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SYNTHESIS OF DIHYDROINDOLES AND TETRAHYDROQUINOLINES BY THE INTRAMOLECULAR DIELS-ALDER REACTION OF *N*-ALKENYLATED 2-ACYLAMINO-3-FURANCARBONITRILES

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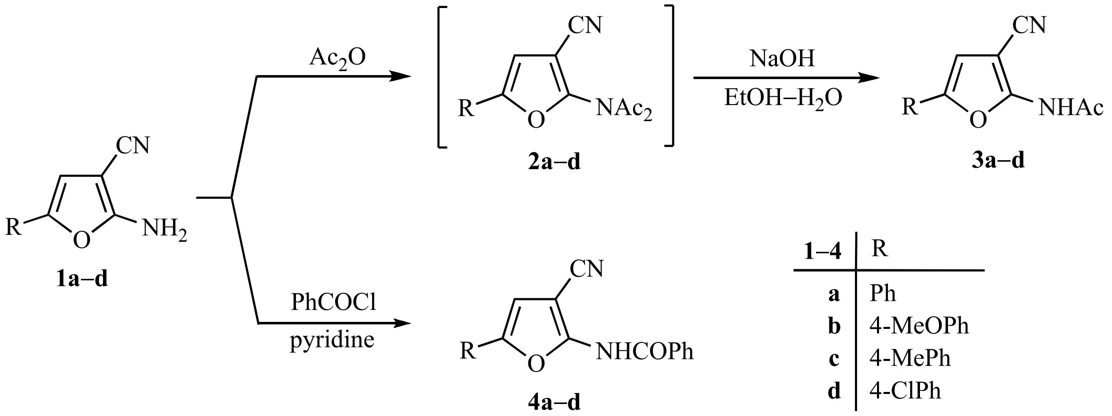
Abstract – An approach to dihydroindoles and tetrahydroquinolines from *N*-alkenylated 2-acylamino-3-furancarbonitriles *via* a [4 + 2] cycloaddition reaction is described. Thermal treatment of *N*-alkenylated 2-acylamino-3-furancarbonitriles **5a–d**, **6a–d**, **9a–d**, and **10a–d**, which were prepared from 2-acylamino-3-furancarbonitriles **3a–d** and/or **4a–d** and 4-bromo-1-butene and/or 5-bromo-1-pentene, caused an intramolecular Diels-Alder reaction to give the corresponding dihydroindole and tetrahydroquinoline derivatives **7a–d**, **8a–d**, **11a–d**, and **12a–d**. This method has the advantage of easier work-up procedure.

Heterocyclic compounds, particularly five- and six-membered ring compounds, have occupied a prominent place among the organic compounds in view of their diverse biological activities. Dihydroindole derivatives, namely indolines, are common structural elements in many biologically active compounds and natural products.[1–6] Tetrahydroquinoline derivatives have also attracted considerable interest due to their importance as synthetic intermediates, pesticides, and pharmaceutical products with a broad range of physiological and biological properties.[7–11] For the reasons given above, a great number of methods have been developed for synthesis of dihydroindoles[12–20] and tetrahydroquinolines.[21–24]

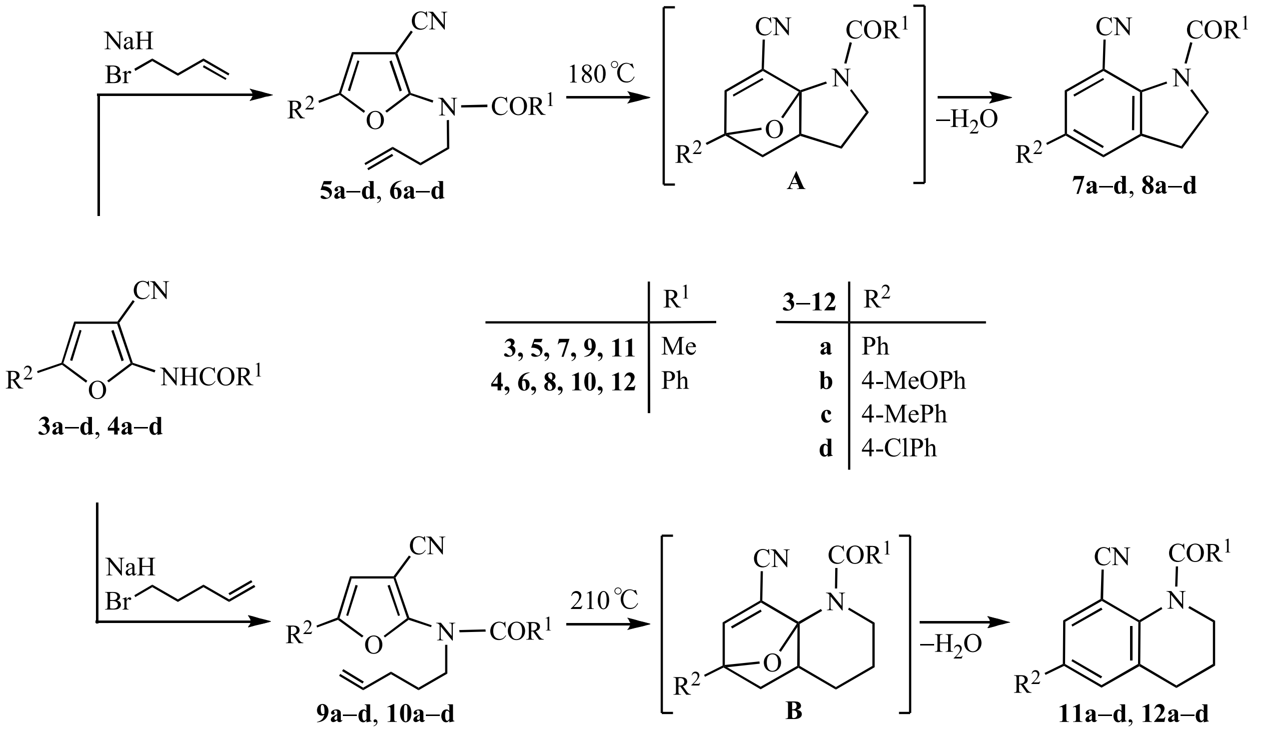
In connection with our current research interests in the synthesis of heterocyclic compounds,[25–29] we recently reported the synthesis of 4-(cyclic amino)-substituted phthalimide derivatives through a Diels-Alder reaction of maleimides with 2-(cyclic amino)-substituted 3-furancarbonitriles as starting materials.[30] Because furan derivatives are useful and versatile synthetic intermediates for heterocyclic compounds, the development of methodologies for the synthesis of such compounds are of significant interest. Among the most significant examples in the furan chemistry, Diels-Alder cycloadditions using this heterocycle as the 4π diene are of particular interest. As part of our efforts in developing new routes in heterocyclic synthesis, we herein describe an efficient procedure for the synthesis of dihydroindole and tetrahydroquinoline derivatives **7**, **8**, **11**, and **12** by an intramolecular Diels-Alder reaction of *N*-alkenylated 2-acylamino-3-furancarbonitriles **5**, **6**, **9**, and **10**.

Initially, we examined the synthesis of 2-acylamino-3-furancarbonitriles **3a–d** and **4a–d** starting from 2-amino-3-furancarbonitriles **1a–d**, which were prepared from phenacylmalononitriles and piperidine according to our previous procedure (Scheme 1).[31–33] Unfortunately, thermal treatment of **1a–d** with acetic anhydride gave 2-(diacetylated amino)-3-furancarbonitriles **2a–d** (**2a**: 49%, **2b**: 54%, **2c**: 55%, **2d**: 67%) together with **3a–d** as minor products. On the basis of this result, we tried to synthesize the desired **3a–d** from **1a–d** and acetic anhydride in a one-pot process, *via* a deacetylation reaction of **2a–d**. Indeed, when a mixture of **1a–d** and acetic anhydride was refluxed for 3 h and then the reaction mixture was treated with sodium hydroxide in aqueous ethanol at room temperature for 30 min, the desired 2-acetylamino-3-furancarbonitriles **3a–d** were obtained in good yields (**3a**: 76%, **3b**: 68%, **3c**: 75%, **3d**: 69%). While, the reaction of **1a–d** with benzoyl chloride in pyridine at 60 °C for 2 h afforded the desired 2-benzoylamino-3-furancarbonitriles **4a–d** (**4a**: 73%,[31] **4b**: 76%, **4c**: 80%, **4d**: 78%). Elemental analyses, mass spectra, ^{1}H and ^{13}C NMR spectra of **3a–d** and **4b–d** are consistent with the assigned structures (see experimental section).



Scheme 1

We next tried to construct dihydroindole derivatives **7a–d** and **8a–d** from *N*-3-buten-1-ylated 2-acylamino-3-furancarbonitriles **5a–d** and **6a–d** (Scheme 2). Thus, compounds **3a–d** were reacted with 4-bromo-1-butene in the presence of sodium hydride in DMF at room temperature to provide the corresponding compounds **5a–d** in moderate yields (entries 1–4 in Table 1). Under the same conditions, however, the reaction of **4a–d** with 4-bromo-1-butene gave the corresponding compounds **6a–d** in very low yields (entries 5–8 in Table 1). Although we examined several reaction conditions, *e.g*. substrate/base molar ratio and solvent, our attempts were unacceptable with respect to yield. In this case, it seemed possible that 4-bromo-1-butene would easily undergo the elimination reaction of hydrogen bromide to afford 1,3-butadiene. Hence, *N*-alkenylation reaction of **4a–d** did not proceed as a major reaction. Treatment of **5a–d** and **6a–d** in boiling 1,2-dichlorobenzene for 4 h caused an intramolecular Diels-Alder reaction to furnish the desired dihydroindole derivatives **7a–d** and **8a–d** in good yields (Table 2). By comparison of the IR spectra, NMR spectra, mass spectra and elemental analyses of **5–8**, it seems that the structural assignments given to these compounds are correct (see experimental section).



