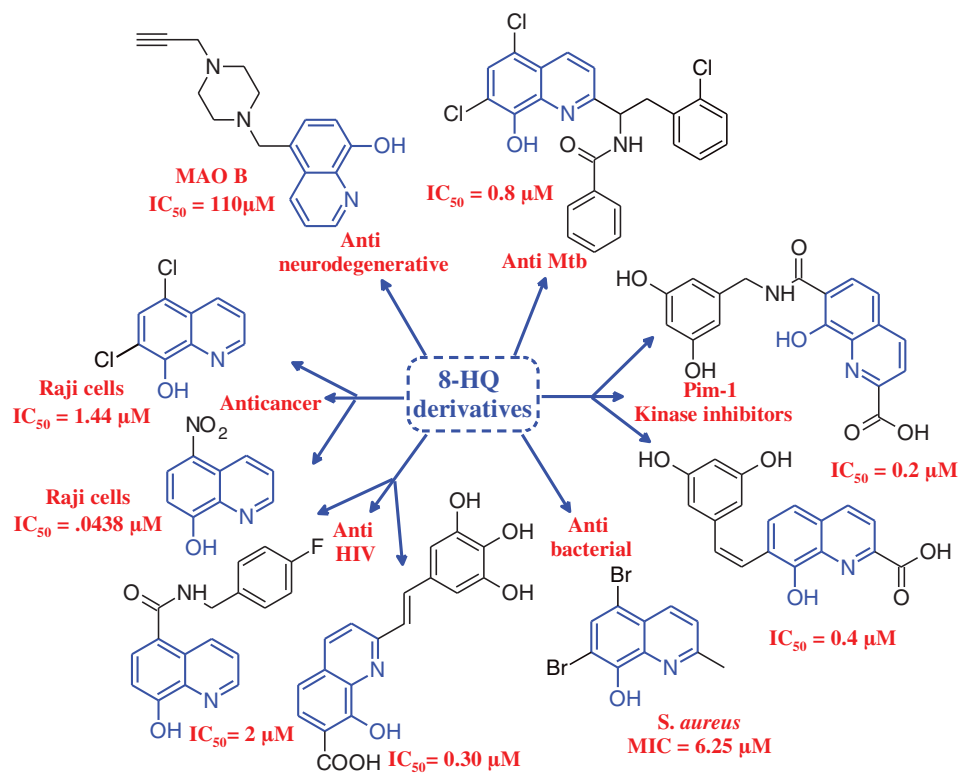
SCHEME 1 Synthesis of **6a** as model reaction [Colour figure can be viewed at wileyonlinelibrary.com]
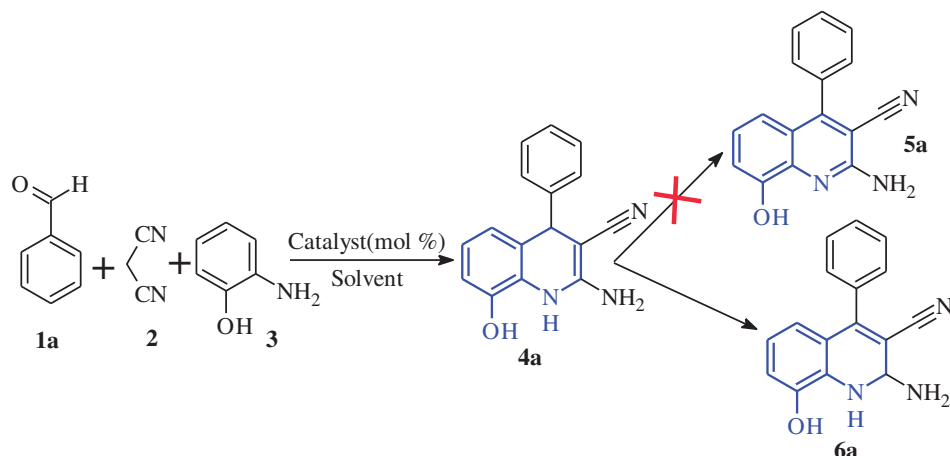
presence of different catalysts. Surprisingly we did not get the product **5a** as reported[66] instead **6a** was produced in all screening protocols confirmed by ^{1}H-NMR and ^{13}C-NMR spectral analysis. To our delight according to screening results (Table 1, entry 1) without using any catalyst 43% of product was obtained in 1 hour at reflux temperature. This reaction proceeded through single step, that is, benzylidenemalononitrile was not separated by the reaction of **1a** and **2** but when **3** was added, firstly intermediate was produced at room temperature then on reflux it yielded the product **6a**, that showed that 2-aminophenol itself acted as catalyst for Knoevenagel

condensation of benzaldehyde and malononitrile. So to increase the yield we tried different catalyst and recorded results in Table 1 and found that when Et$_3$N 10 mol% and 20 mol% (Table 1, entries 2 and 3) was used as catalyst product was obtained in 56% yield and increasing the amount of catalyst did not increase the yield of **6a**. With L-proline (Table 1, entry 4) Knoevenagel condensation reaction was not accomplished and benzaldehyde and malononitrile remained as such even after 24 hours of stirring. Then we tried different ammonium salts (Table 1, entries 5-9) as catalyst and amazingly got 68% yield of product with ammonium acetate in 1 hour at

TABLE 1 Screening of catalysts for model reaction[a]

| Entry | Conditions | | | | Yield %[b] |
	Catalyst (C)	C amount mol%	Solvent	Time	
1[c]	—	—	Ethanol	1 hour	43
2	Et_3N	10	Ethanol	2 hours	56
3	Et_3N	20	Ethanol	2 hours	56
4	L-Proline	20	Ethanol	24 hours	NR
5	NH_4OAc	10	Ethanol	1 hour	68
6	$(NH_4)_2CO_3$	20	Ethanol: Water (4:1)	1 hour	37
7	NH_4Cl	20	Ethanol: Water (4:1)	24 hours	NR
8	$(NH_4)_2SO_4$	20	Ethanol: Water (4:1)	24 hours	NR
9	AcOH	20	Ethanol	24 hours	NR
10	NH_4OAc	20	Ethanol	40 minutes	83
11	NH_4OAc	25	Ethanol	30 minutes	90
12	NH_4OAc	30	Ethanol	20 minutes	**98**
13	NH_4OAc	35	Ethanol	20 minutes	98

Note: Bold values are optimized reaction conditions. Abbreviation: NR, no reaction.
[a]Reaction conditions: **1a** (2 mmol), **2** (2 mmol), catalyst, solvent (5 mL) stirred at room temperature then added **3** (2 mmol) dissolved in 5 mL solvent and refluxed.
[b]Isolated yield in hot reaction mixture.
[c]Without any catalyst.

reflux temperature. Then we performed reaction with different quantities of ammonium acetate and best result was obtained with 30 mol% of ammonium acetate (Table 1, entry 12) which was 98% yield of product in just 20 minutes [5 minutes stirring at room temperature (step 1) and 15 minutes stirring at reflux temperature (step 2)].

After the selection of appropriate catalyst we further investigated different solvents for reaction (Table 2, entries 1-7) and found that ethanol was the most suitable solvent for reaction as product separated during heating and no further purification was required except washing the product with hot ethanol. In water and methanol (Table 2, entries 1 and 2) reaction was not proceeded while in ^{n}propanol and ^{n}butanol (Table 2, entries 4 and 5) product was separated after cooling and in very low yield, that is, 25% and 18%, respectively. When THF and DMSO was used as solvent reaction was accomplished as monitored by TLC but product was not separated even after cooling that might be due to the high solubility of products in these solvents.

