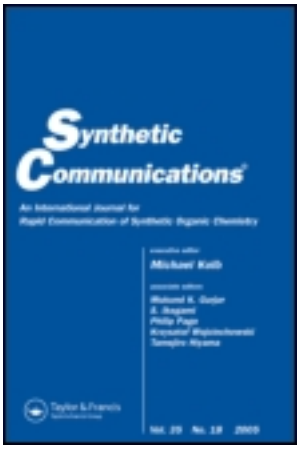

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Cu(acac)$_2$-CATALYZED *N*-ARYLATIONS OF PHENYLUREA WITH ARYL BORONIC ACID

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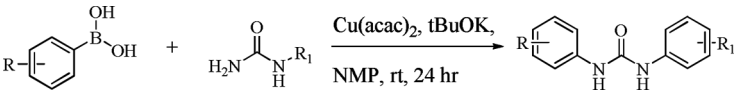
GRAPHICAL ABSTRACT



Abstract *Cu(acac)$_2$ activates aryl boronic acids for the reaction with NH$_2$-phenylurea without additional ligand and heating. The procedure is simple, general, ligand-free, milder than the palladium-catalyzed arylation, and avoids the use of toxic phosphine ligands.*

Keywords Aryl boronic acid; copper catalyzed; ligand free; phenylurea

INTRODUCTION

Transition–metal–catalyzed cross coupling of aryl halides and amines provides an invaluable entry toward the synthesis of a wide range of compounds, including pharmaceuticals and natural products. The copper-catalyzed variant has emerged as an important alternative that is promising for large-scale industrial applications because of lower catalyst cost and toxicity.[1] *N*,*N*′-Diarylureas are valuable subunits for organic synthesis and have found numerous applications as drugs,[2] pesticides,[2] selective anion-binding receptors,[3] and polymer materials.[4] One of the most common synthetic protocols for their preparation is the copper-catalyzed Ullmann reaction[5] and the related Goldberg reaction (copper-catalyzed *N*-arylation of amides).[6] Some ligand-free Ullmann-type coupling reactions have also been reported.[7–11] The palladium-catalyzed reactions are very sensitive to functional groups such as –OH, –NH$_2$, and exogenous air or moisture and also very expensive compared to the copper reagent.[12] Kotecki et al. have reported the palladium-catalyzed amidation of urea with different aryl halides, and Bippyphos was found to be a suitable ligand for these coupling reactions. However, this method suffers from the following disadvantages: (1) the use of toxic phosphine ligands, and

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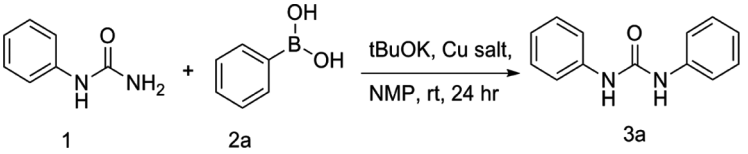


Figure 1. Cu/ligand-free catalyzed *N*-arylation of phenyl-urea and phenylboronic acid in NMP.

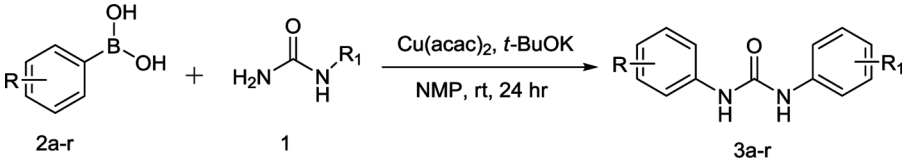


Figure 2. $Cu(acac)_2$-catalyzed *N*-arylation of ureas (**1**) with aryl boronic acids (**2a–r**).

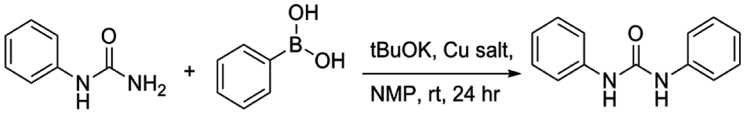
(2) the expensive palladium catalyst.[13] Sergeer et al. have reported that the electron-poor ligand 3,5-(CF_3) 2-xantphos is more effective than xantphos, requires lower catalyst loading, and gives better yields of products than xantphos.[1] An attempt by the same group for the arylation of urea using a copper catalyst was unsuccessful.[14]