Scheme 2

Table 1. Synthesis of *N*-3-buten-1-ylated 2-acylamino-3-furancarbonitriles **5a–d** and **6a–d** according to Scheme 2

Entry	Substrate	R^1	R^2	Product	Yield (%)
1	**3a**	Me	Ph	**5a**	60
2	**3b**	Me	4-MeOPh	**5b**	66
3	**3c**	Me	4-MePh	**5c**	56
4	**3d**	Me	4-ClPh	**5d**	55
5	**4a**	Ph	Ph	**6a**	6
6	**4b**	Ph	4-MeOPh	**6b**	4
7	**4c**	Ph	4-MePh	**6c**	6
8	**4d**	Ph	4-ClPh	**6d**	5

Table 2. Synthesis of dihydroindoles **7a–d** and **8a–d** according to Scheme 2

Entry	Substrate	R^1	R^2	Product	Yield (%)
1	**5a**	Me	Ph	**7a**	84
2	**5b**	Me	4-MeOPh	**7b**	82
3	**5c**	Me	4-MePh	**7c**	83
4	**5d**	Me	4-ClPh	**7d**	74
5	**6a**	Ph	Ph	**8a**	77
6	**6b**	Ph	4-MeOPh	**8b**	79
7	**6c**	Ph	4-MePh	**8c**	83
8	**6d**	Ph	4-ClPh	**8d**	85

Table 3. Synthesis of *N*-4-penten-1-ylated 2-acylamino-3-furancarbonitriles **9a–d** and **10a–d** according to Scheme 2

Entry	Substrate	R^1	R^2	Product	Yield (%)
1	**3a**	Me	Ph	**9a**	83
2	**3b**	Me	4-MeOPh	**9b**	59
3	**3c**	Me	4-MePh	**9c**	56
4	**3d**	Me	4-ClPh	**9d**	60
5	**4a**	Ph	Ph	**10a**	58
6	**4b**	Ph	4-MeOPh	**10b**	34
7	**4c**	Ph	4-MePh	**10c**	43
8	**4d**	Ph	4-ClPh	**10d**	47

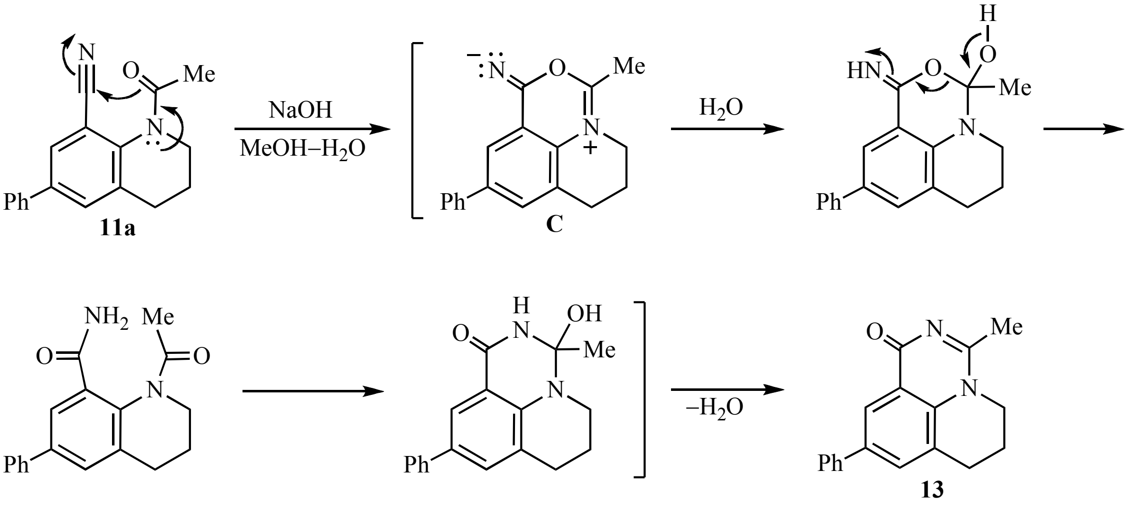
Table 4. Synthesis of tetrahydroquinolines **11a–d** and **12a–d** according to Scheme 2

Entry	Substrate	R^1	R^2	Product	Yield (%)
1	**9a**	Me	Ph	**11a**	58
2	**9b**	Me	4-MeOPh	**11b**	52
3	**9c**	Me	4-MePh	**11c**	52
4	**9d**	Me	4-ClPh	**11d**	45
5	**10a**	Ph	Ph	**12a**	71
6	**10b**	Ph	4-MeOPh	**12b**	57
7	**10c**	Ph	4-MePh	**12c**	60
8	**10d**	Ph	4-ClPh	**12d**	64

By analogy process given above, we examined the synthesis of tetrahydroquinoline derivatives **11a–d** and **12a–d** from *N*-4-penten-1-ylated 2-acylamino-3-furancarbonitriles **9a–d** and **10a–d** (Scheme 2). As a consequence, *N*-alkenylation reaction of compounds **3a–d** and **4a–d** with 5-bromo-1-pentene in the presence of sodium hydride in DMF at 80 °C for 5 h gave the corresponding compounds **9a–d** and **10a–d** in moderate yields (Table 3). Thermal treatment of **9a–d** and **10a–d** in 1-methyl-2-pyrrolidinone for

16–20 h caused an intramolecular Diels-Alder reaction to provide the desired tetrahydroquinoline derivatives **11a–d** and **12a–d** in moderate yields (Table 4). In this reaction, the use of 1-methyl-2-pyrrolidinone as a solvent was better than that of 1,2-dichlorobenzene in the case of the synthesis of dihydroindoles. These products **9–12** gave satisfactory elemental analyses and spectroscopic data (IR, ^{1}H NMR, ^{13}C NMR, mass) consistent with their assigned structures (see experimental section).

These intramolecular Diels-Alder reactions of **5a–d**, **6a–d**, **9a–d**, and **10a–d** are assumed to proceed through the formation of the oxabridged cycloadducts **A** and **B**. Subsequently, a ring-opening/dehydration reaction of cycloadducts **A** and **B** easily occurs and then dihydroindole and tetrahydroquinoline derivatives **7**, **8**, **11**, and **12** would be produced.



Scheme 3

During our study of the synthesis of tetrahydroquinoline derivatives, we found that compound **11a** reacted with sodium hydroxide in boiling aqueous methanol for 30 min to give the pyrido[3,2,1-*ij*]quinazoline derivative **13** in 51% yield. The formation of **13** could be explained by possible mechanism presented in Scheme 3. The reaction of **11a** with sodium hydroxide probably causes an intramolecular cycloaddition to afford the intermediate **C**, which undergoes a Dimroth-type rearrangement[34–38] to yield the pyrido[3,2,1-*ij*]quinazoline derivative **13**.

In conclusion, the intramolecular Diels-Alder reaction of *N*-alkenylated 2-acylamino-3-furancarbonitriles proceeds smoothly to furnish the corresponding dihydroindole and tetrahydroquinoline derivatives. Functionalized dihydroindole and tetrahydroquinoline derivatives are important synthons in organic synthesis and for the preparation of biologically active compounds with interest in medicinal chemistry.

EXPERIMENTAL

All melting points are uncorrected. The IR spectra were recorded on a JASCO FT/IR-4100 spectrometer. The ^{1}H and ^{13}C NMR spectra were measured with a JEOL JNM-A500 spectrometer at 500.00 and 125.65

MHz, respectively. The ^{1}H and ^{13}C chemical shifts (δ) are reported in parts per million (ppm) relative to tetramethylsilane as internal standard. Positive FAB mass spectra were obtained on a JEOL JMS-700T spectrometer. Elemental analyses were performed on YANACO MT-6 CHN analyzer. The starting compounds, 2-amino-3-furancarbonitriles **1a–d**, were prepared in this laboratory according to the procedure reported in literature.[31–33]

General procedure for the preparation of 3a–d from 1a–d and acetic anhydride.

A mixture of **1a–d** (20 mmol) and acetic anhydride (30 mL, 0.317 mol) was refluxed for 3 h. After removal of the solvent *in vacuo*, cold water was added to the residue. The precipitate was isolated by filtration, washed with water, and dried. A mixture of the crude product in 5% aqueous NaOH (5 mL) and EtOH (30 mL) was stirred at rt for 30 min. After removal of the solvent *in vacuo*, cold water was added to the residue. The precipitate was isolated by filtration, washed with water, dried, and recrystallized from acetone to give **3a–d**.

***N*-(3-Cyano-5-phenyl-2-furanyl)acetamide (3a)**

Colorless prisms (3.42 g, 76%), mp 215–216 °C; IR (KBr): 3187, 3120 (NH), 2223 (CN), 1682 (CO) cm^{-1}; ^{1}H NMR (DMSO-d_6): δ 2.14 (s, 3H, $COCH_3$), 7.32 (s, 1H, 4-H), 7.34–7.37 (m, 1H, aryl H), 7.44–7.48 (m, 2H, aryl H), 7.64–7.66 (m, 2H, aryl H), 11.38 (br s, 1H, NH); ^{13}C NMR (DMSO-d_6): δ 22.7 ($COCH_3$), 84.9 (C-3), 107.3 (C-4), 113.3 (CN), 123.3, 128.26, 128.28, 129.0 (C aryl), 147.4 (C-5), 151.0 (C-2), 167.7 (CO); MS: *m/z* 227 [M+H]$^+$. Anal. Calcd for $C_{13}H_{10}N_2O_2$: C, 69.02; H, 4.46; N, 12.38. Found: C, 69.03; H, 4.53; N, 12.38.