With optimized reaction conditions, that is, reaction of **1** and **2** at room temperature using ethanol as solvent in the presence of 30 mol% catalyst and then addition of **3** and reflux for required time, we further investigated the scope and generality of aldehydes for this multicomponent reaction and results are enlisted in Table 3. A variety of aldehydes nonsubstituted (**1a**, **1k**) and substituted with electron withdrawing groups such as

TABLE 2 Screening of solvents for model reaction[a]

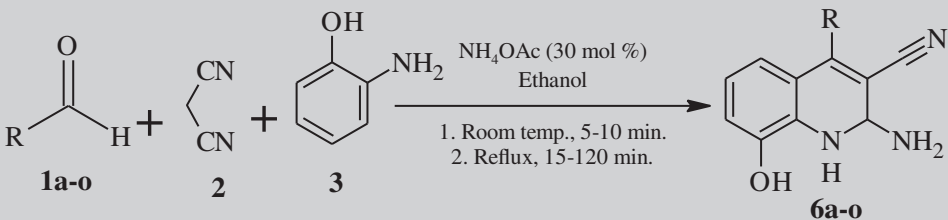| Entry | Conditions | | Yield %[b] |
	Solvent	Time	
1	Water	2 hours	NR
2	Methanol	2 hours	NR
3	Ethanol	20 minutes	98
4	^{n}Propanol	2 hours	25[c]
5	^{n}Butanol	2 hours	18[c]
6	DCM	40 minutes	53
7	Ethanol: Water (1:1)	1 hour	70

Abbreviation: NR, no reaction.
[a]Reaction conditions: **1a** (2 mmol), **2** (2 mmol), catalyst (30 mol% NH_4OAc), solvent (5 mL) stirred at room temperature then added **3** (2 mmol) dissolved in 5 mL solvent and refluxed.
[b]Isolated yield in hot reaction mixture.
[c]Product was isolated after cooling the reaction mixture at room temperature.

NO_2, Cl, Br, F and electron donating groups like OCH_3, CH_3, and OH reacted efficiently with 2-amino phenol (**3**) and malononitrile (**2**) and produced the corresponding 8-hydroxy-4-phenyl-1,2-dihydroquinoline derivatives in moderate to excellent yield (55%-98%) under mild reaction conditions. Benzaldehyde (**1a**) produced the required products **6a** in highest yields which is 98% in just 20 minutes (first step was completed in 5 minutes

TABLE 3 Substrate scope for synthesis of 8-hydroxy-4-phenyl-1,2-dihydroquinoline derivatives (**6a-o**)[a]

Entry	Aldehyde	R	Time (min)	Product	Yield (%)[b]
1	**1a**	-C$_6$H$_5$	20	**6a**	98
2	**1b**	p-OCH$_3$-C$_6$H$_5$	25	**6b**	74
3	**1c**	m-OCH$_3$-C$_6$H$_5$	40	**6c**	83
4	**1d**	m-Br-C$_6$H$_5$	35	**6d**	86
5	**1e**	p-NO$_2$-C$_6$H$_5$	25	**6e**	78
6	**1f**	m-NO$_2$-C$_6$H$_5$	30	**6f**	85
7	**1g**	p-Cl-C$_6$H$_5$	25	**6g**	82
8	**1h**	o-Cl-C$_6$H$_5$	90	**6h**	58
9	**1i**	m-Cl-C$_6$H$_5$	30	**6i**	89
10	**1j**	p-F-C$_6$H$_5$	25	**6j**	65
11	**1k**	β-Naphthyl	20	**6k**	82
12	**1l**	m-OH-C$_6$H$_5$	40	**6l**	69
13	**1m**	p-OH-C$_6$H$_5$	25	**6m**	67
14	**1n**	p-CH$_3$-C$_6$H$_5$	20	**6n**	96
15	**1o**	o-Br-C$_6$H$_5$	120	**6o**	55

[a]Reaction conditions: **1a** (5 mmol), **2** (5 mmol), catalyst (30 mol% NH$_4$OAc), solvent (10 mL) stirred at room temperature then added **3** (5 mmol) dissolved in 10 mL solvent and refluxed.
[b]Isolated yield in hot reaction mixture.

and second step was completed in 15 minutes). Substitution on aldehydes affected the time of completion of reaction, for example, nonsubstituted aldehydes (**1a, 1k**) and *para* substituted aldehyde **1n** converted into products in 20 minutes while all other *para* substituted aldehydes yield product in 25 minutes, *meta* substituted aldehydes took 30 to 40 minutes for completion of reaction and for *ortho* substituted aldehydes longest time was required to convert the reactants into desired product (90-120 minutes). Substitution on aldehydes irrespective of electron withdrawing or electron donating groups, also affected the yield of corresponding quinoline derivatives **6**, such as *meta* substituted aldehydes like **1c, 1d, 1f, 1i, 1k,** and **1l** furnished their corresponding products **6c, 6d, 6f, 6i, 6k,** and **6l** in higher yield 83%, 86%, 85%, 89%, 82%, and 69%, respectively as compared to *para* substituted aldehydes **1b, 1e, 1g, 1j,** and **1m** which furnished the required products **6b, 6e, 6g, 6j,** and **6m** in 74%, 78%, 82%, 65%, and 67% yields, respectively only *P*-tolualdehyde (**1n**) produced the required products **6n** in highest yields which is 96%. *Ortho* substituted aldehydes **1h** and **1o** produced the lowest yield

of products which was for **6h** 58% and for **6o** 55%. Steric effect may be aroused due to steric hindrance of groups present at *ortho, meta* and *para* position of **1** as in *para* substituted aldehydes this effect is lowest as compared to *meta* substituted aldehydes while in *ortho* substituted aldehydes steric hindrance is highest which could be the reason of lowest yield. Some aldehydes did not gave the corresponding products, for example *para* dimethyl amino benzaldehyde only furnished the intermediate which did not get dissolved in hot ethanol and ultimately not reacted with **3** to yield product **6**, similarly heterocyclic aldehydes like 2-pyridine aldehyde, furfural aldehyde did not reacted with **2** to produce the intermediate which could yield the corresponding products.

2.1 | Structure elucidation

Synthesis and structure of 8-hydroxyquinoline derivatives were confirmed by using different techniques like FTIR, ^{1}H-NMR, ^{13}C-NMR, MALDI-TOF-MS, and EI-MS.