Recently, Nandakumar[15] and Hosseinzadeh[16] et al. reported a copper catalyst and Kotecki et al.[13] and Artamkina et al.[17] reported a palladium catalyst system for the amidation of aryl halides with urea. Chan et al. and Lam et al.[18] also reported the preparation of C-N bonds via Cu-mediated coupling of amines with arylboronic acids under milder conditions, where arylboronic acids are used as arylating agents instead of aryl halides (Figure 1).[19] Xia and Taillefer reported a $Cu(acac)_2$ as a catalyst for amination of aryl halide.[20] Herein, we report the use of $Cu(acac)_2$-catalyzed *N*-arylation of *N*-phenylurea with aryl boronic acid using *t*-BuOK as a suitable base (Figure 2). The present methodology is simple, mild, and clean and works efficiently without additional ligand and heating.

RESULTS AND DISCUSSION

Optimization experiments involved phenylboronic acid (**1**) and phenylurea (**2a**) as test substrates and focused on determining the effect of the copper salt, the base, and the amount of boronic acid. Table 1 shows the influence of various copper salts on this transformation. Both copper(I) and copper(II) salts were catalytically active in the coupling reaction even at room temperature. Among the tested copper salts, $Cu(acac)_2$ was found to be the best catalyst, leading to 85% yield of **3a** within 24 h at room temperature (Table 1, entry 9). CuI and $Cu(OAc)_2$ afforded the N-arylated product[21] in moderate yields (Table 1, entries 1 and 8). However, the employment of $CuSO_4$, CuO, Cu_2O, $CuBr_2$, CuBr, and CuCl resulted in lesser yields (Table 1, entries 2–7). Increasing the catalyst amount had only a minor effect on the product yield, and smaller quantities led to longer reaction times and incomplete conversions. The reactions using *t*-BuOK as the base gave the desired product in good yields

Table 1. Cu/ligand-free catalyzed *N*-arylation of phenyl-urea and phenylboronic acid in NMP[a]



1 2a 3a

Entry	Copper salt (10 mol%)	Base	Yield[b] (%)
1	CuI	*t*-BuOK	45
2	$CuSO_4$	*t*-BuOK	22
3	CuO	*t*-BuOK	16
4	Cu_2O	*t*-BuOK	30
5	$CuBr_2$	*t*-BuOK	20
6	CuBr	*t*-BuOK	27
7	CuCl	*t*-BuOK	25
8	$Cu(OAc)_2$	*t*-BuOK	65
9	$Cu(acac)_2$	*t*-BuOK	85
10	No catalyst	*t*-BuOK	0
11	$Cu(acac)_2$	K_2CO_3	30
12	$Cu(acac)_2$	K_3PO_4	60
13	$Cu(acac)_2$	DBU	10
14	$Cu(acac)_2$	TEA	15

[a]Condition: phenylurea **1** (1 equiv), phenylboronic acid **2a** (1.5 equiv), *t*-BuOK (1.5 equiv), Cu salt (0.1 equiv), 0.3 M NMP, rt, 24 h.
[b]Isolated yields; acac: acetyl acetonate.

(Table 1, entry 9), while K_2CO_3, K_3PO_4, 1,8-diazabicyclo[5.4.0] and dec-7-ene (DBU), or triethylancine (TEA) as the base gave the desired product in poor yields (Table 1, entries 11–14).

Table 2 shows that the amount of boronic acid was critical to the reaction outcome. Less than 1.5 equiv of the aryl source drastically reduced the yield of the *N*-arylated product. Even with 1 equiv of the copper salt (Table 2, entries 2 and 6) the reaction of equimolar amounts of phenylboronic acid and phenylurea

Table 2. Dependence of the yield of **3a** on the amounts of $Cu(acac)_2$ and phenyl boronic acid (**2a**) used in the *N*-arylation of phenylurea (1)

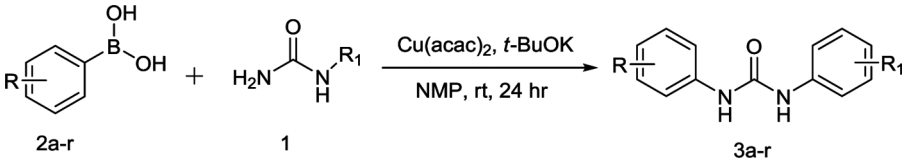
Entry	$Cu(acac)_2$ (equiv)	**2a** (equiv)	Yield[a] of **3a** (%)
1	0.1	1	33
2	1	1	42
3	0.1	1.5	85
4	0.1	2	80
5	0.05	1.5	45
6	1	1.5	62
7	0.1	1.5	55[b]

[a]Isolated yield.
[b]Base (2 eq).

led to only 42% yield. Greater than 1.5 equiv of the base drastically reduced the yield of the desired product (Table 2, entry 7).