***N*-[3-Cyano-5-(4-methoxyphenyl)-2-furanyl]acetamide (3b)**

Colorless needles (3.48 g, 68%), mp 221–222 °C; IR (KBr): 3258, 3195, 3126 (NH), 2234 (CN), 1704 (CO) cm^{-1}; ^{1}H NMR (DMSO-d_6): δ 2.12 (s, 3H, $COCH_3$), 3.80 (s, 3H, OCH_3), 7.01–7.04 (m, 2H, aryl H), 7.13 (s, 1H, 4-H), 7.56–7.59 (m, 2H, aryl H), 11.26 (br s, 1H, NH); ^{13}C NMR (DMSO-d_6): δ 22.6 ($COCH_3$), 55.2 (OCH_3), 85.1 (C-3), 105.3 (C-4), 113.4 (CN), 114.5, 121.0, 125.0 (C aryl), 147.7 (C-5), 150.4 (C-2), 159.3 (C aryl), 167.6 (CO); MS: *m/z* 257 [M+H]$^+$. Anal. Calcd for $C_{14}H_{12}N_2O_3$: C, 65.62; H, 4.72; N, 10.93. Found: C, 65.66; H, 4.75; N, 10.92.

***N*-[3-Cyano-5-(4-methylphenyl)-2-furanyl]acetamide (3c)**

Colorless columns (3.62 g, 75%), mp 192–193 °C; IR (KBr): 3242, 3192, 3124 (NH), 2224 (CN), 1681 (CO) cm^{-1}; ^{1}H NMR (DMSO-d_6): δ 2.13 (s, 3H, $COCH_3$), 2.33 (s, 3H, CH_3), 7.22 (s, 1H, 4-H), 7.25–7.28 (m, 2H, aryl H), 7.52–7.55 (m, 2H, aryl H), 11.31 (br s, 1H, NH); ^{13}C NMR (DMSO-d_6): δ 20.7 (CH_3), 22.7 ($COCH_3$), 85.0 (C-3), 106.4 (C-4), 113.3 (CN), 123.3, 125.6, 129.5, 137.9 (C aryl), 147.7 (C-5), 150.7 (C-2), 167.6 (CO); MS: *m/z* 241 [M+H]$^+$. Anal. Calcd for $C_{14}H_{12}N_2O_2$: C, 69.99; H, 5.03; N, 11.66. Found: C, 70.02; H, 5.13; N, 11.67.

***N*-[5-(4-Chlorophenyl)-3-cyano-2-furanyl]acetamide (3d)**

Pale yellow prisms (3.61 g, 69%), mp 214–215 °C; IR (KBr): 3187, 3120 (NH), 2226 (CN), 1685 (CO) cm^{-1}; ^{1}H NMR (DMSO-d_6): δ 2.13 (s, 3H, $COCH_3$), 7.37 (s, 1H, 4-H), 7.51–7.54 (m, 2H, aryl H), 7.64–7.67 (m, 2H, aryl H), 11.41 (br s, 1H, NH); ^{13}C NMR (DMSO-d_6): δ 22.7 (CO*C*H_3), 84.8 (C-3), 108.1 (C-4), 113.2 (CN), 125.0, 127.1, 129.0, 132.7 (C aryl), 146.1 (C-5), 151.3 (C-2), 167.6 (CO); MS: *m/z* 261 $[M+H]^+$. Anal. Calcd for $C_{13}H_9ClN_2O_2$: C, 59.90; H, 3.48; N, 10.75. Found: C, 59.87; H, 3.56; N, 10.76.

General procedure for the preparation of 4b–d from 1b–d and benzoyl chloride.

A mixture of **1b–d** (20 mmol) and benzoyl chloride (3.37 g, 24 mmol) in pyridine (20 mL) was stirred at 60 °C for 2 h. After removal of the solvent *in vacuo*, cold water was added to the residue. The precipitate was isolated by filtration, washed with water, dried, and recrystallized from acetone to yield **4b–d**. **4a** was prepared in this laboratory according to the procedure reported in literature.[31]

***N*-[3-Cyano-5-(4-methoxyphenyl)-2-furanyl]benzamide (4b)**

Pale yellow needles (4.85 g, 76%), mp 208–209 °C; IR (KBr): 3244 (NH), 2231 (CN), 1683 (CO) cm^{-1}; ^{1}H NMR (DMSO-d_6): δ 3.81 (s, 3H, OCH_3), 7.03–7.07 (m, 2H, aryl H), 7.24 (s, 1H, 4-H), 7.56–7.61 (m, 2H, aryl H), 7.63–7.70 (m, 3H, aryl H), 8.02–8.05 (m, 2H, aryl H), 11.64 (s, 1H, NH); ^{13}C NMR (DMSO-d_6): δ 55.2 (OCH_3), 87.1 (C-3), 105.4 (C-4), 113.3 (CN), 114.5, 121.0, 125.1, 128.0, 128.6, 132.1, 132.7 (C aryl), 148.6 (C-5), 150.6 (C-2), 159.5 (C aryl), 164.6 (CO); MS: *m/z* 319 $[M+H]^+$. Anal. Calcd for $C_{19}H_{14}N_2O_3$: C, 71.69; H, 4.43; N, 8.80. Found: C, 71.62; H, 4.54; N, 8.78.

***N*-[3-Cyano-5-(4-methylphenyl)-2-furanyl]benzamide (4c)**

Pale yellow needles (4.85 g, 80%), mp 242–243 °C; IR (KBr): 3253 (NH), 2233 (CN), 1690 (CO) cm^{-1}; ^{1}H NMR (DMSO-d_6): δ 2.34 (s, 3H, CH_3), 7.28–7.30 (m, 2H, aryl H), 7.33 (s, 1H, 4-H), 7.57–7.62 (m, 4H, aryl H), 7.66–7.70 (m, 1H, aryl H), 8.03–8.06 (m, 2H, aryl H), 11.69 (s, 1H, NH); ^{13}C NMR (DMSO-d_6): δ 20.7 (CH_3), 86.9 (C-3), 106.5 (C-4), 113.3 (CN), 123.4, 125.6, 128.0, 128.6, 129.5, 132.0, 132.7, 138.1 (C aryl), 148.5 (C-5), 150.9 (C-2), 164.6 (CO); MS: *m/z* 303 $[M+H]^+$. Anal. Calcd for $C_{19}H_{14}N_2O_2$: C, 75.48; H, 4.67; N, 9.27. Found: C, 75.54; H, 4.77; N, 9.28.

***N*-[5-(4-Chlorophenyl)-3-cyano-2-furanyl]benzamide (4d)**

Yellow prisms (5.06 g, 78%), mp 241–242 °C; IR (KBr): 3245 (NH), 2236 (CN), 1691 (CO) cm^{-1}; ^{1}H NMR (DMSO-d_6): δ 7.47 (s, 1H, 4-H), 7.53–7.61 (m, 4H, aryl H), 7.66–7.74 (m, 3H, aryl H), 8.02–8.06 (m, 2H, aryl H), 11.78 (s, 1H, NH); ^{13}C NMR (DMSO-d_6): δ 86.7 (C-3), 108.2 (C-4), 113.1 (CN), 125.1, 127.1, 128.1, 128.6, 129.1, 132.0, 132.76, 132.84 (C aryl), 147.0 (C-5), 151.5 (C-2), 164.5 (CO); MS: *m/z* 323 $[M+H]^+$. Anal. Calcd for $C_{18}H_{11}ClN_2O_2$: C, 66.99; H, 3.44; N, 8.68. Found: C, 66.95; H, 3.51; N, 8.72.

General procedure for the preparation of 5a–d and 6a–d from 3a–d and/or 4a–d and 4-bromo-1-butene.

To an ice-cooled and stirred solution of **3a–d** and **4a–d** (5 mmol) in DMF (5 mL) was added 60% NaH (0.24 g, 6 mmol). The stirring was continued at rt until evolution of gas ceased. To the obtained mixture was added 4-bromo-1-butene (1.35 g, 10 mmol) with stirring and then the mixture was stirred at rt for 48 h. After removal of the solvent *in vacuo*, cold water was added to the residue. The resulting mixture was extracted with Et_2O (60 mL). The extract was dried over anhydrous sodium sulfate and concentrated *in vacuo*. The residue was purified by column chromatography on silica gel with CH_2Cl_2 as the eluent to afford **5a–d** and **6a–d**.

***N*-3-Buten-1-yl-*N*-(3-cyano-5-phenyl-2-furanyl)acetamide (5a)**

Yellow oil (0.84 g, 60%); IR (neat): 2237 (CN), 1698 (CO) cm^{-1}; ^{1}H NMR ($CDCl_3$): δ 2.09 (s, 3H, $COCH_3$), 2.36–2.41 (m, 2H, 3-butene 2-H), 3.85 (t, *J* = 7.3 Hz, 2H, 3-butene 1-H), 5.04–5.14 (m, 2H, 3-butene 4-H), 5.70–5.80 (m, 1H, 3-butene 3-H), 6.79 (s, 1H, furan 4-H), 7.37–7.47 (m, 3H, aryl H), 7.60–7.63 (m, 2H, aryl H); ^{13}C NMR ($CDCl_3$): δ 22.0 (CO*C*H$_3$), 32.8 (3-butene C-2), 47.7 (3-butene C-1), 94.0 (furan C-3), 105.8 (furan C-4), 112.1 (CN), 117.5 (3-butene C-4), 124.1, 128.2, 129.1, 129.4 (C aryl), 134.0 (3-butene C-3), 152.4 (furan C-5), 154.3 (furan C-2), 169.7 (CO); MS: *m/z* 281 [M+H]$^+$. Anal. Calcd for $C_{17}H_{16}N_2O_2$: C, 72.84; H, 5.75; N, 9.99. Found: C, 72.88; H, 5.86; N, 9.96.