FTIR spectra of all synthesized compounds were recorded in 4000 to 600 cm^{-1} domain and all spectra have prominent peaks characteristic of synthesized quinoline derivatives (**6a-6o**) (Figures S1-S15) such as NH_2, NH, OH, C≡N, C═C, C—N, and C—O peaks in the vibrational range of 3500 to 1000 cm^{-1}. NH_2 stretching vibrations give rise to two bands in the region of 3500 to 3300 cm^{-1} one for asymmetric stretch at higher frequency and other for symmetric stretch at lower frequency while NH_2 bending vibrations appears as strong band in the region of 1600 to 1500 cm^{-1}[75] and NH peaks appear in the region of 3390 ± 60 cm^{-1} while C≡N showed peaks in the region of 2200 to 2100 cm^{-1} and stretching of OH attached with aromatic rings give rise to a broad peak from 3500 to 3000 cm^{-1}.[76] In all spectra of compounds **6a-o** all corresponding peaks are in accordance with the literature and proposed structure of quinoline derivatives.[77–80] All compounds showed two peaks for NH_2 stretching vibrations, that is, for asymmetric stretching band appear in the region of 3500 to 3400 cm^{-1} and symmetric stretching peak appear in the range of 3400 to 3300 cm^{-1} while for NH there was a single peak in all spectra in the region of 3400 to 3300 cm^{-1} except **6a** (Figure 2), **6h** and **6m** where NH peak is overlapped with NH_2 and OH peaks respectively. Aromatic C—H stretching vibrations are expected to appear in the region of 3200 to 3000 cm^{-1} which is characteristic region for C—H stretching vibrations.[81,82] The aromatic C—H stretching bands of synthesized compounds are appeared in the expected region and are in good agreement with literature values.[81,82] Most important peak for structure elucidation of carbonitrile compounds is C≡N as this group is present in target compounds so showed a strong and sharp peak in the region of 2200 to 2100 cm^{-1} which confirms the presence of this group in synthesized quinoline derivatives. C—N vibration is very difficult to interpret as there are a number of possible bands in this region. However, by taking the help of literature[77–79] C—N bands are assigned to the bands in the range of 1165 to 1185 cm^{-1}. The FTIR peak was observed in the range of 1640 to 11 400 cm^{-1} assigned to C═C vibrations while bands in the range of 1525 to 1508 cm^{-1} to corresponding peak of NH_2 bending vibrations. C—O stretching vibration of C—OH bond appeared in the region of 1051 to 1025 cm^{-1}. C—X (where X = Cl, Br, and F) also observed in their respective region, that is, C—F peak in **6j** appeared at 1231.29 cm^{-1} while peak at 1093.80 and 1125.52 cm^{-1} appointed to C—Cl stretching vibrations in compounds **6g** and **6h** and C—Br peak in compounds 6d and 6o appeared at 1125.87 and 1125.89 cm^{-1} respectively. NO_2 group show two distinct peaks at 1550 and 1350 cm^{-1} assigned to asymmetric stretching and symmetric stretching vibration.[76] In reported compounds **6e** and **6f** asymmetric stretching band of NO_2 seems to be overlapped with NH_2 deformation band while NO_2 symmetric stretch is assigned to the
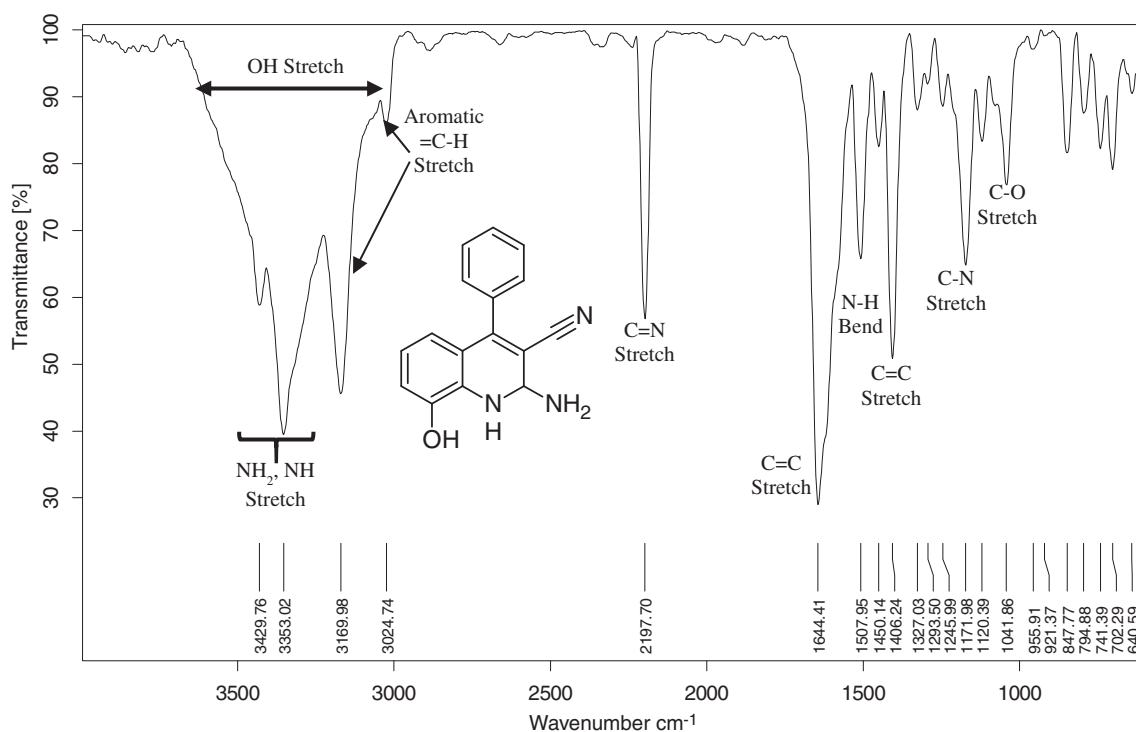

FIGURE 2   FTIR spectrum of **6a**

peak appeared at 1344.97 and 1353.47 cm^{-1} respectively. All the corresponding peaks of synthesized 8-hydroxy-1,-2-dihydroquinoline derivatives are in accordance with literature.[75–78,82]

In ^{1}H-NMR and ^{13}C-NMR spectra of all synthesized compounds (6a-6o) (Figures S16-S45) all required signals conforming the respective proton and carbon nuclei of suggested structures are observed at agreeing chemical shifts (ppm) values which helped in unambiguous characterization of 8-hydroxy-4-phenyl-1,2-dihydroquinoline derivatives. ^{1}H-NMR spectra allow us to identify different proton's chemical shift values, as in our synthesized compounds CH present next to NH of quinoline ring showed a singlet peak in the region of 5.0 to 4.0 ppm while NH$_2$ protons appeared as singlet of integral two in the region

of 5.5.5 to 5.1 ppm. Proton Hb showed a doublet (d) while Ha and Hc appeared as multiplet (m) signal in the range of 7.0 to 6.0 ppm, NH and OH groups appeared as overlapped broad peak at 6.8 to 6.6 ppm while aromatic protons of aldehyde benzene ring showed signals in the region of chemical shift value of 8.0 to 7.0 ppm for example, in ^{1}H-NMR spectrum of 6a (Figure 3A) it is clear that there is a peak of H$_d$ at 4.5 ppm while H$_b$ due to coupling with neighboring *ortho* protons(H$_a$, H$_c$) showed a doublet with $J = 8.1$ Hz at 6.65 ppm. Signals of protons H$_a$, H$_c$, and H$_{e-g}$ due to the presence of *ortho* as well as *meta* protons appeared as multiplet in the range of 6.32 to 6.26 ppm and 7.32 to 7.15 ppm, respectively. NH$_2$ peak appeared as singlet at 5.23 ppm while NH and OH as overlapped broad peak at 6.79 ppm. In all
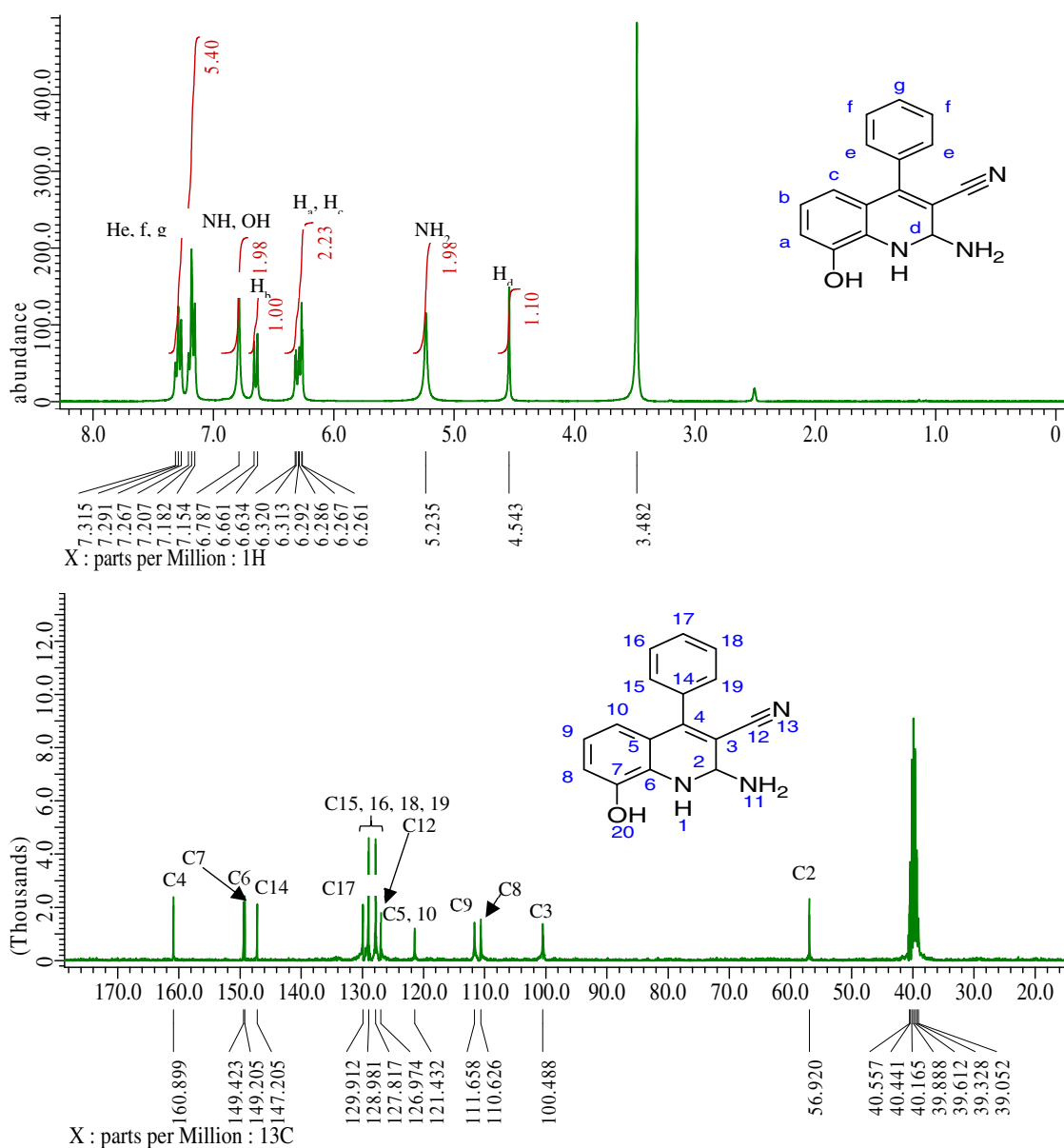

