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Copper(II)-catalyzed coupling reaction: an efficient and regioselective approach to *N'*,*N'*-diaryl acylhydrazines

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Using *N'*-aryl acylhydrazines as aryl donors, a novel copper(II)-catalyzed homo-coupling reaction of *N'*-aryl acylhydrazines has been developed for the synthesis of *N'*,*N'*-diaryl acylhydrazines. We also provided a complementary procedure for the preparation of unsymmetrical diaryl acylhydrazines via cross-coupling reaction. These protocols featured mild reaction conditions, wide functional group tolerance and highly regioselective products. Control experiments indicated that this kind of coupling reaction might undergo a transient acyl diazene intermediate.

Introduction

N',*N'*-Disubstituted hydrazines, particularly *N'*,*N'*-diaryl acylhydrazines, are important building blocks widely exist in various biological active compounds (Figure 1), such as PGI_2 agonists,[1] α-adrenergic antagonists,[2] D_1 receptor antagonists,[3-4] antichagasic candidates,[5] and so on.[6-10] They are also frequently used as precursors for the constructions of indoles,[11-13] indazoles[14-15] and 1,2,4-benzotriazines.[16-17] Therefore, the preparation of *N'*,*N'*-diaryl acylhydrazines has attracted a lot of attention in recent years.

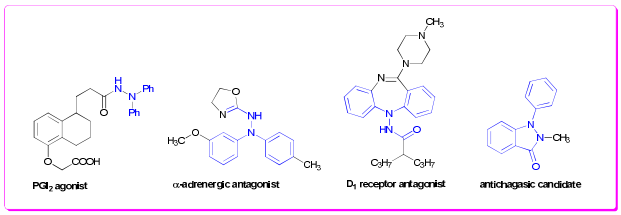
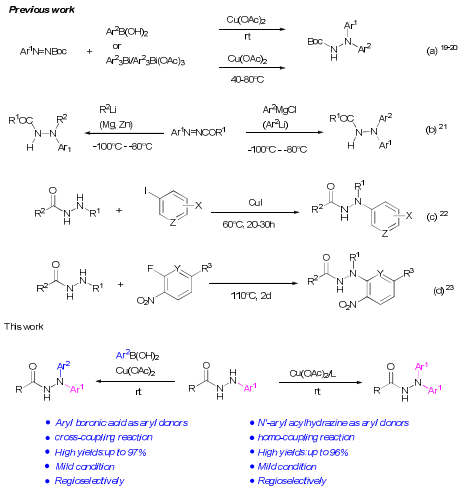


Fig. 1 Diaryl acylhydrazines derived drug candidates.

Metal-catalyzed or metal-mediated *N*-arylation reaction is the most direct method for the preparation of diaryl acylhydrazines.[18] Among them, copper-catalyzed Ullmann-type *N*-arylation of acylhydrazines has already achieved some success. Uno Mäeorg and co-workers have developed several methods, either via copper-catalyzed addition of arylboronic acids (or organobismuth reagents) to azo compounds (Scheme 1a),[19-20] or via the direct addition of organometallic nucleophiles to azo compounds (Scheme 1b).[21] However, these methods suffered from multistep synthesis, harsh reaction conditions and variable yields. Recently, Ma and co-workers realized CuI-catalyzed coupling of acylhydrazines with aryl iodides, which also tolerated a wide range of functional groups (Scheme 1c).[22] Aryl iodide reagents and proper heating were essential for this coupling reaction. Koutentis and co-workers demonstrated a metal-free synthesis of *N'*,*N'*-diaryl acylhydrazines via SNAr arylation reaction (Scheme 1d),[23] yet high reaction temperature, long reaction time and special substrate (1-halo-2-nitroarenes) were needed to ensure good yields and regioselectivities. Hence, a mild, efficient and practical access to *N'*,*N'*-diaryl acylhydrazines is still highly desirable.



Scheme 1 Coupling reaction of *N'*-aryl acylhydrazines with various aryl donors.

Arylhydrazines have already been utilized as aryl donors in many cross-coupling reactions for the constructions of aryl substituted indoles,[24] alcohols,[25] ketones,[26] glycols,[27] amines,[28] olefins,[29] naphthoquinones,[30] and pyridines.[31] Our previous study revealed that *N'*-tosyl arylhydrazine was another efficient coupling partner.[32-33] In an attempt to explore more stable

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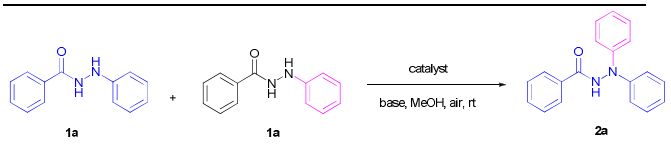
coupling reagent, we noticed that *N'*-aryl hydrazides can be cleaved under mild oxidative conditions to afford aromatic alkenes,[34] which implied that *N'*-aryl hydrazides might also act as aryl donors for some coupling reactions. Herein, we reported the first copper(II)-catalyzed homo-coupling reactions of *N'*-aryl acylhydrazines for the synthesis of symmetrical *N',N'*-diaryl acylhydrazines. Moreover, we also provided a complementary procedure for the preparation of unsymmetrical *N',N'*-diaryl acylhydrazines via cross-coupling reaction between *N'*-aryl acylhydrazines and aryl boronic acids.