To evaluate the substrate scope of this new approach toward *N*-arylated phenylurea, we investigated cross couplings of various commercially available aryl boronic acids and phenylurea. In all cases, the optimized condition described previously proved to be applicable. Reaction of the bulky aryl 1-naphthyl boronic acid with phenyl urea gave *N*-(1-naphthyl)-*N*′-phenylurea in excellent yield (Table 3, entry 2). Good to excellent results were achieved with *para*-substituted boronic acids (Table 3, entries 3–6), irrespective of the electronic nature of the substituent of the boronic acid. Ortho-substituted boronic acids gave good yields (Table 3, entries 7 and 8). In the case of meta-substituted boronic acids, excellent results were achieved with CF_3 and Me (Table 3, entries 10 and 11) but Cl and Br gave poor yields (Table 3, entries 9 and 12). Reaction of heteroaryl boronic acid 2-pyridineboronic acid and 3-pyridineboronic acid gave moderate yield (Table 3, entries 13 and 14). The lower yields in most couplings of ortho-substituted aryl boronic acids indicated the importance of steric effects. The product was characterized on

Table 3. Cu(acac)$_2$-catalyzed *N*-arylation of ureas (**1**) with aryl boronic acids **(2a–r)**[a]



Entry	$ArB(OH)_2$	Ar	R_1	P	Yield[c] (%)
1	**2a**	C_6H_5-	Ph	**3a**	85
2	**2b**	1-napthyl-	Ph	**3b**	82
3	**2c**	4-Me-C_6H_4-	Ph	**3c**	76
4	**2d**	4-OMe-C_6H_4-	Ph	**3d**	70
5	**2e**	4-F-C_6H_4-	Ph	**3e**	90
6	**2f**	4-NO_2-C_6H_4	Ph	**3f**	92
7	**2g**	2-Me-C_6H_4-	Ph	**3g**	65
8	**2h**	2-OMe-C_6H_4-	Ph	**3h**	67
9	**2i**	3-Cl-C_6H_4-	Ph	**3i**	30
10	**2j**	3-CF_3-C_6H_4-	Ph	**3j**	87
11	**2k**	3-Me-C_6H_4-	Ph	**3k**	78
12	**2l**	3-Br-C_6H_4-	Ph	**3l**	32
13	**2m**	3-Pyridine	Ph	**3m**	50
14	**2n**	4-Pyridine	Ph	**3n**	42
15	**2o**	C_6H_5-	H	**3o**	77[b]
16	**2p**	4-Me-C_6H_4-	H	**3p**	72[b]
17	**2q**	4-Cl-C_6H_4-	H	**3q**	40[b]
18	**2r**	4-OMe-C_6H_4-	H	**3r**	66[b]

[a]Reactions condition: phenylurea **1a** (1 equiv), aryl boronic acid **2a–n** (1.5 equiv), *t*-BuOK (1.5 equiv), Cu(acac)$_2$ (0.1 equiv), 0.3 M NMP, rt, 24 h.

[b]Reaction condition: urea **1o** (1 equiv), aryl boronic acid **2o–r** (3.0 equiv), *t*-BuOK (3.0 equiv), Cu(acac)$_2$ (0.2 equiv), 0.3 M NMP, rt, 24 h.

[c]Isolated yields; products were characterized by ^{1}H NMR and mp. P: Products.

the basis of its spectral data and by comparison of its melting point with the literature.[22–27] 2,4,6-Trimethylphenylboronic acid, 3-furanboronic acid, and 3-thiopheneboronic acid failed to give the corresponding *N*-arylated product. The reaction could also be extended to achieve the coupling of urea with aryl boronic acid such as phenyl, 4-methyl phenyl, 4-chloro phenyl, and 4-methoxy phenyl boronic acid (Table 3, entries 15–18).

In conclusion, we reported a novel $Cu(acac)_2$-catalyzed *N*-arylation of phenylurea using boronic acids as arylating agents. The cross couplings proceed under mild reaction conditions at room temperature without additional ligand. Considering the structural diversity and the huge number of boronic acid derivatives, we foresee that this new method will find broad application for the synthesis of a wide variety of phenyl ureas with as-yet-unknown properties.