FIGURE 3 A, ^{1}H-NMR spectrum of 6a. B, ^{13}C-NMR spectrum of 6a [Colour figure can be viewed at wileyonlinelibrary.com]

synthesized quinoline derivatives carbon bonded to NH_2 (C2) group resonated at chemical shift value of 60 to 55 ppm while carbon atom attached with nitrile group is evident in the region of 102 to 100 ppm and carbon bonded to OH group which is C7 appeared in the region of 149 to 150 ppm. In addition, carbon C6, that is, attached to nitrogen of pyridine ring also resonate at 149 to 150 ppm. Carbon of nitrile group (C12) appears at 129 to 136 ppm while C14 aldehyde ring carbon attached to quinoline ring showed a signal in the region of 142 to 148 ppm. Carbon of OCH_3 group (C21) in compounds **6b** and **6c** showed a signal at 55.5 and 55.4 ppm while carbon attached to methoxy group in these compounds resonated at 158.3 and 160.9 ppm, respectively. Signals at 21.1 ppm in ^{13}C NMR spectra of compounds **6n** confirm the presence of CH_3 carbon nuclei while carbon attached to CH_3 group appears at 136.0 ppm. C—F carbon in compounds **6j** showed a doublet with coupling constant 240.75 ppm which is in accordance to literature.[83] C—F of compound **6j** showed two signals at 162.96 and 159.75 ppm. In exemplary ^{13}C-NMR spectrum of **6a** (Figure 3B) C≡N signal appeared at 129.9 ppm while carbons attached with NH_2, CN, and OH groups showed peaks at 56.9, 100.5, and 149.4 ppm, respectively.

Mass of the synthesized compounds were determined by MALDI-TOF-MS by using alpha-cyano-4-hydroxycinnamic acid (α-CHCA) as matrix in positive ion, reflectron mode, and EI-MS by using positive ion mode. MALDI-TOF uses soft ionization method to generate ions and is well known as a high throughput technique.[84] Previously it was mostly used for compounds with higher molecular weight but now a days it is also employed for compounds with low molecular weight with great success.[85,86] Surprisingly $[M-H]^+$, $M^{+\cdot}$, $[M-H_2]^+$, and $[M-H-H_2]^+$ peaks also produced in addition to $[M + H]^+$ peaks in almost all investigated compounds (Table 4) (Figures S46-S60). $[M-H-H_2]^+$ peak observed as most intense peak in most of the spectra which may appear due to the removal of hydrogen molecule from $[M-H]^+$ ion and $[M-H]^+$ ion may be produced due to; (a) transfer of hydrogen atom from radical cation of analyte or (b) by hydride removal from neutral molecule of analyte, or (c) removal of H_2 from protonated molecule of analyte.[87–90] M^+ ion may be observed due to removal of electron from parent molecule by photoionization process and $[M-H_2]^+$ by removal of H_2 from molecular ion. All these mechanisms may occur simultaneously or not depending on the structure of analyte molecule.[91] MALD-TOF-MS spectrum of **6a** (Figure 4A) showed $[M-H]^+$ peak at 262.72 m/z while EI-MS spectrum of **6a** (Figure 4B) showed molecular ion ($M^{+\cdot}$) peak at 263.2 m/z ratio which confirmed the mass of **6a**.

2.2 | Proposed mechanism

Based on the experimental results and previous literature[74,92,93] a proposed mechanism of the reaction was shown in Scheme 2. According to proposed mechanism acetate ion facilitate the removal of H from **2** to yield **I(i)** while ammonium ion catalyzed the formation of iminium ion [**I(ii)**] which due to higher reactivity than carbonyl group expedite the Knoevenagel condensation between **I(i)** and **I(ii)** followed by elimination of ammonium ion to yield benzylidenemalononitrile [**I(iii)**]. Then

Compound	$M^{+\cdot}$	$[M+H]^+$	$[M-H]^+$	$[M-H_2]^+$	$[M-H-H_2]^+$
6a	—	—	262.72	261.75	260.69
6b	293.24	—	292.36	291.23	—
6c	—	—	292.72	291.05	290.71
6d	341.46	342.25	340.42	—	338.39
6e	308.61	—	307.66	—	305.66
6f	308.19	—	—	306.68	305.76
6g	297.17	—	—	295.06	294.67
6h	—	298.23	296.22	—	—
6i	297.05	298.11	296.58		294.54
6j	281.41	—	280.42	—	—
6k	—	—	312.09	311.04	310.72
6l	279.23	280.24	—	—	2276.37
6m	279.49	—	—	277.44	276.43
6n	277.38	—	276.03	—	274.78
6o	341.21	342.53	340.61	—	338.87

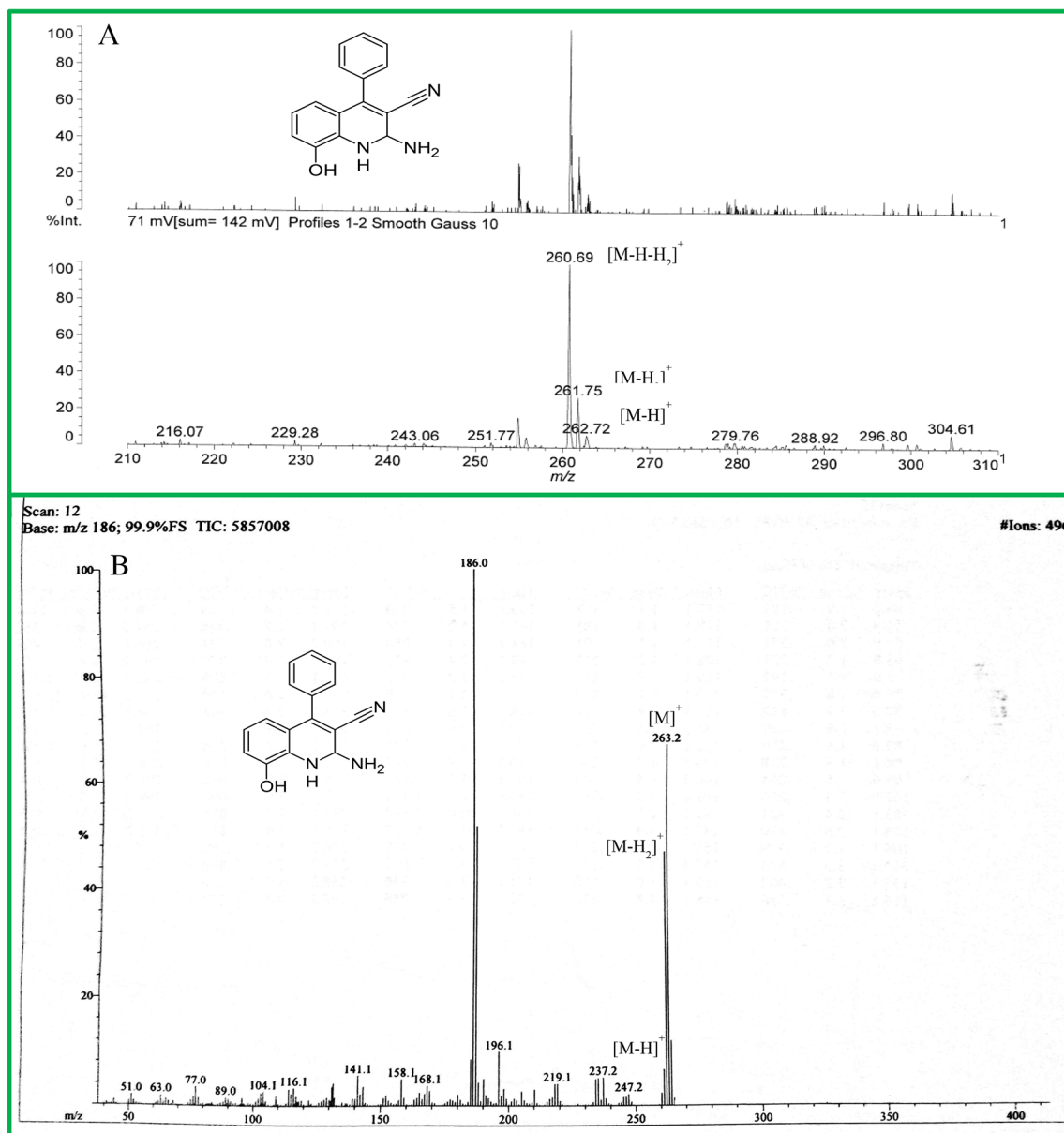**TABLE 4** Observed MALDI-TOF-MS peaks of compounds **6a-o**