Results and discussion

At first, *N'*-phenylbenzohydrazide **1a** was chosen as model substrate for the homo-coupling reaction. In the presence of 10 mol% $Cu(OAc)_2·H_2O$, the reaction proceeded smoothly to afford the desired product **2a** in 35% yield at room temperature (Table 1, entry 1). The existence of TEA improved the yield significantly (from 35% to 56%, entry 2). A detailed investigation on the molar ratio of TEA revealed that 2.0 equiv. of TEA was optimal for this catalytic system (Table 1, entries 2-4). Using excess TEA as both solvent and base, only trace **2a** can be detected (entry 5). Other organic bases, such as DBU, DEA and DMAP were also evaluated (Table 1, entries 6-8). Strong base as DBU dramatically inhibited the progress while weak base as DMAP promoted this reaction. The organic weak base might influence both the oxidation of aryl hydrazide and the subsequent coupling reaction via its coordination with copper salt. Inorganic bases, such as K_2CO_3 and KOH were less effective (entries 9-10), for they might form insoluble precipitates with $Cu(OAc)_2·H_2O$, hence decreasing the catalytic efficiencies. Several conventional copper salts, such as CuBr, CuI and $Cu(OTf)_2$ were also assessed, but none of them was compatible with this process (Table 1, entries 11-13). This might relate with their weaker oxidation abilities in forming azo intermediate. A dramatic decrease in yield was observed when anhydrous $Cu(OAc)_2$ was employed (entry 14), and this catalytic reaction almost did not occur when 95% MeOH was used as solvent (entry 15).

Moreover, we observed a significant solvent effect in this process. Polar protonic alcohols as MeOH and EtOH showed better results (Table 2, entries 1-8). MeOH was the optimal solvent, which offers better solubility for the reaction system. For comparison, the reaction was also performed under pure O_2 atmosphere to afford product **2a** in 90 % yield (entry 10), which indicated that oxygen was quite necessary for this homo-coupling reaction, the higher concentration of molecular oxygen led to higher yield (entry 8 *vs* 10). To our surprise, the reaction did take place under argon atmosphere albeit with much lower yield (entry 9), the reaction might undergo a different mechanism in the absence of oxygen.[35] Decreasing the amount of copper salt to 5 mol% caused a significant drop in yield (entry 11). To further improve this reaction, 4-hydroxyl-*L*-proline and 1,10-phenanthroline were used as ligands respectively for this catalytic system (Table 2, entries 12-16). To our delight, 20 mol% 1,10-phenanthroline monohydrate could increase the yield significantly (up to 96%, entry 13).

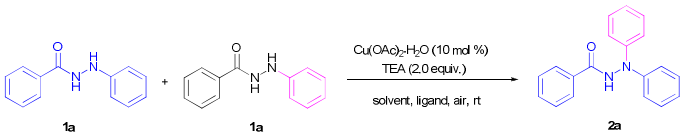
Table 1 Optimization of the reaction conditions[a]



Entry	Catalyst	Base (equiv.)	Yield (%)[b]
1	$Cu(OAc)_2·H_2O$	-	35
2	$Cu(OAc)_2·H_2O$	TEA(1.5)	56
3	$Cu(OAc)_2·H_2O$	TEA(2.0)	84
4	$Cu(OAc)_2·H_2O$	TEA(2.5)	73
5	$Cu(OAc)_2·H_2O$	TEA[c]	trace
6	$Cu(OAc)_2·H_2O$	DBU(2.0)	trace
7	$Cu(OAc)_2·H_2O$	DEA(2.0)	69
8	$Cu(OAc)_2·H_2O$	DMAP(2.0)	83
9	$Cu(OAc)_2·H_2O$	K_2CO_3(1.0)	54
10	$Cu(OAc)_2·H_2O$	KOH(1.0)	39
11	CuBr	TEA(2.0)	22
12	CuI	TEA(2.0)	15
13	$Cu(OTf)_2$	TEA(2.0)	28
14	$Cu(OAc)_2$	TEA(2.0)	44
15	$Cu(OAc)_2·H_2O$	TEA(2.0)	trace[d]

[a] **1a** (0.3 mmol), catalyst (10 mol%), MeOH (anhydrous, 2.0 mL), rt, 12-24 h. [b] Isolated yields. [c] TEA (2.0 mL) as solvent. [d] 95% MeOH as solvent.