EXPERIMENTAL

All reagents and solvents were purchased and used without further purification. ^1H NMR and ^{13}C NMR spectra were measured on a 300-MHz and 400-MHz Bruker spectrometer (^1H 300 MHz and 400 MHz, ^{13}C 75 MHz and 101 MHz), using dimethylsulfoxide (DMSO) as the solvent with tetramethylsilane (TMS) as the internal standard at room temperature. NMR chemical shifts were reported in δ (ppm) using the δ 2.54 signal of DMSO (^1H NMR) and the δ 39.94 signal of DMSO (^{13}C NMR) as internal standards. High-resolution mass spectra (HRMS) spectra were recorded on a Jeol JMS-DX300 instrument. Melting points were determined in a capillary tube and are uncorrected. Thin-layer chromatography (TLC) was carried out on SiO_2 (silica gel 60F254, Merck), and the spots were located with ultraviolet (UV) light. Flash chromatography was carried out on SiO_2 (silica gel 60, Merck, 100 to 200-mesh ASTM). Drying of organic extracts after workup of reactions was performed over anhydrous Na_2SO_4. Evaporation of solvents was accomplished with a Büchi rotatory evaporator.

Typical Procedure for *N*-Arylation of Aryl Ureas

A screw-capped tube was charged with the phenylurea (1.0 mmol), aryl boronic acid (1.5 mmol), *t*-BuOK (1.5 mmol), $Cu(acac)_2$ (10 mol%), and anhydrous N-methyl-2 pyrrolidone (NMP) (3 mL). The vial was degassed with N_2, sealed, and stirred at room temperature for 24 h. After completion, the reaction mixture was quenched with water (100 mL), extracted with diethyl ether (3 × 100 mL), and dried over anhydrous $MgSO_4$. The solvents were removed under vacuum, and the residue was purified by silica-gel chromatography (hexane–ethyl acetate, 8:2). The identity and purity of the known products was confirmed by ^1H and ^{13}C NMR spectroscopic analysis, and the new products were fully characterized.

Typical Procedure for *N*-Arylation of Ureas

A screw-capped tube was charged with the urea (1.0 mmol), aryl boronic acid (3.0 mmol), *t*-BuOK (3.0 mmol), $Cu(acac)_2$ (20 mol%), and anhydrous NMP (3 mL). The vial was degassed with N_2, sealed, and stirred at room temperature for 24 h.

After completion, the reaction mixture was quenched with water (100 mL), extracted with diethyl ether (3 × 100 mL), and dried over anhydrous $MgSO_4$. The solvents were removed under vacuum, and the residue was purified by silica-gel chromatography (hexane–ethyl acetate, 8:2). The identity and purity of the known products was confirmed by ^1H and ^{13}C NMR spectroscopic analysis, and the new products were fully characterized.

1,3-Diphenylurea (Carbanilide) (3a). White solid in 85% isolated yield; mp 237.5 °C (lit. 238 °C); ^1H NMR (400 MHz, DMSO): δ = 8.63 (s, 2H), 7.45 (d, *J* = 8.6, Hz, 4H), 7.27 (t, *J* = 7.9 Hz, 4H), 6.96 (t, *J* = 7.3 Hz, 2H). ^{13}C NMR (101 MHz, DMSO): δ = 151.9, 139.1, 128.2, 121.3, 117.7. HRMS (ESI): *m*/*z* $[M]^+$ calcd. for $C_{13}H_{12}N_2O$: 212.2512; found: 212.2514.

***N*-(1-Naphthalenyl)-*N'*-phenyl-urea (3b).** White solid in 80% isolated yield; mp 221–223 °C; ^1H NMR (300 MHz, DMSO): δ = 9.08 (s, 1H), 8.79 (s, 1H), 8.15 (d, *J* = 8.7 Hz, 1H), 8.05 (d, *J* = 7.6 Hz, 1H), 7.93 (d, J = 7.6 Hz, 1H), 7.45–7.72 (m, 6H), 7.32 (t, *J* = 7.9 Hz, 2H), 6.96–7.09 (m, 1H). ^{13}C NMR (300 MHz, DMSO): δ = 153.38, 140.23, 134.75, 129.31, 128.88, 126.37, 123.37, 122.30, 121.75, 118.57, 117.84. HRMS (ESI): *m*/*z* $[M]^+$ calcd. for $C_{17}H_{14}N_2O$: 262.3178; found: 262.3175.