FIGURE 4 Mass spectra of **6a**. A, MALDI-TOF-MS, B, EI-MS [Colour figure can be viewed at wileyonlinelibrary.com]

benzylidenemalononitrile through Michael addition with intermediate **I(iv)** produced **I(v)** which by imine-enamine tautomerization and cyclization yielded **I(vi)** and **I(vii),** respectively. Intermediate **I(vii)** might exhibit in three possible tautomeric forms out of which **6b** is the most stable as indicated by NMR and mass spectral analysis.

3 | CONCLUSION

In summary, we successfully synthesized 8-hydroxy-4-phenyl-1,2-dihydroquinoline derivatives (**6a-o**) by a convenient one-pot, three component reaction in 55% to

98% yield. The reaction proceeds through Knoevenagel condensation, Michael addition, rearrangements, and cyclization. It is worth mentioning that this protocol proceeded without the use of toxic solvents, co-catalysts, precious metals, inert atmosphere, and harsh reaction conditions. This one-pot atom economic method furnished an excellent yield of corresponding products with a wide range of substituted aldehydes and thus provided high substrate scope under mild reaction conditions. Furthermore, all synthesized compounds were characterized by various techniques including FTIR, ^{1}H-NMR, ^{13}C-NMR, MALDI-TOF-MS, and EI-MS which confirmed their synthesis. In addition, significance of this protocol to a variety of substrates and bio screening
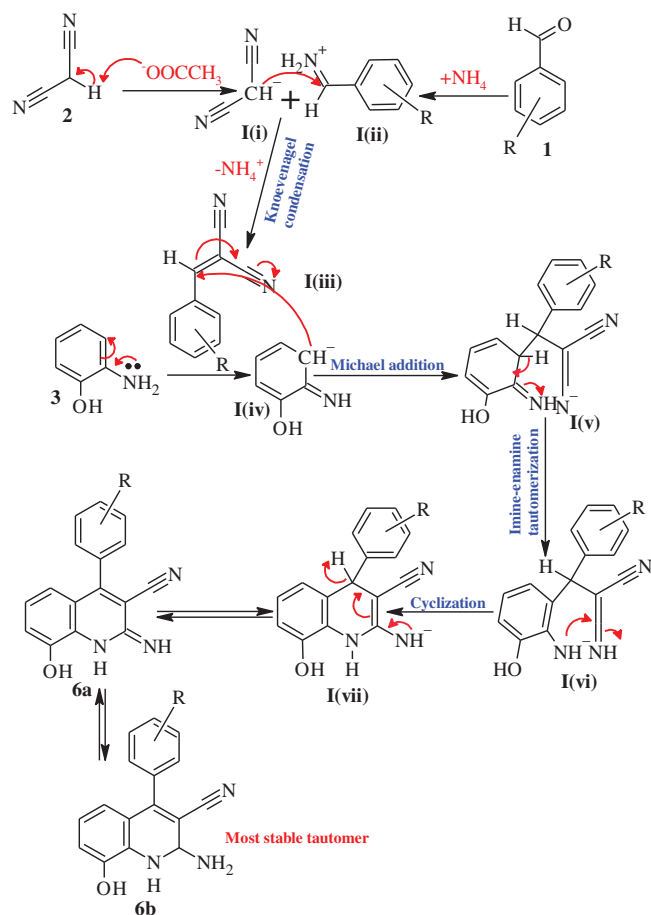
SCHEME 2 Proposed mechanism for the synthesis of compound **6** [Colour figure can be viewed at wileyonlinelibrary.com]

of synthesized compounds are in progress in our laboratory.

4 | EXPERIMENTAL

4.1 | General information

All reagents were from Sigma Aldrich, Merck, Alfa Aesar and BDH and were used without further purification. Melting points were on Stuart SMP10 and are uncorrected. Silica gel plates were used to monitor the progress of reaction by TLC using acetone: *n*-hexane solvent system (7:3) which were visualized under UV. FTIR spectra were recorded on Bruker Tensor 27 FTIR spectrophotometer using KBr disks. ^{1}H-NMR and ^{13}C-NMR spectra were recorded on Bruker DMZ NMR spectrophotometer operating at 300 MHz. Mass spectra were recorded by MALDI-TOF-MS technique on Shimadzu Biotech Axima Performance mass spectrometer using alpha-cyano-4-hydroxycinnamic acid (α-CHCA) as matrix in positive ion, reflectron mode. EI-MS spectra

were recorded in positive ion mode using JEOL-600H-1 mass spectrometer.

4.2 | General procedure for the synthesis of 8-hydroxy-4-phenylquinoline derivatives (6a-o)

To a 10 mL solution of malononitrile **2** (0.33 g, 5.0 mmol) and ammonium acetate (0.116 g, 30 mol%) in ethanol, respective benzaldehyde **1** (5.0 mmol) was added and stirred at room temperature for 5 to 10 minutes. Intermediate benzylidenemalononitrile was obtained as solid product which was then heated at 70°C which helped to dissolve intermediate in ethanol. After getting clear solution of reaction mixture, solution of 2-amino phenol (0.545 g, 5.0 mmol) in 10 mL ethanol was added in it and refluxed for 15 to 120 minutes. The solid thus obtained was filtered and washed with hot ethanol to obtain highly pure corresponding product **6a-o** in 55% to 98% yield.

4.3 | 2-amino-8-hydroxy-4-phenyl-1,2-dihydroquinoline-3-carbonitrile (6a)

Dark yellow solid, Yield: 98%, m.p: 218°C to 220°C, Rf: 0.64 [Acetone: *n*-hexane (7:3)], FTIR (KBr disk, cm^{-1}): 3429.76, 3353.01 (NH$_2$, NH stretch), 3500 to 31 (OH), 3169.98 (Ar CH), 3024.74 (Ar CH), 2197.70 (C≡N), 1644.41 (C=C), 1507.95 (NH$_2$ bend), 1406.24 (C=C), 1171.98 (C—N), 1041.90 (C—O), ^{1}H-NMR (300 MHz, DMSO-d$_6$) δ 7.32 to 7.15 (m, 5H, He, Hf, Hg), 6.79 (s, 2H, NH, OH), 6.65 (d, *J* = 8.1 Hz, 1H, Hb), 6.32 to 6.26 (m, 2H, Ha, Hc), 5.23 (s, 2H, NH$_2$), 4.54 (s, 1H, Hd), ^{13}C-NMR (75 MHz, DMSO-d$_6$) δ 160.9 (C4), 149.4 (C7), 149.2 (C6), 147.2 (C14), 129.9 (C12), 129.0 (C16, C18), 127.8 (C15, C19), 127.0 (C17), 121.4 (C5, C10), 111.7 (C9), 110.6 (C8), 100.5 (C3), 56.9 (C2), MALDI-TOF-MS *m/z*: [M-H]$^+$, required for C$_{16}$H$_{12}$N$_3$O$^+$: 262.097, found: 262.72 EI-MS *m/z*: M$^+$ required for C$_{16}$H$_{13}$N$_3$O$^+$: 263.11, found: 263.2.