Table 2 Further optimization of the reaction conditions[a]



Entry	Ligand	Solvent	Yield (%)[b]
1	-	dioxane	trace
2	-	toluene	30
3	-	THF	28
4	-	DMSO	NR
5	-	MeCN	52
6	-	DMF	trace
7	-	EtOH	64
8	-	MeOH	84
9	-	MeOH	63[c]
10	-	MeOH	90[d]
11	-	MeOH	40[e]
12	4-OH-*L*-proline (20 mol%)	MeOH	65
13	**1,10-phen[f] (20 mol%)**	**MeOH**	**96**
14	1,10-phen (10 mol%)	MeOH	86
15	1,10-phen (20 mol%)	MeOH	82[g]
16	1,10-phen (20 mol%)	MeOH	85[h]

[a] **1a** (0.3 mmol), $Cu(OAc)_2·H_2O$ (10 mol%), TEA (2.0 equiv.), solvent (anhydrous, 2.0 mL), rt, 12-24 h. [b] Isolated yields. [c] Proceed under Ar. [d] Proceed under O_2. [e] $Cu(OAc)_2·H_2O$ (5 mol%) was used. [f] 1,10-phenanthroline monohydrate. [g] No TEA was used. [h] TEA (1.0 equiv.) was used.

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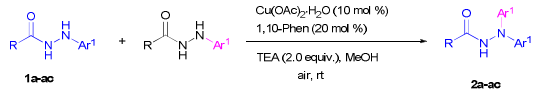
Table 3 Homo-coupling of various *N'*-aryl benzohydrazides.[a]

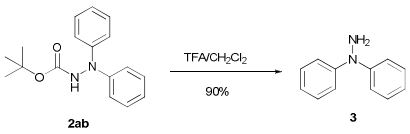


Entry	R	Ar^1	Product	Yield (%)[b]
1	Ph (**1a**)	Ph	**2a**	96
2	Ph (**1b**)	4-FC_6H_4	**2b**	82
3	Ph (**1c**)	4-ClC_6H_4	**2c**	83
4	Ph (**1d**)	4-BrC_6H_4	**2d**	87
5	Ph (**1e**)	3-ClC_6H_4	**2e**	81
6	Ph (**1f**)	2-ClC_6H_4	**2f**	64
7	Ph (**1g**)	4-$OMeC_6H_4$	**2g**	94
8	Ph (**1h**)	3-$OMeC_6H_4$	**2h**	85
9	Ph (**1i**)	2-$OMeC_6H_4$	**2i**	52
10	Ph (**1j**)	4-$OCF_3C_6H_4$	**2j**	73
11	Ph (**1k**)	4-$SO_2MeC_6H_4$	**2k**	54
12	Ph (**1l**)	4-$NO_2C_6H_4$	**2l**	53
13	Ph (**1m**)	4-MeC_6H_4	**2m**	92
14	Ph (**1n**)	3-MeC_6H_4	**2n**	91
15	Ph (**1o**)	2-MeC_6H_4	**2o**	59
16	Ph (**1p**)	3,5-*di*-MeC_6H_3	**2p**	93
17	Ph (**1q**)	3,4-*di*-MeC_6H_3	**2q**	87
18	Ph (**1r**)		**2r**	76
19	Ph (**1s**)	Benzyl	**2s**	NR[c]
20	4-$OMeC_6H_4$ (**1t**)	Ph	**2t**	87
21	4-OHC_6H_4 (**1u**)	Ph	**2u**	88
22	4-BrC_6H_4 (**1v**)	Ph	**2v**	73
23	4-$NH_2C_6H_4$ (**1w**)	Ph	**2w**	79
24	4-$NO_2C_6H_4$ (**1x**)	Ph	**2x**	87
25	3-$NO_2C_6H_4$ (**1y**)	Ph	**2y**	90
26	Me (**1z**)	Ph	**2z**	85
27	CF_3 (**1aa**)	Ph	**2aa**	63
28	*t*-BuO (**1ab**)	Ph	**2ab**	84
29	*t*-BuO (**1ac**)	4-ClC_6H_4	**2ac**	78

[a] **1** (0.3 mmol), $Cu(OAc)_2 \cdot H_2O$ (10 mol%), 1,10-phenanthroline monohydrate (20 mol%), TEA (2.0 equiv.), MeOH (anhydrous, 2.0 mL), rt, 12-24 h. [b] Isolated yields. [c] No reaction.