***N*-(4-Methylphenyl)-*N'*-phenyl-urea (3c).** White solid in 76% isolated yield; mp 219–220 °C (lit. 221–222 °C); ^1H NMR (400 MHz, DMSO): δ = 8.58 (s, 1H), 8.52 (s, 1H), 7.43 (d, *J* = 8.6 Hz, 2H), 7.32 (d, *J* = 8.4 Hz, 2H), 7.25 (t, *J* = 7.9 Hz, 2H), 7.07 (d, *J* = 8.6 Hz, 2H), 6.94 (t, *J* = 7.3 Hz, 1H), 2.24 (s, 3H). ^{13}C NMR (101 MHz, DMSO): δ = 151.9, 139.2, 136.5, 130.1, 128.6, 128.2, 121.2, 117.8, 117.6, 20.4. HRMS (ESI): *m*/*z* $[M]^+$ calcd. for $C_{14}H_{14}N_2O$: 226.2825; found: 226.2830.

***N*-(4-Methoxyphenyl)-*N'*-phenyl-urea (3d).** White solid in 70% isolated yield; mp 195–196 °C (lit. 193–194 °C); ^1H NMR (400 MHz, DMSO): δ = 8.54 (s, 1H), 8.43 (s, 1H), 7.42 (d, *J* = 8.7 Hz, 2H), 7.34 (d, *J* = 9.1 Hz, 2H), 7.25 (t, *J* = 7.9 Hz, 2H), 6.93 (t, *J* = 7.3 Hz, 1H), 6.85 (d, *J* = 9.1 Hz, 2H), 3.71 (s, 3H). ^{13}C NMR (101 MHz, DMSO): δ = 153.8, 152.1, 139.3, 132.2, 128.2, 121.1, 119.5, 117.6, 113.5, 55.0. HRMS (ESI): *m*/*z* $[M]^+$ calcd. for $C_{14}H_{14}N_2O_2$: 242.2856; found: 242.2855.

***N*-(4-Fluorophenyl)-*N'*-phenyl-urea (3e).** White solid in 90% isolated yield; mp 240–242 °C (lit. 241 °C); ^1H NMR (300 MHz, DMSO): δ = 8.68 (s, 1H), 8.64 (s, 1H), 7.41–7.52 (m, 4H), 7.27 (t, *J* = 7.9 Hz, 2H), 7.06–7.17 (m, 2H), 6.92-7.01 (m, 1H). ^{13}C NMR (300 MHz, DMSO): δ = 159.35, 156.2, 153.07, 140.07, 136.45, 129.2, 122.28, 120.46, 118.69, 115.83. HRMS (ESI): *m*/*z* $[M]^+$ calcd. for $C_{13}H_{11}FN_2O$: 230.2443; found: 230.2442.

***N*-(4-Nitrophenyl)-*N'*-phenyl-urea (3f).** Orange solid in 92% isolated yield; mp 210–211 °C (lit. 209 °C); ^1H NMR (400 MHz, DMSO): δ = 9.40 (s, 1H), 8.89 (s, 1H), 8.18 (d, *J* = 9.3 Hz, 2H), 7.68 (d, *J* = 9.3 Hz, 2H), 7.47 (d, *J* = 8.6 Hz, 2H), 7.30 (t, *J* = 7.9 Hz, 2H), 7.01 (t, *J* = 7.4 Hz, 1H). ^{13}C NMR (101 MHz, DMSO): δ = 151.3, 145.8, 140.4, 138.4, 128.3, 124.6, 122.0, 118.2, 117.0. HRMS (ESI): *m*/*z* $[M]^+$ calcd. for $C_{13}H_{11}N_3O_3$: 257.2532; found: 257.2537.