4.4 | 2-amino-8-hydroxy-4-(4-methoxyphenyl)-1,2-dihydroquinoline-3-carbonitrile (6b)

Dark yellow solid, Yield: 74%, m.p: 214°C to 216°C, Rf: 0.69 [Acetone: *n*-hexane (7:3)], FTIR (KBr disk, cm^{-1}): 3447.91, 3366.47, 3314.98 (NH$_2$, NH stretch), 3229.85, 3187.3196, 3036.44 (Ar CH), 3012.07, 2955.86, 2903.02 (CH$_3$ stretch), 2188.67 (C≡N), 1636.15 (C=C), 1510.03

(NH$_2$ bend), 1414.22 (C=C), 1250.27 (C—N), 1031.74 (C—O), ^{1}H-NMR (300 MHz, DMSO-d$_6$) δ 7.07 (d, J = 8.5 Hz, 2H, He), 6.85 (d, J = 8.5 Hz, 2H, Hf), 6.73 (s, 2H, NH, OH), 6.61 (d, J = 8.3 Hz, 1H, Hb), 6.30 to 6.23 (m, 2H, Ha, Hc), 5.22 (s, 2H, NH$_2$), 4.48 (s, 1H, Hd), 3.71 (s, 3H, OCH$_3$), ^{13}C-NMR (75 MHz, DMSO-d$_6$) δ 160.7 (C4), 158.3(C17), 149.3 (C7), 149.1(C6), 139.3 (C14), 129.9 (C12), 128.9 (C15, C19), 121.5 (C10), 115.7 (C5), 114.3 (C16, C18), 111.6 (C9), 110.9 (C8), 100.4 (C3), 57.2 (C2), 55.5 (C21), MALDI-TOF-MS *m/z*: [M-H]$^+$, required for C$_{17}$H$_{14}$N$_3$O$_2{}^+$: 292.11, found: 292.63.

4.5 | 2-amino-8-hydroxy-4-(3-methoxyphenyl)-1,2-dihydroquinoline-3-carbonitrile (6c)

Yellow solid, Yield: 83%, m.p: 188°C to 190°C, Rf: 0.61 [Acetone: *n*-hexane (7:3)], FTIR (KBr disk, cm^{-1}): 3460.94, 3377.73, 3337.81 (NH$_2$, NH stretch), 3009.90 (Ar CH), 2941.36, 2903.02 (CH$_3$ stretch), 2192.05 (C≡N), 1638.99 (C=C), 1511.91 (NH$_2$ bend), 1407.62 (C=C), 1270.5110 (C—N), 1044.98 (C—O), ^{1}H-NMR (300 MHz, DMSO-d$_6$) δ 7.21 (t, J = 8.1 Hz, 1H, Hf), 6.78 to 6.65 (m, 6H, He, Hg, Hh, Hb, NH, OH), 6.30 to 6.22 (m, 2H, Ha, Hc), 5.24 (s, 2H, NH$_2$), 4.49 (s, 1H, Hd), 3.74 (s, 3H, OCH$_3$), ^{13}C-NMR (75 MHz, DMSO-d$_6$) δ 160.9 (C18), 159.8(C4), 149.4 (C7), 149.2 (C6), 148.8 (C14), 130.1 (C12), 129.8 (C16), 121.4 (C5, C10), 120.0 (C15), 113.9 (C17), 111.8 (C19), 111.6 (C9), 110.4 (C8), 100.4 (C3), 56.7 (C2), 55.4 (C21), MALDI-TOF-MS *m/z*: [M-H]$^+$, required for C$_{17}$H$_{14}$N$_3$O$_2{}^+$: 292.11, found: 292.72.

4.6 | 2-amino-4-(3-bromophenyl)-8-hydroxy-1,2-dihydroquinoline-3-carbonitrile (6d)

Off white solid, Yield: 86%, m.p: 220°C to 223°C, Rf: 0.65 [Acetone: *n*-hexane (7:3)], FTIR (KBr disk, cm^{-1}): 3461.42, 3378.56, 3336.89(NH$_2$, NH stretch), 3242.74, 3190.21, 3068.68 (Ar CH), 2192.58 (C≡N), 1639.21 (C=C), 1513.09 (NH$_2$ bend), 1413.58 (C=C), 1174.24 (C—N), 1125.87 (C—Br) 1035.80 (C—O), ^{1}H-NMR (300 MHz, DMSO-d$_6$) δ 7.39 (d, J = 8.1 Hz, 1H, Hg), 7.32 to 7.24 (m, 2H, He, Hf), 7.19 (s, 1H, Hh), 6.88 (s, 2H, NH, OH), 6.65 (d, J = 8.3 Hz, 1H, Hb), 6.32 to 6.24 (m, 2H, Ha, Hc), 5.29 (s, 2H, NH$_2$), 4.58 (s, 1H, Hd), ^{13}C-NMR (75 MHz, DMSO-d$_6$) δ 161.0 (C4), 150.0 (C7), 149.5 (C6), 149.4 (C14), 131.3 (C12), 130.4 (C17), 129.9 (C15), 129.9 (C18), 127.0 (C19), 122.3 (C16), 121.2 (C10), 111.7 (C9), 109.7 (C8), 100.4 (C3), 56.3 (C2), MALDI-TOF-MS *m/z*: [M-H]$^+$, required for C$_{16}$H$_{11}$BrN$_3$O$^+$: 340.00, found: 340.42.

4.7 | 2-amino-8-hydroxy-4-(4-nitrophenyl)-1,2-dihydroquinoline-3-carbonitrile (6e)

Yellow solid, Yield: 78%, m.p: 195°C to 197°C, Rf: 0.64 [Acetone: *n*-hexane (7:3)], FTIR (KBr disk, cm^{-1}): 3478.24, 3433.18, 3386.56, 3338.31 (NH$_2$, NH stretch), 3108.20 (Ar CH), 2189.28 (C≡N), 1643.83 (C=C), 1573.82 (NO$_2$ asym. stretch), 1514.42 (NH$_2$ bend), 1412.37 (C=C), 1344.97 (NO$_2$ sym. stretch), 1174.53 (C—N), 1122.60 (C—N), 1043.36 (C—O), ^{1}H-NMR (300 MHz, DMSO-d$_6$) δ 8.18 (d, J = 8.3 Hz, 2H, Hf), 7.43 (d, J = 8.3 Hz, 2H, He), 6.95 (s, 2H, NH, OH), 6.63 (d, J = 8.3 Hz, 1H, Hb), 6.30 to 6.26 (m, 2H, Ha, Hc), 5.31 (s, 2H, NH$_2$), 4.75 (s, 1H, Hd), ^{13}C-NMR (75 MHz, DMSO-d$_6$) δ 161.0 (C4), 154.7 (C17), 149.7 (C7), 149.4 (C6), 146.6 (C14), 129.9 (C12), 129.1 (C15, C19), 124.5 (C16, C18), 121.0 (C10), 111.7 (C9), 109.0 (C8), 100.5 (C3), 55.7 (C2), MALDI-TOF-MS *m/z*: [M-H]$^+$, required for C$_{16}$H$_{11}$N$_4$O$_3{}^+$: 307.08, found: 307.66.

4.8 | 2-amino-8-hydroxy-4-(3-nitrophenyl)-1,2-dihydroquinoline-3-carbonitrile (6f)

Yellow solid, Yield: 85%, m.p: 235°C to 237°C, Rf: 0.71 [Acetone: *n*-hexane (7:3)], FTIR (KBr disk, cm^{-1}): 3456.25, 3407.14, 3360.42 (NH$_2$, NH stretch), 3219.53, 3102.23, 3049.04 (Ar CH), 2182.19 (C≡N), 1648.94(C=C), 1578.20 (NO$_2$ asym. stretch), 1523.17, 1448.58 (NH$_2$ bend), 1401.14 (C=C), 1353.47 (NO$_2$ sym. stretch), 1176.40 (C—N), 1051.95 (C—O), ^{1}H-NMR (300 MHz, DMSO-d$_6$) δ 8.06 to 8.01 (m, 2H, Hg, Hh), 7.62 (dd, J = 20.7, 7.9 Hz, 2H, He, Hf), 6.98 (s, 2H, NH, OH), 6.68 (d, J = 8.1 Hz, 1H, Hb), 6.36 to 6.33 (m, 2H, Ha, Hc), 5.31 (s, 2H, NH$_2$), 4.82 (s, 1H, Hd), ^{13}C-NMR (75 MHz, DMSO-d$_6$) δ 161.1 (C4), 149.6 (C18), 149.5 (C7), 149.4 (C6), 148.4 (C14), 134.7 (C12), 130.6 (C15), 130.0 (C16), 122.2 (C17, C19), 121.2 (C10), 111.9 (C9), 109.3 (C8), 100.6 (C3), 56.1 (C2), MALDI-TOF-MS *m/z*: [M]$^+$, calcd for C$_{16}$H$_{12}$N$_4$O$_3{}^+$: 308.09, found: 308.19.