Having established the optimal reaction conditions, the scope of this copper catalyzed homo-coupling of *N'*-aryl benzohydrazides was investigated. Various *N'*-aryl benzohydrazides with both electron-donating and electron-withdrawing groups attached to the aromatic ring were all good partners in this transformation, affording the corresponding products in good to excellent yields (Table 3). Generally, substrates with electron-donating groups as Me and OMe on Ar^1 ring were more effective than these with electron-withdrawing groups on Ar^1 ring (Table 3, entries 7-8, 13-14, 16-17). *N'*-Aryl benzohydrazides with halide substituents as chloride and bromide on Ar^1 ring, which were especially useful for they can undergo stepwise coupling reaction to form multi-aryl molecules with high biological activities, also participated in the desired homo-coupling process (Table 3, entries 3-5). This reaction was sensitive to the steric hindrance of the substrates, for example, *ortho*-substituted *N'*-aryl benzohydrazides only provided moderate yields (Table 3, entries 6, 9 and 15). *N'*-benzyl benzohydrazide **1s** was also tested under optimized conditions, but no desired product was observed (entry 19).

The reaction scope was further expanded to various *N*-acyl-*N'*-aryl hydrazines. It was found that most substituted aryl acyl groups bearing both electron-rich and electron-deficient substituents provided good to excellent yields (Table 3, entries 20-25). Unprotected hydroxyl substituent was tolerant in this reaction and showed good yield (entry 21). *N*'-Aryl alkanoylhydrazines were also evaluated under optimal conditions (entries 26-29), the yields were generally good. An exception was *N*'-phenyl trifluoroacetylhydrazine **1aa** for the strong electron-withdrawing ability of CF_3 group. It is note worthing that the Boc group of *tert*-butyl 2,2-diphenylhydrazinecarboxylate (**2ab**) can be easily removed under TFA/CH_2Cl_2 to afford 1,1-diphenylhydrazine **3** in 90% yield (Scheme 2), which implies a convenient synthetic protocol for these commercially uncommon *N',N'*-disubstituted arylhydrazines.



Scheme 2 Synthesis of commercially uncommon **3**.

To further explore the mechanism of this homo-coupling reaction, we also carried out several competition experiments. When *N'*-(*m*-tolyl)benzohydrazide **1n** and *N'*-(4-nitrophenyl)benzohydrazide **1l** were mixed in 1:1 ratio under the standard conditions at room temperature, homo-coupling products **2n** and **2l** were formed preferably to cross-coupling product **2ad** (Scheme 3, **2n**: **2ad**: **2l** = 4.3: 1.0: 3.7). When the same reaction proceeded under low temperature as -40 °C, the increased ratio of **2ad** was observed (**2n**: **2ad**: **2l** = 3.3: 4.9: 1.0). We assumed that electronic effects might influence both the decomposition of the aryl hydrazide and the arylation reaction. At lower temperature as -40 °C, the decomposition of aryl hydrazide is the rate-determing step, and electron-rich aryl hydrazide decomposed preferably, which was proved by the product

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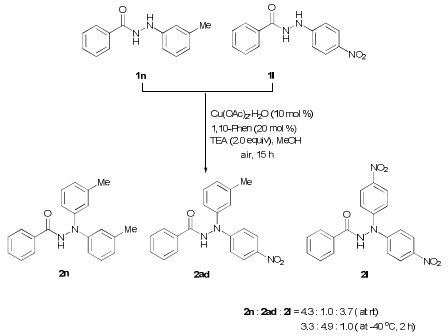
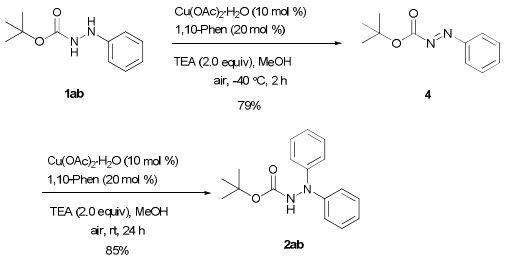
distribution. But at room temperature, the decomposition rates of various aryl hydrazides were comparable, and now the arylation reaction showed some sort of matching phenomenon, in which the electron-rich aryl group prefers the electron-rich aryl hydrazide and the electron-deficient nitrophenyl prefers the electron-deficient hydrazide. Further study on the reaction mechanism is still carried out in our lab.



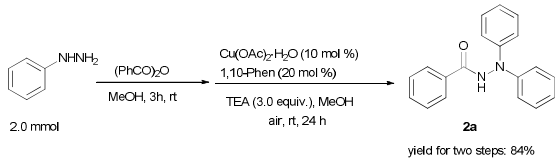
Scheme 3 Competition experiments between **1n** and **1l**.

In an independent experiment, we did isolate *tert*-butyl 2-phenyldiazenecarboxylate **4** in 79% yield when *tert*-butyl 2-phenylhydrazinecarboxylate **1ab** was put in the standard reaction system at -40 °C for 2 h. **4** can be further converted to coupling product **2ab** if maintaining the temperature at rt for 24 h (Scheme 4), which implied that this kind of reaction might proceed via azo intermediate.



Scheme 4 Homo-coupling of **1ab** via acyl diazene intermediate.