***N*-3-Buten-1-yl-*N*-[3-cyano-5-(4-methoxyphenyl)-2-furanyl]acetamide (5b)**

Colorless needles (1.03 g, 66%), mp 91–92 °C (Et_2O); IR (KBr): 2231 (CN), 1714 (CO) cm^{-1}; ^{1}H NMR ($CDCl_3$): δ 2.08 (s, 3H, $COCH_3$), 2.35–2.41 (m, 2H, 3-butene 2-H), 3.83 (t, *J* = 7.3 Hz, 2H, 3-butene 1-H), 3.85 (s, 3H, OCH_3), 5.03–5.13 (m, 2H, 3-butene 4-H), 5.70–5.80 (m, 1H, 3-butene 3-H), 6.64 (s, 1H, furan 4-H), 6.94–6.98 (m, 2H, aryl H), 7.53–7.56 (m, 2H, aryl H); ^{13}C NMR ($CDCl_3$): δ 22.0 (CO*C*H$_3$), 32.7 (3-butene C-2), 47.6 (3-butene C-1), 55.4 (OCH_3), 94.0 (furan C-3), 104.1 (furan C-4), 112.3 (CN), 114.6 (C aryl), 117.4 (3-butene C-4), 121.0, 125.8 (C aryl), 134.1 (3-butene C-3), 152.4 (furan C-5), 153.7 (furan C-2), 160.6 (C aryl), 169.8 (CO); MS: *m/z* 311 [M+H]$^+$. Anal. Calcd for $C_{18}H_{18}N_2O_3$: C, 69.66; H, 5.85; N, 9.03. Found: C, 69.64; H, 5.91; N, 9.03.

***N*-3-Buten-1-yl-*N*-[3-cyano-5-(4-methylphenyl)-2-furanyl]acetamide (5c)**

Colorless columns (0.82 g, 56%), mp 69–70 °C (Et_2O); IR (KBr): 2236 (CN), 1693 (CO) cm^{-1}; ^{1}H NMR ($CDCl_3$): δ 2.08 (s, 3H, $COCH_3$), 2.35–2.41 (m, 2H, 3-butene 2-H), 2.39 (s, 3H, CH_3), 3.84 (t, *J* = 7.3 Hz, 2H, 3-butene 1-H), 5.03–5.13 (m, 2H, 3-butene 4-H), 5.70–5.78 (m, 1H, 3-butene 3-H), 6.72 (s, 1H, furan 4-H), 7.23–7.26 (m, 2H, aryl H), 7.49–7.52 (m, 2H, aryl H); ^{13}C NMR ($CDCl_3$): δ 21.3 (CH_3), 22.0 (CO*C*H$_3$), 32.8 (3-butene C-2), 47.6 (3-butene C-1), 94.0 (furan C-3), 105.1 (furan C-4), 112.2 (CN), 117.4 (3-butene C-4), 124.1, 125.5, 129.5, 129.8 (C aryl), 134.1 (3-butene C-3), 139.7 (C aryl), 152.5 (furan C-5), 153.9 (furan C-2), 169.7 (CO); MS: *m/z* 295 [M+H]$^+$. Anal. Calcd for $C_{18}H_{18}N_2O_2$: C, 73.45; H, 6.16; N, 9.52. Found: C, 73.52; H, 6.27; N, 9.42.

***N*-3-Buten-1-yl-*N*-[5-(4-chlorophenyl)-3-cyano-2-furanyl]acetamide (5d)**

Colorless columns (0.86 g, 55%), mp 87–88 °C (Et_2O); IR (KBr): 2238 (CN), 1693 (CO) cm^{-1}; ^1H NMR ($CDCl_3$): δ 2.09 (s, 3H, $COCH_3$), 2.36–2.41 (m, 2H, 3-butene 2-H), 3.85 (t, *J* = 7.3 Hz, 2H, 3-butene 1-H), 5.04–5.13 (m, 2H, 3-butene 4-H), 5.71–5.77 (m, 1H, 3-butene 3-H), 6.79 (s, 1H, furan 4-H), 7.40–7.44 (m, 2H, aryl H), 7.53–7.57 (m, 2H, aryl H); ^{13}C NMR ($CDCl_3$): δ 22.0 ($COCH_3$), 32.8 (3-butene C-2), 47.7 (3-butene C-1), 94.2 (furan C-3), 106.3 (furan C-4), 111.9 (CN), 117.5 (3-butene C-4), 125.4, 126.6, 129.4 (C aryl), 134.0 (3-butene C-3), 135.4 (C aryl), 151.1 (furan C-5), 154.5 (furan C-2), 169.5 (CO); MS: *m/z* 315 $[M+H]^+$. Anal. Calcd for $C_{17}H_{15}ClN_2O_2$: C, 64.87; H, 4.80; N, 8.90. Found: C, 64.84; H, 4.84; N, 8.91.

_N_-3-Buten-1-yl-_N_-(3-cyano-5-phenyl-2-furanyl)benzamide (6a)

Colorless prisms (0.11 g, 6%), mp 57–59 °C (Et_2O/petroleum ether); IR (KBr): 2234 (CN), 1682 (CO) cm^{-1}; ^1H NMR ($CDCl_3$): δ 2.51–2.57 (m, 2H, 3-butene 2-H), 4.04 (t, *J* = 7.3 Hz, 2H, 3-butene 1-H), 5.08–5.19 (m, 2H, 3-butene 4-H), 5.80–5.87 (m, 1H, 3-butene 3-H), 6.53 (s, 1H, furan 4-H), 7.25–7.30 (m, 2H, aryl H), 7.34–7.45 (m, 6H, aryl H), 7.47–7.51 (m, 2H, aryl H); ^{13}C NMR ($CDCl_3$): δ 32.7 (3-butene C-2), 48.3 (3-butene C-1), 93.5 (furan C-3), 105.8 (furan C-4), 111.9 (CN), 117.6 (3-butene C-4), 124.0, 127.7, 128.2, 129.0, 129.2, 131.1 (C aryl), 134.1 (3-butene C-3), 134.8 (C aryl), 151.3 (furan C-5), 154.6 (furan C-2), 169.6 (CO); MS: *m/z* 343 $[M+H]^+$. Anal. Calcd for $C_{22}H_{18}N_2O_2$: C, 77.17; H, 5.30; N, 8.18. Found: C, 77.26; H, 5.41; N, 8.19.

_N_-3-Buten-1-yl-_N_-[3-cyano-5-(4-methoxyphenyl)-2-furanyl]benzamide (6b)

Colorless needles (0.07 g, 4%), mp 86–87 °C (Et_2O/petroleum ether); IR (KBr): 2233 (CN), 1681 (CO) cm^{-1}; ^1H NMR ($CDCl_3$): δ 2.50–2.56 (m, 2H, 3-butene 2-H), 3.84 (s, 3H, OCH_3), 4.02 (t, *J* = 7.3 Hz, 2H, 3-butene 1-H), 5.08–5.19 (m, 2H, 3-butene 4-H), 5.80–5.89 (m, 1H, 3-butene 3-H), 6.38 (s, 1H, furan 4-H), 6.91–6.95 (m, 2H, aryl H), 7.25–7.30 (m, 2H, aryl H), 7.34–7.38 (m, 1H, aryl H), 7.40–7.44 (m, 4H, aryl H); ^{13}C NMR ($CDCl_3$): δ 32.7 (3-butene C-2), 48.3 (3-butene C-1), 55.4 (OCH_3), 93.6 (furan C-3), 104.1 (furan C-4), 112.1 (CN), 114.5 (C aryl), 117.6 (3-butene C-4), 121.1, 125.6, 127.7, 128.2, 131.0 (C aryl), 134.1 (3-butene C-3), 134.9 (C aryl), 151.5 (furan C-5), 154.0 (furan C-2), 160.5 (C aryl), 169.7 (CO); MS: *m/z* 373 $[M+H]^+$. Anal. Calcd for $C_{23}H_{20}N_2O_3$: C, 74.18; H, 5.41; N, 7.52. Found: C, 74.07; H, 5.49; N, 7.51.

_N_-3-Buten-1-yl-_N_-[3-cyano-5-(4-methylphenyl)-2-furanyl]benzamide (6c)

Colorless needles (0.11 g, 6%), mp 109–110 °C (Et_2O); IR (KBr): 2233 (CN), 1679 (CO) cm^{-1}; ^1H NMR ($CDCl_3$): δ 2.38 (s, 3H, CH_3), 2.51–2.56 (m, 2H, 3-butene 2-H), 4.03 (t, *J* = 7.3 Hz, 2H, 3-butene 1-H), 5.08–5.19 (m, 2H, 3-butene 4-H), 5.79–5.88 (m, 1H, 3-butene 3-H), 6.46 (s, 1H, furan 4-H), 7.20–7.22 (m, 2H, aryl H), 7.25–7.29 (m, 2H, aryl H), 7.33–7.40 (m, 3H, aryl H), 7.41–7.44 (m, 2H, aryl H); ^{13}C NMR ($CDCl_3$): δ 21.3 (CH_3), 32.7 (3-butene C-2), 48.3 (3-butene C-1), 93.5 (furan C-3), 105.0 (furan C-4), 112.0 (CN), 117.6 (3-butene C-4), 124.0, 125.5, 127.7, 128.2, 129.7, 131.0 (C aryl), 134.1

(3-butene C-3), 134.8, 139.4 (C aryl), 151.6 (furan C-5), 154.3 (furan C-2), 169.6 (CO); MS: *m/z* 357 $[M+H]^+$. Anal. Calcd for $C_{23}H_{20}N_2O_2$: C, 77.51; H, 5.66; N, 7.86. Found: C, 77.51; H, 5.76; N, 7.87.

***N*-3-Buten-1-yl-*N*-[5-(4-chlorophenyl)-3-cyano-2-furanyl]benzamide (6d)**

Colorless columns (0.10 g, 5%), mp 118–119 °C (Et_2O); IR (KBr): 2236 (CN), 1672 (CO) cm^{-1}; ^1H NMR ($CDCl_3$): δ 2.51–2.56 (m, 2H, 3-butene 2-H), 4.04 (t, *J* = 7.3 Hz, 2H, 3-butene 1-H), 5.08–5.18 (m, 2H, 3-butene 4-H), 5.79–5.88 (m, 1H, 3-butene 3-H), 6.53 (s, 1H, furan 4-H), 7.25–7.30 (m, 2H, aryl H), 7.35–7.44 (m, 7H, aryl H); ^{13}C NMR ($CDCl_3$): δ 32.8 (3-butene C-2), 48.4 (3-butene C-1), 93.4 (furan C-3), 106.2 (furan C-4), 111.7 (CN), 117.7 (3-butene C-4), 125.2, 126.7, 127.7, 128.3, 129.3, 131.1 (C aryl), 134.0 (3-butene C-3), 134.7, 135.1 (C aryl), 150.1 (furan C-5), 154.9 (furan C-2), 169.5 (CO); MS: *m/z* 377 $[M+H]^+$. Anal. Calcd for $C_{22}H_{17}ClN_2O_2$: C, 70.12; H, 4.55; N, 7.43. Found: C, 70.13; H, 4.63; N, 7.46.