4.9 | 2-amino-4-(4-chlorophenyl)-8-hydroxy-1,2-dihydroquinoline-3-carbonitrile (6g)

Light yellow solid, Yield: 82%, m.p: 228°C to 231°C, Rf: 0.70 [Acetone: *n*-hexane (7:3)], FTIR (KBr disk, cm^{-1}): 3446.95, 3367.26, 3314.64 (NH$_2$, NH stretch), 3229.62, 3187.99, 3040.58 (Ar CH), 2189.90 (C≡N), 1634.8708 (C=C), 1514.58 (NH$_2$ bend), 1414.14 (C=C), 1185.70

(C—N), 1093.80 (C—Cl), 1026.53 (C—O), ^{1}H-NMR (300 MHz, DMSO-d$_6$) δ 7.34 (d, J = 8.3 Hz, 2H, Hf), 7.18 (d, J = 8.3 Hz, 2H, He), 6.85 (s, 2H, NH, OH), 6.62 (d, J = 8.3 Hz, 1H, Hb), 6.32 to 6.27 (m, 2H, Ha, Hc), 5.26 (s, 2H, NH$_2$), 4.58 (s, 1H, Hd), ^{13}C-NMR (75 MHz, DMSO-d$_6$) δ 160.9(C4), 149.3 (C7, C6), 146.1 (C14), 131.6 (C12), 129.9 (C17), 129.7 (C16, C18), 128.9 (C15, C19), 121.3 (C10), 111.7 (C9), 110.0 (C8), 100.5 (C3), 56.5 (C2), MALDI-TOF-MS m/z: [M]$^+$, required for C$_{16}$H$_{12}$ClN$_3$O$^+$: 297.07, found: 297.17.

4.10 | 2-amino-4-(2-chlorophenyl)-8-hydroxy-1,2-dihydroquinoline-3-carbonitrile (6h)

White solid, Yield: 58%, m.p: 196°C to 199°C, Rf: 0.66 [Acetone: n-hexane (7:3)], FTIR (KBr disk, cm^{-1}): 3477.12, 3378.93 (NH$_2$ stretch), 3219.14, 3051.65 (Ar CH), 2182.67 (C≡N), 1647.30 (C═C), 1511.02 (NH$_2$ bend), 1401.93 (C═C), 1177.08 (C—N), 1125.52 (C—Cl), 1038.82 (C—O), ^{1}H-NMR (300 MHz, DMSO-d$_6$) δ 7.39 (d, J = 7.7 Hz, 1H, Hh), 7.30 to 7.16 (m, 3H, He, Hf, Hg), 6.87 (s, 2H, NH, OH), 6.61 (d, J = 8.3 Hz, 1H, Hb), 6.30 (dd, J = 10.5, 2.0 Hz, 2H, Ha, Hc), 5.27 (s, 2H, NH$_2$), 5.09 (s, 1H, Hd), ^{13}C-NMR (75 MHz, DMSO-d$_6$) δ 161.2 (C4), 149.54 (C7), 149.46 (C6), 143.7 (C14), 132.3 (C12), 131.1 (C19), 130.1 (C17), 129.2 (C18), 128.8 (C15), 128.2 (C16), 121.1 (C10), 111.7 (C9), 109.4 (C8), 100.5 (C3), 55.5 (C2), MALDI-TOF-MS m/z: [M-H]$^+$, required for C$_{16}$H$_{11}$ClN$_3$O$^+$: 296.06, found: 296.22.

4.11 | 2-amino-4-(3-chlorophenyl)-8-hydroxy-1,2-dihydroquinoline-3-carbonitrile (6i)

Off white solid, Yield: 89%, m.p: 222°C to 224°C, Rf: 0.67 [Acetone: n-hexane (7:3)], FTIR (KBr disk, cm^{-1}): 3461.95, 3378.58, 3332.95 (NH$_2$, NH stretch), 3232.42, 3188.15, 3072.15 (Ar CH), 2193.12 (C≡N), 1637.79 (C═C), 1513.14 (NH$_2$ bend), 1414.94 (C═C), 1174.52 (C—N), 1125.91 (C—Cl), 1034.60 (C—O), ^{1}H-NMR (300 MHz, DMSO-d$_6$) δ 7.34 to 7.13 (m, 4H, He, Hf, Hg, Hh), 6.88 (s, 2H, NH, OH), 6.66 (d, J = 8.3 Hz, 1H, Hb), 6.34 to 6.28 (m, 2H, Ha, Hc), 5.28 (s, 2H, NH$_2$), 4.60 (s, 1H, Hd), ^{13}C-NMR (75 MHz, DMSO-d$_6$) δ 161.0 (C4), 149.7 (C7), 149.43 (C6), 149.40 (C14), 133.6 (C12), 130.9 (C18), 129.9 (C16), 127.5 (C17), 127.0 (C19), 126.6 (C15), 121.2 (C10), 111.8 (C9), 109.8 (C8), 100.5 (C3), 56.3 (C2), MALDI-TOF-MS m/z: [M-H]$^+$, calcd for C$_{16}$H$_{11}$ClN$_3$O$^+$: 296.06, found: 296.58 EI-MS m/z: M$^+$ required for C$_{16}$H$_{12}$ClN$_3$O$^+$: 297.07, found: 297.2.

4.12 | 2-amino-4-(4-fluorophenyl)-8-hydroxy-1,2-dihydroquinoline-3-carbonitrile (6j)

Off white solid, Yield: 65%, m.p: 215°C to 218°C, Rf: 0.69 [Acetone: n-hexane (7:3)], FTIR (KBr disk, cm^{-1}): 3450.07, 3368.91, 3317.09 (NH$_2$, NH stretch), 3232.29, 3189.48, 3050.86 (Ar CH), 2189.07 (C≡N), 1637.51 (C═C), 1509.25 (NH$_2$ bend), 1414.28 (C═C), 1231.29 (C—F), 1176.64 (C—N), 1030.38 (C—O), ^{1}H-NMR (300 MHz, DMSO-d$_6$) δ 7.22 to 7.08 (m, 4H, He, Hf), 6.81 (s, 2H, NH, OH), 6.63 (d, J = 8.1 Hz, 1H, Hb), 6.29 (t, J = 8.7 Hz, 2H, Ha, Hc), 5.24 (s, 2H, NH$_2$), 4.58 (s, 1H, Hd), ^{13}C-NMR (75 MHz, DMSO-d$_6$) δ 163.0 (C17, J = 242.66), 160.8 (C4), 159.8(C17, J = 242.66), 149.4 (C7), 149.3 (C6), 143.38 (C14), 143.35 (C5), 129.9 (C12), 129.7 (C15), 129.6 C19), 121.3 (C10), 15.5 (C16, C18), 111.7 (C9), 110.4 (C8), 100.5 (C3), 56.9 (C2), MALDI-TOF-MS m/z: [M-H]$^+$, required for C$_{16}$H$_{11}$FN$_3$O$^+$: 280.09, found: 280.42.