Besides, we also tried the one-pot synthesis of *N'*,*N'*-diphenylbenzohydrazide **2a** on 2 mmol scale (Scheme 5). Using phenylhydrazine as starting material, benzoic anhydride as acylating reagent, *N'*-phenylbenzohydrazide **1a** can be generated in 3 h. Without any additional isolation, **1a** then underwent the subsequent homo-coupling reaction to give **2a** in 84% overall yield.



Scheme 5 One-pot synthesis of **2a**.

Based on these experiments and literatures,[36-40] we proposed a possible mechanism for this homo-coupling reaction (Figure 2). *N'*-aryl acylhydrazine (**A**) was oxidized by Cu(II) under basic condition to give azo intermediate **B**. The reductive Cu(I) species coordinated with **B** to form azo-metal complex, which further interacted with MeOH to give the key intermediate **C** and carboxylic acid ester **5**, the latter was isolated and confirmed by ^{1}H NMR. Here MeOH not only acted as solvent, but also as promoter for the formation of complex **C**, and this explained why polar protonic alcohol was crucial for the catalytic cycle. The transient intermediate **D** might be formed either by the interaction of **C** with azo intermediate **B** (route b, verified by control experiment at -40 °C), or by the direct reaction of **C** with **A** (route a, control experiment at rt). The desired product **E** was obtained via reductive elimination of **D** along with the release of $Cu(I)L_2$, the latter can be oxidated to Cu(II) in the presence of air.

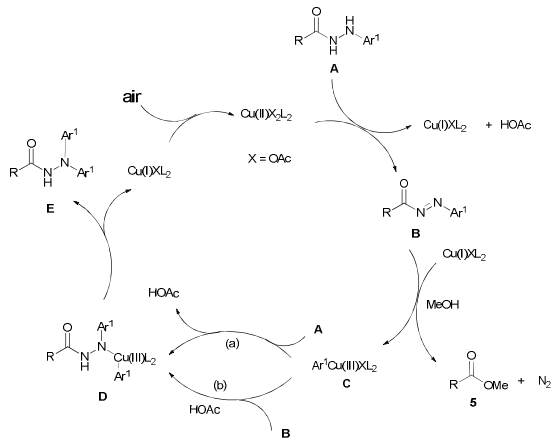


Fig. 2 Proposed mechanism for the copper(II)-catalyzed homo-coupling reaction.

Our experiments indicated that this homo-coupling reaction might undergo a transient acyl diazene intermediate. On the other hand, diazenes have been reported to couple with arylboronic acids to give multisubstituted protected/arylated hydrazines under mild conditions.[19] We envisioned that the direct reaction between *N'*-aryl acylhydrazine and arylboronic acid might provide a complementary procedure for the synthesis of unsymmetrical diaryl acylhydrazines. To our delight, the model reaction worked well under the optimal conditions: 10 mol% $Cu(OAc)_2{\cdot}H_2O$ as catalyst, dioxane as solvent, at room temperature and air as terminal oxidant (for the optimization of reaction conditions, see Supporting Information).

Furthermore, we explored the reaction scope via coupling various *N'*-aryl acylhydrazines with arylboronic acid, and the results were summarized in Table 4. Both electron-rich and electron-deficient aryl boronic acids were compatible with these conditions, providing the corresponding unsymmetrical diaryl acylhydrazines in 78-98% yields (entries 1-9). *Ortho*-substituted *N'*-aryl benzohydrazide **1i** only provided 63% yield for its bulky steric hindrance (Table 4, entry 10). *N'*-Benzyl benzohydrazide was not suitable for this catalytic system (entry 13). Similarly, we also proposed a possible mechanism for the cross-coupling reaction of *N'*-aryl acylhydrazines with aryl boronic acids (Figure 3). The use of dioxane as solvent could avoid the generation of homo-coupling product efficiently.

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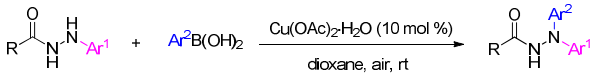
Table 4 Cross-coupling reaction of various *N'*-aryl acylhydrazines with arylboronic acids.[a]