***N*-(2-Methylphenyl)-*N'*-phenyl-urea (3g).** White solid in 67% isolated yield; mp 199–200 °C (lit. 201–203 °C); ^{1}H NMR (400 MHz, DMSO): $\delta = 8.99$ (s, 1H), 7.90 (s, 1H), 7.83 (dd, $J = 1.1$, 8.1 Hz, 1H), 7.45 (dt, $J = 1.6$, 8.7 Hz, 2H), 7.30 – 7.24 (m, 2H), 7.18 – 7.10 (m, $J = 7.6$, 15.5 Hz, 2H), 6.99 – 6.90 (m, 2H), 2.24 (s, 3H). ^{13}C NMR (101 MHz, DMSO): $\delta = 152.0$, 139.3, 136.8, 129.6, 128.3, 126.9, 125.6, 122.1, 121.2, 120.5, 117.5, 18.0). HRMS (ESI): m/z $[M]^+$ calcd. for $C_{14}H_{14}N_2O$: 226.2827; found: 226.2831.

***N*-(2-Methoxyphenyl)-*N'*-phenyl-urea (3h).** White solid in 65% isolated yield; mp 149–150 °C (lit. 148.2–148.8 °C); ^{1}H NMR (500 MHz, acetone-d_6): $\delta = 8.59$ (s, 1H), 8.30 (d, $J = 7.7$ Hz, 1H), 7.86 (s, 1H), 7.55 (d, $J = 8.1$ Hz, 2H), 7.27 (t, $J = 7.5$ Hz, 2H), 6.98–6.90 (m, 4H), 3.87 (s, 3H). HRMS (ESI): m/z $[M]^+$ calcd. for $C_{14}H_{14}N_2O_2$: 242.2856; found: 242.2853.

***N*-(3-Chlorophenyl)-*N'*-phenyl-urea (3i).** Off-white solid in 30% isolated yield; mp 184–186 °C; ^{1}H NMR (300 MHz, DMSO): $\delta = 8.87$ (s, 1H), 8.72(s, 1H), 7.64–7.77 (m, 1H), 7.44 (d, $J = 7.6$ Hz, 2H), 7.14–7.33 (m, 4H), 6.93–7.04 (m, 2H). ^{13}C NMR (300 MHz, DMSO): $\delta = 152.8$, 141.7, 139.8, 133.6, 130.8, 129.2, 122.5, 121.8, 118.8, 117.9, 117.0. HRMS (ESI): m/z $[M]^+$ calcd. for $C_{13}H_{11}ClN_2O$: 246.7045; found: 246.7047.

***N*-(3-Trifluoromethylphenyl)-*N'*-phenyl-urea (3j).** White solid in 87% isolated yield; mp 203–205 °C; ^{1}H NMR (300 MHz, DMSO): $\delta = 9.02$ (s, 1H), 8.77 (s, 1H), 8.00 (s, 1H), 7.40–7.61 (m, 4H), 7.23–7.37 (m, 3H), 6.92–7.07 (m, 1H). ^{13}C NMR (300 MHz, DMSO): $\delta = 152.9$, 141.0, 139.7, 130.4, 130.1, 129.2, 122.6, 122.2, 118.9, 118.6, 118.5, 114.5. HRMS (ESI): m/z $[M]^+$ calcd. for $C_{14}H_{11}F_3N_2O$: 280.2567; found: 280.2562.

***N*-(3-Methylphenyl)-*N'*-phenyl-urea (3k).** White solid in 78% isolated yield; mp 174–175 °C; ^{1}H NMR (300 MHz, DMSO): $\delta = 8.62$ (s, 1H), 8.56 (s, 1H), 7.44 (d, $J = 7.6$ Hz, 1H), 7.11–7.31 (m, 5H), 6.92–7.01 (m, 2H), 6.77 (d, $J = 7.6$ Hz, 1H), 2.26 (s, 3H). ^{13}C NMR (300 MHz, DMSO): $\delta = 152.9$, 140.1, 140.0, 138.4, 129.2, 129.0, 123.0, 122.2, 119.1, 118.5, 115.8, 21.6. HRMS (ESI): m/z $[M]^+$ calcd. for $C_{14}H_{14}N_2O$: 226.2825; found: 226.2822.

***N*-(3-Bromophenyl)-*N'*-phenyl-urea (3l).** Off-white solid in 35% isolated yield; mp 171–174 °C; ^{1}H NMR (300 MHz, DMSO): $\delta = 8.87$ (s, 1H), 8.72 (s, 1H), 7.85 (s, 1H), 7.35–7.48 (m, 2H), 7.08–7.31 (m, 5H), 6.74–7.02 (m, 1H). ^{13}C NMR (300 MHz, DMSO): $\delta = 152.8$, 141.8, 140.1, 131.1, 129.2, 124.7, 122.5, 122.2, 120.8, 118.8, 117.4. HRMS (ESI): m/z $[M]^+$ calcd. for $C_{13}H_{11}BrN_2O$: 291.1512; found: 291.1516.