4.13 | 2-amino-8-hydroxy-4-(naphthalen-2-yl)-1,2-dihydroquinoline-3-carbonitrile (6k)

Off white solid, Yield: 82%, m.p: 260°C to 262°C, Rf: 0.67 [Acetone: n-hexane (7:3)], FTIR (KBr disk, cm^{-1}): 3447.88, 3366.88, 3313.35 (NH$_2$, NH stretch), 3227.30, 3184.84, 3051.86 (Ar CH), 2188.97 (C≡N), 1636.44 (C═C), 1509.66 (NH$_2$ bend), 1413.05 (C═C), 1168.79 (C—N), 1032.80 (C—O), ^{1}H-NMR (300 MHz, DMSO-d$_6$) δ 7.90 to 7.82 (m, 3H, Hf, Hh), 7.74 (s, 1H, He), 7.50 to 7.46 (m, 2H, Hg), 7.25 (dd, J = 8.5, 1.7 Hz, 1H, Hi), 6.85 (s, 2H, NH, OH), 6.65 (d, J = 9.0 Hz, 1H, Hb), 6.27 (dd, J = 5.7, 2.1 Hz, 2H, Ha, Hb), 5.26 (s, 2H, NH$_2$), 4.72 (s, 1H, Hd), ^{13}C-NMR (75 MHz, DMSO-d$_6$) δ 160.8 (C4), 149.4 (C7), 149.3 (C6), 144.4 (C14), 133.3 (C12), 132.5 (C17), 130.1 (C22), 129.9 (C18), 128.9 (C21), 128.1 (C15), 128.0 (C16), 126.7 (C19), 126.5 (C20), 126.2 (C23), 125.8 (C5), 121.4 (C10), 111.7 (C9), 110.2 (C8), 100.5 (C3), 56.8 (C2), MALDI-TOF-MS m/z: [M-H]$^+$, required for C$_{20}$H$_{14}$N$_3$O$^+$: 312.11, found: 312.09.

4.14 | 2-amino-8-hydroxy-4-(3-hydroxyphenyl)-1,2-dihydroquinoline-3-carbonitrile (6l)

Off white solid, Yield: 69%, m.p: 217°C to 220°C, Rf: 0.67 [Acetone: n-hexane (7:3)], FTIR (KBr disk, cm^{-1}): 3414.20, 3353.32 (NH$_2$, NH stretch), 3138.79, 3037.49 (Ar CH), 2182.38 (C≡N), 1643.03 (C═C), 1512.23, 1479.26 (NH$_2$ bend), 1409.92 (C═C), 1169.48 (C—N), 1045.31

(C—O), ^{1}H-NMR (300 MHz, DMSO-d$_6$) δ 7.08 (t, $J = 7.8$ Hz, 1H, Hf), 6.76 (s, 2H, NH, OH), 6.67 to 6.54 (m, 4H, He, Hg, Hh, Hb), 6.31 to 6.23 (m, 2H, Ha, Hc), 5.22 (s, 2H, NH$_2$), 4.42 (s, 1H, Hd), 3.52, ^{13}C-NMR (75 MHz, DMSO-d$_6$) δ 160.8 (C16), 157.9 (C4), 149.4 (C7), 149.2 (C6), 148.7 (C14), 129.8 (C18, C12), 121.5 (C10), 118.6 (C19), 114.5 (C17), 114.1 (C15), 111.6 (C9), 110.7 (C8), 100.4 (C3), 56.9 (C2), MALDI-TOF-MS m/z: [M]$^+$, required for C$_{16}$H$_{13}$N$_3$O$_2$$^+$: 279.10, found: 279.23.

4.15 | 2-amino-8-hydroxy-4-(4-hydroxyphenyl)-1,2-dihydroquinoline-3-carbonitrile (6m)

Light yellow solid, Yield: 67%, m.p: 264°C to 266°C, Rf: 0.65 [Acetone: *n*-hexane (7:3)], FTIR (KBr disk, cm^{-1}): 3454.63, 3396.53, 3325.57 (NH$_2$, NH stretch), 3200.75, 3103.26, 3042.21(Ar CH), 2182.58 (C≡N), 1651.23 (C=C), 1509.34 (NH$_2$ bend), 1398.19 (C=C), 1168.60 (C—N), 1036.17 (C—O), ^{1}H-NMR (300 MHz, DMSO-d$_6$) δ 9.32 (s, 1H, OH), 6.97 (d, $J = 8.3$ Hz, 2H, He), 6.72 to 6.61 (m, 5H, Hf, NH, OH, Hb), 6.31 to 6.23 (m, 2H, Ha, Hc), 5.19 (s, 2H, NH$_2$), 4.43 (s, 1H, Hd), ^{13}C-NMR (75 MHz, DMSO-d$_6$) δ 160.7 (C17), 156.4 (C4), 149.3 (C7), 149.0 (C6), 137.7 (14), 129.9 (C12), 128.8 (C15, C19), 121.5 (C10), 115.9 (C5), 115.7 (C16, C18), 111.6 (C9), 111.3 (C8), 100.4 (C3), 57.4 (C2), MALDI-TOF-MS m/z: [M]$^+$, required for C$_{16}$H$_{13}$N$_3$O$_2$$^+$: 279.10, found: 279.29.

4.16 | 2-amino-8-hydroxy-4-(4-methylphenyl)-1,2-dihydroquinoline-3-carbonitrile (6n)

Light orange solid, Yield: 96%, m.p: 216°C to 218°C, Rf: 0.70 [Acetone: *n*-hexane (7:3)], FTIR (KBr disk, cm^{-1}): 3453.1240, 3453.1240, 3371.9891, 3317.5286 (NH$_2$, NH stretch), 3231.94, 3187.58, 3034.65 (Ar CH), 2922.98 (CH$_3$ stretch), 2190.15 (C≡N), 1637.29 (C=C), 1512.01 (NH$_2$ bend), 1412.23 (C=C), 1174.58 (C—N), 1031.78 (C—O), ^{1}H-NMR (300 MHz, DMSO-d$_6$) δ 7.07 (dd, $J = 15.4$, 8.1 Hz, 4H, He, Hf), 6.76 (s, 2H, NH, OH), 6.62 (d, $J = 8.3$ Hz, 1H, Hb), 6.28 (td, $J = 8.3$, 2.1 Hz, 2H, Ha, Hc), 5.04 to 5.42 (2H, NH$_2$), 4.49 (s, 1H, Hd), 2.25 (s, 3H, CH$_3$), ^{13}C-NMR (75 MHz, DMSO-d$_6$) δ 160.8 (C4), 149.4 (7), 149.1 (C6), 144.3 (C14), 136.0 (C12), 129.9 (C5), 129.5 (C15, C19), 127.7 (C16, C18), 121.4 (C10), 111.6 (C9), 110.8 (C8), 100.4 (C3), 57.1 (C2), 21.1 (C21) MALDI-TOF-MS m/z: [M-H]$^+$, required for C$_{17}$H$_{14}$N$_3$O$^+$: 276.11, found: 276.03 EI-MS m/z: M$^{+\cdot}$ required for C$_{17}$H$_{15}$N$_3$O$^+$: 277.12, found: 277.2.

4.17 | 2-amino-4-(2-bromophenyl)-8-hydroxy-1,2-dihydroquinoline-3-carbonitrile (6o)

Off white solid, Yield: 55%, m.p: 195°C to 197°C, Rf: 0.72 [Acetone: *n*-hexane (7:3)], FTIR (KBr disk, cm^{-1}): 3461.54, 3378.56, 3336.85 (NH$_2$, NH stretch), 3233.97, 3189.03, 3068.35 (Ar CH), 2192.58 (C≡N), 1639.28 (C=C), 1513.09 (NH$_2$ bend), 1413.49 (C=C), 1174.30 (C—N), 1035.17 (C—O), ^{1}H-NMR (300 MHz, DMSO-d$_6$) δ 7.56 (d, $J = 7.5$ Hz, 1H, Hh), 7.30 to 7.11 (m, 3H, He, Hf, Hg), 6.88 (s, 2H, NH, OH), 6.63 (d, $J = 7.5$ Hz, 1H, Hb), 6.32 (d, $J = 7.7$ Hz, 2H, Ha, Hc), 5.20 (d, $J = 43.3$ Hz, 3H, NH2, Hd), ^{13}C-NMR (75 MHz, DMSO-d$_6$) δ 161.1 (C4), 149.5 (C7, C6), 145.5 (C14), 133.2 (C12), 131.4 (C16), 129.2 (C19), 129.1 (C18), 128.8 (C17), 122.8 (C15), 121.0 (C10), 111.8 (C9), 109.6 (C8), 100.6 (C3), 55.9 (C2), MALDI-TOF-MS m/z: [M + H]$^+$, required for C$_{16}$H$_{11}$BrN$_3$O$^+$: 340.00, found: 340.61.

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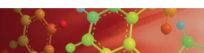
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