1a, 1d, 1m, 1l 1i, 1v, 1ab, 1s — 6a-g — 7a-m

Entry	R	Ar^1	Ar^2	Product	Yield (%)[b]
1	Ph	Ph (**1a**)	4-$OMeC_6H_4$ (**6a**)	**7a**	97
2	Ph	Ph (**1a**)	4-MeC_6H_4 (**6b**)	**7b**	93
3	Ph	Ph (**1a**)	4-ClC_6H_4 (**6c**)	**7c**	98
4	Ph	Ph (**1a**)	3-MeC_6H_4 (**6d**)	**7d**	91
5	Ph	Ph (**1a**)	3-ClC_6H_4 (**6e**)	**7e**	96
6	Ph	Ph (**1a**)	2-Naphthyl (**6f**)	**7f**	83
7	Ph	4-BrC_6H_4 (**1d**)	4-$OMeC_6H_4$ (**6g**)	**7g**	78
8	Ph	4-MeC_6H_4 (**1m**)	4-$OMeC_6H_4$ (**6g**)	**7h**	95
9	Ph	4-$NO_2C_6H_4$ (**1l**)	4-$OMeC_6H_4$ (**6g**)	**7i**	87
10	Ph	2-$OMeC_6H_4$ (**1i**)	4-$OMeC_6H_4$ (**6g**)	**7j**	63
11	4-BrC_6H_4	Ph (**1v**)	4-$OMeC_6H_4$ (**6g**)	**7k**	82
12	*t*-BuO	Ph (**1ab**)	4-$OMeC_6H_4$ (**6g**)	**7l**	75
13	Ph	Benzyl (**1s**)	4-$OMeC_6H_4$ (**6g**)	**7m**	NR[c]

[a] *N*-acyl arylhydrazine (0.2 mmol), arylboronic acid (0.24 mmol), dioxane (2.0 mL), rt, air, 12-24 h. [b] Isolated yields. [c] No reaction.

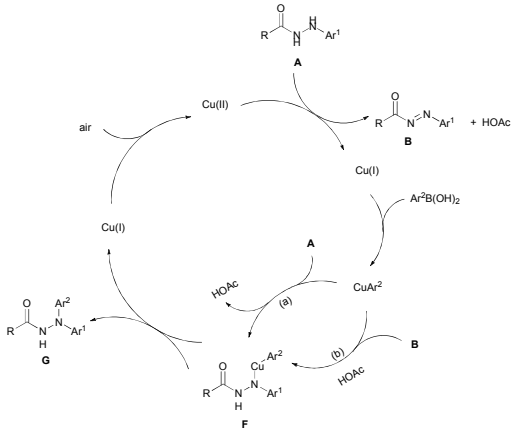


Fig. 3 Proposed mechanism for the copper(II)-catalyzed cross-coupling reaction.

Conclusions

In summary, with *N'*-aryl acylhydrazines as aryl donors, we have developed a novel, mild and regioselective *N*-arylation method for the synthesis of *N',N'*-diaryl acylhydrazines via copper(II)-catalyzed coupling reaction. We also provided a complemental procedure for the preparation of unsymmetrical diaryl acylhydrazines via cross-coupling reaction. These novel protocols are quite simple and environmentally friendly, which might find applications in practical organic synthesis.

Experimental Section

The solvents were distilled from standard drying agents. Unless otherwise stated, commercial reagents purchased from Alfa Aesar, Acros and Aldrich chemical companies were used without further purification. Reaction products were purified by flash chromatography using Qing Dao Sea Chemical Reagent silica gel (200–300 mesh). ^{1}H NMR spectra were recorded on a Bruker Avance III 400 (400 MHz) spectrometer and referenced internally to the residual proton resonance in $CDCl_3$ (δ = 7.26 ppm), or with tetramethylsilane (TMS, δ = 0.00 ppm) as the internal standard. Chemical shifts were reported as parts per million (ppm) in the δ scale downfield from TMS. Multiplicity is indicated as follows: s (singlet), d (doublet), t (triplet), q (quartet), quint (quintet), m (multiplet), dd (doublet of doublet), bs (broad singlet). ^{13}C NMR spectra were recorded on Bruker spectrometer with complete proton decoupling, and chemical shifts were reported in ppm from TMS with the solvent as the internal reference ($CDCl_3$, δ = 77.0 ppm). Low-resolution MS spectra were obtained on an Agilent LC-MS 6120 instrument with an ESI mass detector, the data were obtained in the positive or negative ion mode. High resolution mass spectra were recorded on an ESI-ion trap mass spectrometer (Shimadzu, LCMS-IT-TOF). Analytical TLC was performed using EM separations percolated silica gel 0.2 mm layer UV 254 fluorescent sheets.

Preparation of *N'*-aryl acylhydrazines 1a-r, 1t-y: To a solution of aryl carboxylic acid (4.0 mmol) in DMF (10 mL) was added EDC·HCl (4.4 mmol) and HOBt (4.4 mmol), then arylhydrazine was added and the reaction mixture was stirred at ambient temperature under nitrogen atmosphere for 24-48 h. The reaction mixture was poured into H_2O (150 mL) and extracted with ethyl acetate (30 mL ×3). The organic phases were combined and

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washed with saturated $NaHCO_3$ (30 mL ×2) and saturated NaCl (30 mL×1) respectively, dried over Na_2SO_4. The solution was concentrated *in vacuo* and purified by column chromatography on silica gel (eluting with 3:1 to 1:1 petroleum ether/ethyl acetate) to give the desired product (see Supporting Information).