***N*-(3-Pyridinyl)-*N'*-phenyl-urea (3m).** White solid in 50% isolated yield; mp 164–166 °C (lit. 164 °C); ^{1}H NMR (400 MHz, DMSO): $\delta = 8.83$ (s, 1H), 8.79 (s, 1H), 8.18 (d, $J = 3.5$ Hz, 1H), 7.93 (ddd, $J = 1.5$, 2.5, 8.3 Hz, 1H), 7.41–7.49 (m, 3H), 7.24–7.34 (m, 3H), 6.98 (t, $J = 7.3$ Hz, 1H). ^{13}C NMR (101 MHz, DMSO): $\delta = 151.9$, 142.2, 139.5, 138.8, 135.9, 128.3, 124.6, 123.1, 121.6, 117.9. HRMS (ESI): m/z $[M]^+$ calcd. for $C_{12}H_{11}N_3O$: 213.2415; found: 213.2416.

***N*-(4-Pyridinyl)-*N'*-phenyl-urea (3n).** White solid in 42% isolated yield; mp 181-183 °C (lit. 184 °C); ^{1}H NMR (300 MHz, DMSO): δ = 9.15 (s, 1H), 8.89 (s, 1H), 8.36 (d, J = 5.5, 2H), 7.39–7.48 (m, 4H), 7.27–7.33 (m, 2H), 6.99–7.05 (m, 1H). ^{13}C NMR (300 MHz, DMSO): δ = 151.5, 149.5, 145.9, 138.5, 128.3, 121.9, 118.1, 111.8. HRMS (ESI): m/z $[M]^+$ calcd. for $C_{12}H_{11}N_3O$: 213.2415; found: 213.2418.

1,3-Diphenylurea (carbanilide) (3o). White solid in 85% isolated yield; mp 237.0 °C (lit. 238 °C); ^{1}H NMR (400 MHz, DMSO): δ = 8.65 (s, 2H), 7.47 (d, J = 8.6, Hz, 4H), 7.30 (t, J = 7.9 Hz, 4H), 6.96 (t, J = 7.3 Hz, 2H). ^{13}C NMR (101 MHz, DMSO): δ = 152.1, 139.4, 128.2, 121.5, 117.8. HRMS (ESI): m/z $[M]^+$ calcd. for $C_{13}H_{12}N_2O$: 212.2512; found: 212.2515.

1,3-Bis(4-methylphenyl)urea (3p). White solid in 72% isolated yield; mp 267–268 °C (lit. 267–268 °C); ^{1}H NMR (300 MHz, DMSO): δ = 8.49 (s, 2H), 7.31 (d, J = 8.4, 4H), 7.07(d, J = 8.2, 4H), 2.23(s, 6H). ^{13}C NMR (300 MHz, DMSO): δ = 153.07, 137.68, 130.94, 129.60, 118.66, 20.79. HRMS (ESI): m/z $[M]^+$ calcd. for $C_{15}H_{16}N_2O$: 240.3115; found: 240.3118.

1,3-Bis(4-chlorophenyl)urea (3q). White solid in 40% isolated yield; mp 304–305 °C (lit. 303–305 °C); ^{1}H NMR (300 MHz, DMSO): δ = 8.84 (s, 2H), 7.48 (d, J = 8.8, 4H), 7.32(d, J = 8.8, 4H). ^{13}C NMR (101 MHz, DMSO): δ = 152.80, 139.00, 129.08, 125.97, 120.29. HRMS (ESI): m/z $[M]^+$ calcd. for $C_{13}H_{10}Cl_2N_2O$: 281.1421; found: 281.1423.

1,3-Bis(4-methoxyphenyl)urea (3r). White solid in 66% isolated yield; mp 239–240 °C (lit. 240–241 °C); ^{1}H NMR (300 MHz, DMSO): δ = 8.36 (s, 2H), 7.34 (d, J = 9.0, 4H), 6.85 (d, J = 9.0, 4H), 3.71 (s, 6H). ^{13}C NMR (101 MHz, DMSO): δ = 154.81, 153.42, 133.40, 120.39, 114.42, 55.61. HRMS (ESI): m/z $[M]^+$ calcd. for $C_{15}H_{16}N_2O_3$: 272.3117; found: 272.3115.

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