General procedure for the preparation of dihydroindoles 7a–d and 8a–d from 5a–d and 6a–d.

A mixture of **5a–d** and **6a–d** (1 mmol) in 1,2-dichlorobenzene (1 mL) was stirred at 180 °C for 4 h. After removal of the solvent *in vacuo*, cold water was added to the residue. The precipitate was isolated by filtration, washed with water, dried, and recrystallized from an appropriate solvent to give **7a–d** and **8a–d**.

1-Acetyl-2,3-dihydro-5-phenyl-1*H*-indole-7-carbonitrile (7a)

Colorless columns (0.22 g, 84%), mp 177–178 °C (acetone); IR (KBr): 2224 (CN), 1675 (CO) cm^{-1}; ^1H NMR (DMSO-d_6): δ 2.26 (s, 3H, $COCH_3$), 3.19 (t, *J* = 8.2 Hz, 2H, 3-H), 4.20 (t, *J* = 8.2 Hz, 2H, 2-H), 7.36–7.40 (m, 1H, aryl H), 7.44–7.48 (m, 2H, aryl H), 7.68–7.71 (m, 2H, aryl H), 7.77–7.79 (m, 1H, aryl H), 7.86–7.87 (m, 1H, aryl H); ^{13}C NMR (DMSO-d_6): δ 23.4 ($COCH_3$), 28.1 (C-3), 49.7 (C-2), 101.5 (C aryl), 117.0 (CN), 126.4, 127.5, 127.7, 128.9, 129.4, 136.3, 136.9, 137.9, 142.2 (C aryl), 168.3 (CO); MS: *m/z* 263 $[M+H]^+$. Anal. Calcd for $C_{17}H_{14}N_2O$: C, 77.84; H, 5.38; N, 10.68. Found: C, 77.89; H, 5.49; N, 10.67.

1-Acetyl-2,3-dihydro-5-(4-methoxyphenyl)-1*H*-indole-7-carbonitrile (7b)

Colorless needles (0.24 g, 82%), mp 188–189 °C (acetone); IR (KBr): 2225 (CN), 1676 (CO) cm^{-1}; ^1H NMR (DMSO-d_6): δ 2.26 (s, 3H, $COCH_3$), 3.17 (t, *J* = 8.2 Hz, 2H, 3-H), 3.80 (s, 3H, OCH_3), 4.18 (t, *J* = 8.2 Hz, 2H, 2-H), 7.00–7.03 (m, 2H, aryl H), 7.63–7.65 (m, 2H, aryl H), 7.71–7.72 (m, 1H, aryl H), 7.81–7.82 (m, 1H, aryl H); ^{13}C NMR (DMSO-d_6): δ 23.3 ($COCH_3$), 28.1 (C-3), 49.7 (C-2), 55.1 (OCH_3), 101.5, 114.4 (C aryl), 117.1 (CN), 127.0, 127.6, 128.7, 130.2, 136.0, 136.8, 141.6, 159.1 (C aryl), 168.3 (CO); MS: *m/z* 293 $[M+H]^+$. Anal. Calcd for $C_{18}H_{16}N_2O_2$: C, 73.95; H, 5.52; N, 9.58. Found: C, 73.98; H, 5.57; N, 9.55.

1-Acetyl-2,3-dihydro-5-(4-methylphenyl)-1*H*-indole-7-carbonitrile (7c)

Colorless prisms (0.23 g, 83%), mp 200–201 °C (acetone); IR (KBr): 2221 (CN), 1666 (CO) cm^{-1}; ^1H

NMR (DMSO-d_6): δ 2.26 (s, 3H, $COCH_3$), 2.34 (s, 3H, CH_3), 3.18 (t, *J* = 8.2 Hz, 2H, 3-H), 4.19 (t, *J* = 8.2 Hz, 2H, 2-H), 7.25–7.28 (m, 2H, aryl H), 7.57–7.61 (m, 2H, aryl H), 7.74–7.75 (m, 1H, aryl H), 7.83–7.85 (m, 1H, aryl H); ^{13}C NMR (DMSO-d_6): δ 20.5 (CH_3), 23.3 ($COCH_3$), 28.1 (C-3), 49.7 (C-2), 101.5 (C aryl), 117.1 (CN), 126.2, 127.3, 129.1, 129.5, 135.0, 136.2, 136.8, 137.1, 141.9 (C aryl), 168.3 (CO); MS: *m/z* 277 $[M+H]^+$. Anal. Calcd for $C_{18}H_{16}N_2O$: C, 78.24; H, 5.84; N, 10.14. Found: C, 78.25; H, 5.90; N, 10.14.

1-Acetyl-5-(4-chlorophenyl)-2,3-dihydro-1*H*-indole-7-carbonitrile (7d)

Colorless needles (0.22 g, 74%), mp 179–180 °C (acetone); IR (KBr): 2222 (CN), 1678 (CO) cm^{-1}; ^1H NMR (DMSO-d_6): δ 2.26 (s, 3H, $COCH_3$), 3.19 (t, *J* = 8.2 Hz, 2H, 3-H), 4.20 (t, *J* = 8.2 Hz, 2H, 2-H), 7.48–7.52 (m, 2H, aryl H), 7.71–7.75 (m, 2H, aryl H), 7.80–7.81 (m, 1H, aryl H), 7.86–7.87 (m, 1H, aryl H); ^{13}C NMR (DMSO-d_6): δ 23.4 ($COCH_3$), 28.1 (C-3), 49.7 (C-2), 101.6 (C aryl), 116.9 (CN), 127.4, 128.2, 128.8, 129.5, 132.6, 134.9, 136.7, 136.9, 142.4 (C aryl), 168.4 (CO); MS: *m/z* 297 $[M+H]^+$. Anal. Calcd for $C_{17}H_{13}ClN_2O$: C, 68.81; H, 4.42; N, 9.44. Found: C, 68.89; H, 4.46; N, 9.47.

1-Benzoyl-2,3-dihydro-5-phenyl-1*H*-indole-7-carbonitrile (8a)

Colorless prisms (0.25 g, 77%), mp 267–268 °C (CH_2Cl_2); IR (KBr): 2229 (CN), 1662 (CO) cm^{-1}; ^1H NMR ($CDCl_3$): δ 3.16 (t, *J* = 7.9 Hz, 2H, 3-H), 4.23 (t, *J* = 7.9 Hz, 2H, 2-H), 7.36–7.40 (m, 1H, aryl H), 7.44–7.49 (m, 4H, aryl H), 7.52–7.55 (m, 3H, aryl H), 7.56–7.65 (m, 1H, aryl H), 7.72–7.73 (m, 1H, aryl H), 7.75–7.77 (m, 2H, aryl H); ^{13}C NMR ($CDCl_3$): δ 29.5 (C-3), 53.3 (C-2), 103.8 (C aryl), 116.8 (CN), 126.9, 127.7, 128.0, 128.5, 128.8, 129.1, 130.5, 131.9, 134.6, 136.2, 138.5, 138.9, 143.6 (C aryl), 169.4 (CO); MS: *m/z* 325 $[M+H]^+$. Anal. Calcd for $C_{22}H_{16}N_2O$: C, 81.46; H, 4.97; N, 8.64. Found: C, 81.39; H, 5.08; N, 8.69.

1-Benzoyl-2,3-dihydro-5-(4-methoxyphenyl)-1*H*-indole-7-carbonitrile (8b)

Pale yellow columns (0.28 g, 79%), mp 214–215 °C (acetone); IR (KBr): 2231 (CN), 1660 (CO) cm^{-1}; ^1H NMR (DMSO-d_6): δ 3.15 (t, *J* = 7.9 Hz, 2H, 3-H), 3.81 (s, 3H, OCH_3), 4.18 (t, *J* = 7.9 Hz, 2H, 2-H), 7.02–7.05 (m, 2H, aryl H), 7.53–7.57 (m, 2H, aryl H), 7.61–7.63 (m, 1H, aryl H), 7.67–7.70 (m, 2H, aryl H), 7.76–7.79 (m, 2H, aryl H), 7.83–7.84 (m, 1H, aryl H), 7.88–7.89 (m, 1H, aryl H); ^{13}C NMR (DMSO-d_6): δ 29.0 (C-3), 53.1 (C-2), 55.2 (OCH_3), 102.5, 114.4 (C aryl), 116.7 (CN), 127.2, 127.7, 128.3, 128.4, 128.5, 130.3, 131.7, 134.6, 136.8, 137.3, 142.8, 159.2 (C aryl), 168.5 (CO); MS: *m/z* 355 $[M+H]^+$. Anal. Calcd for $C_{23}H_{18}N_2O_2$: C, 77.95; H, 5.12; N, 7.90. Found: C, 78.03; H, 5.23; N, 7.89.