Typical procedure for the Cu(II)-catalyzed homocoupling of *N'*-aryl acylhydrazines: A mixture of aryl acylhydrazine (0.3 mmol), $Cu(OAc)_2 \cdot H_2O$ (0.03 mmol), 1,10-Phen·H_2O (0.06 mmol) and TEA (0.60 mmol) in MeOH (2.0 mL) was stirred at ambient temperature for 12-24 h. After completion of the reaction (indicated by TLC), the mixture was quenched with saturated NaCl solution, extracted by EtOAc, and dried over Na_2SO_4. The crude product was purified by flash column chromatography to provide the corresponding product **2a-ad**.

***N',N'-di*Phenylbenzohydrazide (2a).** White solid; mp: 159-160 ℃; ^{1}H NMR (400 MHz, $CDCl_3$) δ: 8.36 (s, 1H), 7.88-7.83 (m, 2H), 7.58-7.53 (m, 1H), 7.46 (t, *J* = 7.6 Hz, 2H), 7.32-7.27 (m, 4H), 7.21 (dd, *J* = 8.7, 1.1 Hz, 4H), 7.03 (dd, *J* = 10.3, 4.2 Hz, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ: 166.5, 145.8, 132.5, 132.2, 129.2, 128.8, 127.3, 123.0, 119.5; HRMS (ESI) calcd. for $C_{19}H_{17}N_2O$ $[M+H]^+$: 289.1335, found: 289.1325.

***N',N'*-bis(4-Fluorophenyl)benzohydrazide (2b).** White solid; mp: 172-173 ℃; ^{1}H NMR (400 MHz, $CDCl_3$) δ: 8.36 (s, 1H), 7.85-7.79 (m, 2H), 7.57 (t, *J* = 7.4 Hz, 1H), 7.46 (t, *J* = 7.6 Hz, 2H), 7.15-7.07 (m, 4H), 7.02-6.93 (m, 4H); ^{13}C NMR (100 MHz, $CDCl_3$) δ: 166.5, 160.2, 157.7, 142.3, 132.4, 132.2, 128.9, 127.2, 121.2, 121.2, 116.1, 115.8; HRMS (ESI) calcd. for $C_{19}H_{13}F_2N_2O$ $[M-H]^-$: 323.1001, found: 323.1005.

***N',N'*-bis(4-Chlorophenyl)benzohydrazide (2c).** Off-white solid; mp: 208-209 ℃; ^{1}H NMR (400 MHz, $CDCl_3$) δ: 8.38 (s, 1H), 7.82 (d, *J* = 7.3 Hz, 2H), 7.58 (t, *J* = 7.4 Hz, 1H), 7.47 (t, *J* = 7.6 Hz, 2H), 7.27-7.22 (m, 4H), 7.10 (d, *J* = 8.8 Hz, 4H); ^{13}C NMR (100 MHz, $CDCl_3$) δ: 166.6, 144.1, 132.6, 131.9, 129.3, 128.9, 128.3, 127.3, 120.7; HRMS (ESI) calcd. for $C_{19}H_{15}Cl_2N_2O$ $[M+H]^+$: 357.0556, found: 357.0545.

***N',N'*-bis(4-Bromophenyl)benzohydrazide (2d).** Off-white solid; mp: 216-217 ℃; ^{1}H NMR (400 MHz, DMSO-d_6) δ: 11.32 (s, 1H), 7.97-7.88 (m, 2H), 7.62 (t, *J* = 7.4 Hz, 1H), 7.53 (t, *J* = 7.5 Hz, 2H), 7.50-7.43 (m, 4H), 7.16-7.07 (m, 4H); ^{13}C NMR (100 MHz, DMSO-d_6) δ: 166.2, 145.2, 132.7, 132.6, 132.4, 129.1, 128.0, 121.3, 114.4; HRMS (ESI) calcd. for $C_{19}H_{13}Br_2N_2O$ $[M-H]^-$: 442.9400, found: 442.9420.

***N',N'*-bis(3-Chlorophenyl)benzohydrazide (2e).** Light brown solid; mp: 158-159 ℃; ^{1}H NMR (400 MHz, $CDCl_3$) δ: 8.59 (s, 1H), 7.82 (d, *J* = 7.3 Hz, 2H), 7.57 (t, *J* = 7.4 Hz, 1H), 7.45 (t, *J* = 7.7 Hz, 2H), 7.22-7.13 (m, 4H), 7.08-6.99 (m, 4H); ^{13}C NMR (100 MHz, $CDCl_3$) δ: 166.7, 146.4, 135.0, 132.6, 131.8, 130.3, 128.9, 127.3, 123.5, 119.6, 117.7; HRMS (ESI) calcd. for $C_{19}H_{13}Cl_2N_2O$ $[M-H]^-$: 355.0410, found: 355.0418.