1-Benzoyl-2,3-dihydro-5-(4-methylphenyl)-1*H*-indole-7-carbonitrile (8c)

Pale brown prisms (0.28 g, 83%), mp 201–202 °C (acetone); IR (KBr): 2231 (CN), 1668 (CO) cm^{-1}; ^1H NMR (DMSO-d_6): δ 2.35 (s, 3H, CH_3), 3.16 (t, *J* = 7.9 Hz, 2H, 3-H), 4.18 (t, *J* = 7.9 Hz, 2H, 2-H), 7.28–7.30 (m, 2H, aryl H), 7.53–7.57 (m, 2H, aryl H), 7.61–7.64 (m, 3H, aryl H), 7.77–7.79 (m, 2H, aryl H), 7.86 (s, 1H, aryl H), 7.91 (s, 1H, aryl H); ^{13}C NMR (DMSO-d_6): δ 20.6 (CH_3), 28.9 (C-3), 53.1 (C-2), 102.5 (C aryl), 116.7 (CN), 126.4, 127.4, 128.4, 128.5, 128.6, 129.5, 131.7, 134.6, 135.0, 136.9, 137.3, 143.1 (C aryl), 168.5 (CO); MS: *m/z* 339 $[M+H]^+$. Anal. Calcd for $C_{23}H_{18}N_2O$: C, 81.63; H, 5.36; N, 8.28. Found: C, 81.63; H, 5.48; N, 8.26.

1-Benzoyl-5-(4-chlorophenyl)-2,3-dihydro-1*H*-indole-7-carbonitrile (8d)

Colorless prisms (0.30 g, 85%), mp 235–236 °C (acetone); IR (KBr): 2236 (CN), 1665 (CO) cm^{-1}; ^1H NMR (DMSO-d_6): δ 3.17 (t, *J* = 7.9 Hz, 2H, 3-H), 4.20 (t, *J* = 7.9 Hz, 2H, 2-H), 7.52–7.58 (m, 4H, aryl H), 7.61–7.64 (m, 1H, aryl H), 7.76–7.79 (m, 4H, aryl H), 7.92–7.93 (m, 1H, aryl H), 7.94–7.95 (m, 1H, aryl H); ^{13}C NMR (DMSO-d_6): δ 28.9 (C-3), 53.1 (C-2), 102.6 (C aryl), 116.6 (CN), 127.7, 128.4, 128.47, 128.52, 128.9, 129.1, 131.8, 132.8, 134.5, 135.6, 136.8, 137.5, 143.7 (C aryl), 168.6 (CO); MS: *m/z* 359 $[M+H]^+$. Anal. Calcd for $C_{22}H_{15}ClN_2O$: C, 73.64; H, 4.21; N, 7.81. Found: C, 73.67; H, 4.31; N, 7.78.

General procedure for the preparation of 9a–d and 10a–d from 3a–d and/or 4a–d and 5-bromo-1-pentene.

To an ice-cooled and stirred solution of **3a–d** and **4a–d** (5 mmol) in DMF (5 mL) was added 60% NaH (0.24 g, 6 mmol). The stirring was continued at rt until evolution of gas ceased. To the obtained mixture was added 5-bromo-1-pentene (1.49 g, 10 mmol) with stirring and then the mixture was stirred at 80 °C for 5 h. After removal of the solvent *in vacuo*, cold water was added to the residue. The resulting mixture was extracted with Et_2O (60 mL). The extract was dried over anhydrous sodium sulfate and concentrated *in vacuo*. The residue was purified by column chromatography on silica gel with CH_2Cl_2 as the eluent to afford **9a–d** and **10a–d**.

***N*-(3-Cyano-5-phenyl-2-furanyl)-*N*-4-penten-1-ylacetamide (9a)**

Brown oil (1.22 g, 83%); IR (neat): 2236 (CN), 1698 (CO) cm^{-1}; ^1H NMR ($CDCl_3$): δ 1.69–1.76 (m, 2H, 4-pentene 2-H), 2.09 (s, 3H, $COCH_3$), 2.10–2.15 (m, 2H, 4-pentene 3-H), 3.78 (t, *J* = 7.6 Hz, 2H, 4-pentene 1-H), 4.95–5.05 (m, 2H, 4-pentene 5-H), 5.74–5.83 (m, 1H, 4-pentene 4-H), 6.79 (s, 1H, furan 4-H), 7.37–7.47 (m, 3H, aryl H), 7.60–7.63 (m, 2H, aryl H); ^{13}C NMR ($CDCl_3$): δ 22.0 ($COCH_3$), 27.5 (4-pentene C-2), 30.6 (4-pentene C-3), 47.8 (4-pentene C-1), 94.0 (furan C-3), 105.8 (furan C-4), 112.1 (CN), 115.5 (4-pentene C-5), 124.1, 128.2, 129.1, 129.4 (C aryl), 137.2 (4-pentene C-4), 152.2 (furan C-5), 154.4 (furan C-2), 169.7 (CO); MS: *m/z* 295 $[M+H]^+$. Anal. Calcd for $C_{18}H_{18}N_2O_2$: C, 73.45; H, 6.16; N, 9.52. Found: C, 73.48; H, 6.25; N, 9.45.

***N*-[3-Cyano-5-(4-methoxyphenyl)-2-furanyl]-*N*-4-penten-1-ylacetamide (9b)**

Colorless columns (0.96 g, 59%), mp 56–57 °C (Et_2O/petroleum ether); IR (KBr): 2235 (CN), 1691 (CO) cm^{-1}; ^1H NMR ($CDCl_3$): δ 1.68–1.75 (m, 2H, 4-pentene 2-H), 2.07 (s, 3H, $COCH_3$), 2.09–2.14 (m, 2H, 4-pentene 3-H), 3.76 (t, *J* = 7.5 Hz, 2H, 4-pentene 1-H), 3.85 (s, 3H, OCH_3), 4.95–5.04 (m, 2H, 4-pentene 5-H), 5.74–5.83 (m, 1H, 4-pentene 4-H), 6.64 (s, 1H, furan 4-H), 6.94–6.98 (m, 2H, aryl H), 7.53–7.56 (m, 2H, aryl H); ^{13}C NMR ($CDCl_3$): δ 22.0 ($COCH_3$), 27.5 (4-pentene C-2), 30.7 (4-pentene C-3), 47.8

(4-pentene C-1), 55.4 (OCH_3), 94.0 (furan C-3), 104.1 (furan C-4), 112.3 (CN), 114.6 (C aryl), 115.4 (4-pentene C-5), 121.0, 125.8 (C aryl), 137.2 (4-pentene C-4), 152.4 (furan C-5), 153.8 (furan C-2), 160.6 (C aryl), 169.8 (CO); MS: *m/z* 325 $[M+H]^+$. Anal. Calcd for $C_{19}H_{20}N_2O_3$: C, 70.35; H, 6.21; N, 8.64. Found: C, 70.39; H, 6.28; N, 8.61.

***N*-[3-Cyano-5-(4-methylphenyl)-2-furanyl]-*N*-4-penten-1-ylacetamide (9c)**

Colorless columns (0.87 g, 56%), mp 54–55 °C (Et_2O/petroleum ether); IR (KBr): 2236 (CN), 1697 (CO) cm^{-1}; ^1H NMR ($CDCl_3$): δ 1.68–1.75 (m, 2H, 4-pentene 2-H), 2.07 (s, 3H, $COCH_3$), 2.08–2.14 (m, 2H, 4-pentene 3-H), 2.39 (s, 3H, CH_3), 3.77 (t, *J* = 7.6 Hz, 2H, 4-pentene 1-H), 4.95–5.04 (m, 2H, 4-pentene 5-H), 5.73–5.82 (m, 1H, 4-pentene 4-H), 6.72 (s, 1H, furan 4-H), 7.23–7.26 (m, 2H, aryl H), 7.49–7.52 (m, 2H, aryl H); ^{13}C NMR ($CDCl_3$): δ 21.3 (CH_3), 22.0 ($COCH_3$), 27.5 (4-pentene C-2), 30.7 (4-pentene C-3), 47.8 (4-pentene C-1), 94.0 (furan C-3), 105.0 (furan C-4), 112.2 (CN), 115.4 (4-pentene C-5), 124.1, 125.5, 129.8 (C aryl), 137.2 (4-pentene C-4), 139.7 (C aryl), 152.5 (furan C-5), 154.1 (furan C-2), 169.8 (CO); MS: *m/z* 309 $[M+H]^+$. Anal. Calcd for $C_{19}H_{20}N_2O_2$: C, 74.00; H, 6.54; N, 9.08. Found: C, 74.06; H, 6.56; N, 9.10.

***N*-[5-(4-Chlorophenyl)-3-cyano-2-furanyl]-*N*-4-penten-1-ylacetamide (9d)**

Colorless columns (0.98 g, 60%), mp 56–57 °C (Et_2O/petroleum ether); IR (KBr): 2238 (CN), 1696 (CO) cm^{-1}; ^1H NMR ($CDCl_3$): δ 1.68–1.75 (m, 2H, 4-pentene 2-H), 2.09 (s, 3H, $COCH_3$), 2.09–2.14 (m, 2H, 4-pentene 3-H), 3.77 (t, *J* = 7.6 Hz, 2H, 4-pentene 1-H), 4.96–5.04 (m, 2H, 4-pentene 5-H), 5.73–5.82 (m, 1H, 4-pentene 4-H), 6.79 (s, 1H, furan 4-H), 7.40–7.44 (m, 2H, aryl H), 7.53–7.57 (m, 2H, aryl H); ^{13}C NMR ($CDCl_3$): δ 22.0 ($COCH_3$), 27.5 (4-pentene C-2), 30.6 (4-pentene C-3), 47.9 (4-pentene C-1), 94.1 (furan C-3), 106.3 (furan C-4), 111.9 (CN), 115.5 (4-pentene C-5), 125.4, 126.6, 129.4, 135.4 (C aryl), 137.1 (4-pentene C-4), 151.1 (furan C-5), 154.6 (furan C-2), 169.5 (CO); MS: *m/z* 329 $[M+H]^+$. Anal. Calcd for $C_{18}H_{17}ClN_2O_2$: C, 65.75; H, 5.21; N, 8.52. Found: C, 65.82; H, 5.29; N, 8.50.

***N*-(3-Cyano-5-phenyl-2-furanyl)-*N*-4-penten-1-ylbenzamide (10a)**

Colorless prisms (1.03 g, 58%), mp 101–102 °C (Et_2O/petroleum ether); IR (KBr): 2237 (CN), 1666 (CO) cm^{-1}; ^1H NMR ($CDCl_3$): δ 1.83–1.90 (m, 2H, 4-pentene 2-H), 2.17–2.23 (m, 2H, 4-pentene 3-H), 3.95–3.99 (m, 2H, 4-pentene 1-H), 4.98–5.09 (m, 2H, 4-pentene 5-H), 5.79–5.88 (m, 1H, 4-pentene 4-H), 6.54 (s, 1H, furan 4-H), 7.25–7.30 (m, 2H, aryl H), 7.33–7.45 (m, 6H, aryl H), 7.47–7.50 (m, 2H, aryl H); ^{13}C NMR ($CDCl_3$): δ 27.4 (4-pentene C-2), 30.8 (4-pentene C-3), 48.6 (4-pentene C-1), 93.5 (furan C-3), 105.8 (furan C-4), 111.9 (CN), 115.5 (4-pentene C-5), 124.0, 127.7, 128.2, 129.0, 129.2, 131.0, 134.9 (C aryl), 137.2 (4-pentene C-4), 151.3 (furan C-5), 154.7 (furan C-2), 169.6 (CO); MS: *m/z* 357 $[M+H]^+$. Anal. Calcd for $C_{23}H_{20}N_2O_2$: C, 77.51; H, 5.66; N, 7.86. Found: C, 77.57; H, 5.74; N, 7.88.

***N*-[3-Cyano-5-(4-methoxyphenyl)-2-furanyl]-*N*-4-penten-1-ylbenzamide (10b)**

Colorless columns (0.66 g, 34%), mp 95–96 °C (Et_2O); IR (KBr): 2233 (CN), 1679 (CO) cm^{-1}; ^1H NMR

($CDCl_3$): δ 1.82–1.89 (m, 2H, 4-pentene 2-H), 2.17–2.23 (m, 2H, 4-pentene 3-H), 3.84 (s, 3H, OCH_3), 3.93–3.97 (m, 2H, 4-pentene 1-H), 4.98–5.09 (m, 2H, 4-pentene 5-H), 5.79–5.88 (m, 1H, 4-pentene 4-H), 6.39 (s, 1H, furan 4-H), 6.91–6.95 (m, 2H, aryl H), 7.25–7.30 (m, 2H, aryl H), 7.33–7.38 (m, 1H, aryl H), 7.40–7.45 (m, 4H, aryl H); ^{13}C NMR ($CDCl_3$): δ 27.4 (4-pentene C-2), 30.8 (4-pentene C-3), 48.6 (4-pentene C-1), 55.4 (OCH_3), 93.5 (furan C-3), 104.0 (furan C-4), 112.0 (CN), 114.5 (C aryl), 115.5 (4-pentene C-5), 121.1, 125.6, 127.6, 128.2, 130.9, 134.9 (C aryl), 137.2 (4-pentene C-4), 151.6 (furan C-5), 154.1 (furan C-2), 160.4 (C aryl), 169.7 (CO); MS: *m/z* 387 $[M+H]^+$. Anal. Calcd for $C_{24}H_{22}N_2O_3$: C, 74.59; H, 5.74; N, 7.25. Found: C, 74.70; H, 5.84; N, 7.25.

_N_-[3-Cyano-5-(4-methylphenyl)-2-furanyl]-_N_-4-penten-1-ylbenzamide (10c)

Colorless needles (0.80 g, 43%), mp 95–96 °C (Et_2O); IR (KBr): 2232 (CN), 1673 (CO) cm^{-1}; ^1H NMR ($CDCl_3$): δ 1.83–1.90 (m, 2H, 4-pentene 2-H), 2.17–2.23 (m, 2H, 4-pentene 3-H), 2.38 (s, 3H, CH_3), 3.94–3.98 (m, 2H, 4-pentene 1-H), 4.98–5.09 (m, 2H, 4-pentene 5-H), 5.79–5.88 (m, 1H, 4-pentene 4-H), 6.47 (s, 1H, furan 4-H), 7.19–7.23 (m, 2H, aryl H), 7.25–7.29 (m, 2H, aryl H), 7.33–7.40 (m, 3H, aryl H), 7.41–7.44 (m, 2H, aryl H); ^{13}C NMR ($CDCl_3$): δ 21.3 (CH_3), 27.4 (4-pentene C-2), 30.8 (4-pentene C-3), 48.6 (4-pentene C-1), 93.5 (furan C-3), 105.0 (furan C-4), 112.0 (CN), 115.5 (4-pentene C-5), 124.0, 125.5, 127.6, 128.2, 129.7, 131.0, 134.9 (C aryl), 137.2 (4-pentene C-4), 139.4 (C aryl), 151.6 (furan C-5), 154.4 (furan C-2), 169.7 (CO); MS: *m/z* 371 $[M+H]^+$. Anal. Calcd for $C_{24}H_{22}N_2O_2$: C, 77.81; H, 5.99; N, 7.56. Found: C, 77.89; H, 6.10; N, 7.59.

_N_-[5-(4-Chlorophenyl)-3-cyano-2-furanyl]-_N_-4-penten-1-ylbenzamide (10d)

Pale yellow prisms (0.92 g, 47%), mp 120–121 °C (Et_2O); IR (KBr): 2237 (CN), 1673 (CO) cm^{-1}; ^1H NMR ($CDCl_3$): δ 1.83–1.89 (m, 2H, 4-pentene 2-H), 2.17–2.23 (m, 2H, 4-pentene 3-H), 3.95–3.99 (m, 2H, 4-pentene 1-H), 4.98–5.08 (m, 2H, 4-pentene 5-H), 5.78–5.87 (m, 1H, 4-pentene 4-H), 6.54 (s, 1H, furan 4-H), 7.25–7.31 (m, 2H, aryl H), 7.35–7.44 (m, 7H, aryl H); ^{13}C NMR ($CDCl_3$): δ 27.4 (4-pentene C-2), 30.8 (4-pentene C-3), 48.6 (4-pentene C-1), 93.4 (furan C-3), 106.2 (furan C-4), 111.7 (CN), 115.6 (4-pentene C-5), 125.2, 126.7, 127.6, 128.3, 129.3, 131.1, 134.8, 135.2 (C aryl), 137.2 (4-pentene C-4), 150.2 (furan C-5), 155.0 (furan C-2), 169.5 (CO); MS: *m/z* 391 $[M+H]^+$. Anal. Calcd for $C_{23}H_{19}ClN_2O_2$: C, 70.68; H, 4.90; N, 7.17. Found: C, 70.72; H, 5.02; N, 7.18.

General procedure for the preparation of tetrahydroquinolines 11a–d and 12a–d from 9a–d and 10a–d.

A mixture of **9a–d** and **10a–d** (1 mmol) in 1-methyl-2-pyrrolidinone (1 mL) was stirred at 210 °C for 16 h (in the case of the preparation of **11a–d**, **12a**, and **12d**) or for 20 h (in the case of the preparation of **12b**,**c**). After removal of the solvent *in vacuo*, cold water was added to the residue. Further processing of the resulting mixture is described in the following paragraphs.

(A) The resulting mixture was extracted with CH_2Cl_2 (30 mL). The extract was dried over anhydrous sodium sulfate and concentrated *in vacuo*. The residue was purified by column chromatography on silica gel with CH_2Cl_2-acetone (4:1) as the eluent to afford **11a–d**.

(B) The precipitate was isolated by filtration, washed with water, dried, and recrystallized from an appropriate solvent to give **12a–d**.

1-Acetyl-1,2,3,4-tetrahydro-6-phenyl-8-quinolinecarbonitrile (11a)

Colorless columns (0.16 g, 58%), mp 136–137 °C (acetone/petroleum ether); IR (KBr): 2231 (CN), 1659 (CO) cm^{-1}; ^1H NMR (DMSO-d_6): δ 1.97 (br s, 2H, 3-H), 2.23 (br s, 3H, $COCH_3$), 2.85 (br s, 2H, 4-H), 3.78 (br s, 2H, 2-H), 7.38–7.43 (m, 1H, aryl H), 7.46–7.50 (m, 2H, aryl H), 7.72–7.75 (m, 2H, aryl H), 7.85 (br s, 1H, aryl H), 7.93 (br s, 1H, aryl H); ^{13}C NMR (DMSO-d_6): δ 22.1 ($COCH_3$), 23.3 (C-3), 25.9 (C-4), 45.0 (C-2), 109.9 (C aryl), 117.2 (CN), 126.6, 128.0, 128.4, 128.9, 131.3, 137.3, 137.7 (C aryl), 169.7 (CO); MS: *m/z* 277 $[M+H]^+$. Anal. Calcd for $C_{18}H_{16}N_2O$: C, 78.24; H, 5.84; N, 10.14. Found: C, 78.31; H, 5.96; N, 10.12.

1-Acetyl-1,2,3,4-tetrahydro-6-(4-methoxyphenyl)-8-quinolinecarbonitrile (11b)

Brown oil (0.16 g, 52%); IR (neat): 2228 (CN), 1670 (CO) cm^{-1}; ^1H NMR (DMSO-d_6): δ 1.96 (br s, 2H, 3-H), 2.21 (br s, 3H, $COCH_3$), 2.83 (br s, 2H, 4-H), 3.81 (br s, 2H, 2-H), 3.81 (s, 3H, OCH_3), 7.01–7.05 (m, 2H, aryl H), 7.67–7.70 (m, 2H, aryl H), 7.80 (br s, 1H, aryl H), 7.88 (br s, 1H, aryl H); ^{13}C NMR (DMSO-d_6): δ 22.1 ($COCH_3$), 23.4 (C-3), 25.8 (C-4), 45.0 (C-2), 55.2 (OCH_3), 114.4 (C aryl), 117.3 (CN), 127.8, 130.0, 130.7, 159.3 (C aryl), 169.7 (CO); MS: *m/z* 307 $[M+H]^+$. Anal. Calcd for $C_{19}H_{18}N_2O_2 \cdot 0.25H_2O$: C, 73.41; H, 6.00; N, 9.01. Found: C, 73.45; H, 6.08; N, 8.91.

1-Acetyl-1,2,3,4-tetrahydro-6-(4-methylphenyl)-8-quinolinecarbonitrile (11c)

Pale brown prisms (0.15 g, 52%), mp 129–130 °C (acetone/petroleum ether); IR (KBr): 2224 (CN), 1665 (CO) cm^{-1}; ^1H NMR (DMSO-d_6): δ 1.96 (br s, 2H, 3-H), 2.22 (br s, 3H, $COCH_3$), 2.35 (s, 3H, CH_3), 2.83 (br s, 2H, 4-H), 3.78 (br s, 2H, 2-H), 7.27–7.30 (m, 2H, aryl H), 7.61–7.64 (m, 2H, aryl H), 7.82 (br s, 1H, aryl H), 7.90 (br s, 1H, aryl H); ^{13}C NMR (DMSO-d_6): δ 20.6 (CH_3), 22.1 ($COCH_3$), 23.3 (C-3), 25.8 (C-4), 44.9 (C-2), 117.2 (CN), 126.4, 128.1, 129.5, 130.9, 134.7, 137.1, 137.5 (C aryl), 169.7 (CO); MS: *m/z* 291 $[M+H]^+$. Anal. Calcd for $C_{19}H_{18}N_2O$: C, 78.59; H, 6.25; N, 9.65. Found: C, 78.64; H, 6.31; N, 9.63.

1-Acetyl-6-(4-chlorophenyl)-1,2,3,4-tetrahydro-8-quinolinecarbonitrile (11d)

Colorless prisms (0.14 g, 45%), mp 129–130 °C (Et_2O); IR (KBr): 2232 (CN), 1674 (CO) cm^{-1}; ^1H NMR (DMSO-d_6): δ 1.96 (br s, 2H, 3-H), 2.23 (br s, 3H, $COCH_3$), 2.84 (br s, 2H, 4-H), 3.79 (br s, 2H, 2-H), 7.51–7.55 (m, 2H, aryl H), 7.75–7.79 (m, 2H, aryl H), 7.86 (br s, 1H, aryl H), 7.96 (br s, 1H, aryl H); ^{13}C NMR (DMSO-d_6): δ 22.1 ($COCH_3$), 23.3 (C-3), 25.8 (C-4), 45.0 (C-2), 117.1 (CN), 128.4, 128.9, 131.2, 132.9, 136.5 (C aryl), 169.7 (CO); MS: *m/z* 311 $[M+H]^+$. Anal. Calcd for $C_{18}H_{15}ClN_2O$: C, 69.57; H, 4.86; N, 9.01. Found: C, 69.51; H, 4.94; N, 8.97.

1-Benzoyl-1,2,3,4-tetrahydro-6-phenyl-8-quinolinecarbonitrile (12a)

Colorless prisms (0.24 g, 71%), mp 238–239 °C (CH_2Cl_2); IR (KBr): 2224 (CN), 1664 (CO) cm^{-1}; ^1H NMR (DMSO-d_6): δ 1.95 (br s, 2H, 3-H), 2.95 (t, J = 6.7 Hz, 2H, 4-H), 3.80 (br s, 2H, 2-H), 7.38–7.54 (m, 8H, aryl H), 7.73–7.75 (m, 2H, aryl H), 7.86–7.88 (m, 1H, aryl H), 7.91–7.93 (m, 1H, aryl H); ^{13}C NMR (DMSO-d_6): δ 23.4 (C-3), 25.9 (C-4), 46.1 (C-2), 109.4 (C aryl), 116.9 (CN), 126.6, 128.1, 128.2, 128.5, 129.0, 130.9, 131.4, 134.9, 135.0, 137.2, 137.5, 140.5 (C aryl), 170.5 (CO); MS: *m/z* 339 $[M+H]^+$. Anal. Calcd for $C_{23}H_{18}N_2O$: C, 81.63; H, 5.36; N, 8.28. Found: C, 81.55; H, 5.43; N, 8.25.

1-Benzoyl-1,2,3,4-tetrahydro-6-(4-methoxyphenyl)-8-quinolinecarbonitrile (12b)

Pale brown prisms (0.21 g, 57%), mp 192–193 °C (acetone); IR (KBr): 2232 (CN), 1661 (CO) cm^{-1}; ^1H NMR (DMSO-d_6): δ 1.95 (br s, 2H, 3-H), 2.93 (t, J = 6.7 Hz, 2H, 4-H), 3.77–3.81 (m, 3H, 2-H), 3.80 (s, 3H, OCH_3), 7.01–7.04 (m, 2H, aryl H), 7.41–7.45 (m, 2H, aryl H), 7.48–7.51 (m, 3H, aryl H), 7.67–7.70 (m, 2H, aryl H), 7.80–7.82 (m, 1H, aryl H), 7.86–7.87 (m, 1H, aryl H); ^{13}C NMR (DMSO-d_6): δ 23.5 (C-3), 25.9 (C-4), 46.0 (C-2), 55.2 (OCH_3), 109.3, 114.4 (C aryl), 116.9 (CN), 127.7, 127.8, 128.2, 128.5, 129.8, 130.7, 130.8, 134.8, 135.1, 137.0, 139.8, 159.4 (C aryl), 170.4 (CO); MS: *m/z* 369 $[M+H]^+$. Anal. Calcd for $C_{24}H_{20}N_2O_2$: C, 78.24; H, 5.47; N, 7.60. Found: C, 78.31; H, 5.61; N, 7.59.

1-Benzoyl-1,2,3,4-tetrahydro-6-(4-methylphenyl)-8-quinolinecarbonitrile (12c)

Colorless columns (0.21 g, 60%), mp 171–172 °C (acetone); IR (KBr): 2227 (CN), 1653 (CO) cm^{-1}; ^1H NMR (DMSO-d_6): δ 1.95 (br s, 2H, 3-H), 2.35 (s, 3H, CH_3), 2.94 (t, J = 6.7 Hz, 2H, 4-H), 3.79 (br s, 2H, 2-H), 7.27–7.29 (m, 2H, aryl H), 7.41–7.45 (m, 2H, aryl H), 7.49–7.53 (m, 3H, aryl H), 7.61–7.64 (m, 2H, aryl H), 7.83–7.84 (m, 1H, aryl H), 7.88–7.90 (m, 1H, aryl H); ^{13}C NMR (DMSO-d_6): δ 20.6 (CH_3), 23.4 (C-3), 25.9 (C-4), 46.1 (C-2), 109.4 (C aryl), 116.9 (CN), 126.4, 128.1, 128.2, 128.5, 129.6, 130.9, 131.1, 134.6, 134.8, 135.0, 137.2, 137.5, 140.2 (C aryl), 170.5 (CO); MS: *m/z* 353 $[M+H]^+$. Anal. Calcd for $C_{24}H_{20}N_2O$: C, 81.79; H, 5.72; N, 7.95. Found: C, 81.79; H, 5.84; N, 7.93.

1-Benzoyl-6-(4-chlorophenyl)-1,2,3,4-tetrahydro-8-quinolinecarbonitrile (12d)

Colorless columns (0.24 g, 64%), mp 221–222 °C (acetone); IR (KBr): 2229 (CN), 1650 (CO) cm^{-1}; ^1H NMR (DMSO-d_6): δ 1.95–1.97 (m, 2H, 3-H), 2.95 (t, J = 6.7 Hz, 2H, 4-H), 3.79 (br s, 2H, 2-H), 7.42–7.46 (m, 2H, aryl H), 7.50–7.54 (m, 5H, aryl H), 7.76–7.79 (m, 2H, aryl H), 7.90–7.91 (m, 1H, aryl H), 7.92–7.94 (m, 1H, aryl H); ^{13}C NMR (DMSO-d_6): δ 23.4 (C-3), 25.9 (C-4), 46.2 (C-2), 109.5 (C aryl), 116.8 (CN), 128.2, 128.4, 128.48, 128.50, 128.9, 130.9, 131.4, 133.0, 134.9, 135.0, 135.8, 136.3, 140.8 (C aryl), 170.5 (CO); MS: *m/z* 373 $[M+H]^+$. Anal. Calcd for $C_{23}H_{17}ClN_2O$: C, 74.09; H, 4.60; N, 7.51. Found: C, 74.07; H, 4.71; N, 7.48.

Preparation of pyridoquinazoline 13 from 11a.

A mixture of **11a** (0.276 g, 1 mmol) in 10% aqueous NaOH (1 mL) and MeOH (5 mL) was refluxed for 30 min. After removal of the solvent *in vacuo*, cold water was added to the residue. The precipitate was isolated by filtration, washed with water, dried, and recrystallized from acetone to yield 3-methyl-9-phenyl-1*H*,5*H*-pyrido[3,2,1-*ij*]quinazolin-1(6*H*)-one (**13**) (0.14 g, 51%) as colorless needles, mp 258–259 °C; IR (KBr): 1632 (CO) cm^{-1}; ^{1}H NMR (DMSO-d_6): δ 2.07–2.13 (m, 2H, 6-H), 2.53 (s, 3H, CH_3), 3.00 (t, J = 6.1 Hz, 2H, 7-H), 4.14 (t, J = 5.8 Hz, 2H, 5-H), 7.37–7.41 (m, 1H, aryl H), 7.47–7.51 (m, 2H, aryl H), 7.70–7.73 (m, 2H, aryl H), 7.86–7.87 (m, 1H, aryl H), 8.10–8.11 (m, 1H, aryl H); ^{13}C NMR (DMSO-d_6): δ 20.6 (C-6), 22.9 (CH_3), 25.9 (C-7), 46.7 (C-5), 119.6, 122.0, 126.4, 127.6, 127.8, 129.0, 130.7, 136.2, 137.0, 138.7 (C aryl), 160.8 (C-3), 167.8 (CO); MS: *m/z* 277 [M+H]$^+$. Anal. Calcd for $C_{18}H_{16}N_2O$: C, 78.24; H, 5.84; N, 10.14. Found: C, 78.16; H, 5.84; N, 10.11.

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