***N',N'*-bis(2-Chlorophenyl)benzohydrazide (2f).** White solid; mp: 211-212 ℃; ^{1}H NMR (400 MHz, $CDCl_3$) δ: 8.74 (s, 1H), 7.86-7.81 (m, 2H), 7.58-7.52 (m, 1H), 7.46 (t, *J* = 7.5 Hz, 2H), 7.36 (td, *J* = 7.9, 1.4 Hz, 4H), 7.22 (td, *J* = 7.8, 1.5 Hz, 2H), 7.08 (td, *J* = 7.8, 1.5 Hz, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ: 167.1, 143.3, 132.3, 130.6, 128.8, 127.9, 127.4, 125.8, 125.2; HRMS (ESI) calcd. for $C_{19}H_{13}Cl_2N_2O$ $[M-H]^-$: 355.0410, found: 355.0408.

***N',N'*-bis(4-Methoxyphenyl)benzohydrazide (2g).** White solid; mp: 212-213 ℃; ^{1}H NMR (400 MHz, $CDCl_3$) δ: 8.18 (s, 1H), 7.83 (d, *J* = 7.4 Hz, 2H), 7.58-7.52 (m, 1H), 7.46 (t, *J* = 7.5 Hz, 2H), 7.11 (d, *J* = 8.9 Hz, 4H), 6.83 (d, *J* = 8.9 Hz, 4H), 3.78 (s, 6H); ^{13}C NMR (100 MHz, DMSO-d_6) δ: 165.9, 154.6, 140.2, 132.8, 131.8, 128.5, 127.4, 120.3, 114.3, 55.3; HRMS (ESI) calcd. for $C_{21}H_{19}N_2O_3$ $[M-H]^-$: 347.1401, found: 347.1409.

***N',N'*-bis(3-Methoxyphenyl)benzohydrazide (2h).** White solid; mp: 167-168 ℃; ^{1}H NMR (400 MHz, $CDCl_3$) δ: 8.25 (s, 1H), 7.88-7.82 (m, 2H), 7.56 (t, *J* = 7.4 Hz, 1H), 7.46 (t, *J* = 7.6 Hz, 2H), 7.19 (t, *J* = 8.1 Hz, 2H), 6.84-6.78 (m, 4H), 6.59 (dd, *J* = 8.2, 1.7 Hz, 2H), 3.75 (s, 6H); ^{13}C NMR (100 MHz, $CDCl_3$) δ: 166.4, 160.5, 147.1, 132.5, 132.3, 129.9, 128.8, 127.3, 112.2, 108.6, 105.9, 55.3. HRMS (ESI) calcd. for $C_{21}H_{19}N_2O_3$ $[M-H]^-$: 347.1401, found: 347.1398.

***N',N'*-bis(2-Methoxyphenyl)benzohydrazide (2i).** Off-white solid; mp: 178-179 ℃; ^{1}H NMR (400 MHz, $CDCl_3$) δ: 8.58 (s, 1H), 7.82-7.76 (m, 2H), 7.51 (t, *J* = 7.3 Hz, 1H), 7.43 (t, *J* = 7.5 Hz, 2H), 7.18 (d, *J* = 8.1 Hz, 2H), 7.07 (dd, *J* = 11.0, 4.5 Hz, 2H), 6.89 (t, *J* = 7.4 Hz, 4H), 3.75 (s, 6H); ^{13}C NMR (100 MHz, $CDCl_3$) δ: 167.0, 152.3, 136.0, 133.6, 131.7, 128.66, 127.2, 125.0, 123.4, 120.9, 112.1, 55.8; HRMS (ESI) calcd. for $C_{21}H_{19}N_2O_3$ $[M-H]^-$: 347.1401, found: 347.1410.

***N',N'*-bis(4-(*tri*Fluoromethoxy)phenyl)benzohydrazide (2j).** White solid; mp: 163-164 ℃; ^{1}H NMR (400 MHz, $CDCl_3$) δ: 8.48 (s, 1H), 7.86-7.80 (m, 2H), 7.58 (t, *J* = 7.5 Hz, 1H), 7.46 (t, *J* = 7.7 Hz, 2H), 7.19-7.11 (m, 8H); ^{13}C NMR (100 MHz, $CDCl_3$) δ: 166.7, 144.8, 144.2, 132.7, 131.9, 128.9, 127.3, 122.1, 121.8, 120.6, 119.3; HRMS (ESI) calcd. for $C_{21}H_{13}F_6N_2O_3$ $[M-H]^-$: 455.0836, found: 455.0827.

***N',N'*-bis(4-(Methylsulfonyl)phenyl)benzohydrazide (2k).** Brown solid; mp: 240-241 ℃; ^{1}H NMR (400 MHz, DMSO-d_6) δ: 11.63 (s, 1H), 8.00-7.96 (m, 2H), 7.90-7.86 (m, 4H), 7.68-7.63 (m, 1H), 7.57 (t, *J* = 7.5 Hz, 2H), 7.47-7.42 (m, 4H), 3.19 (s, 6H); ^{13}C NMR (100 MHz, DMSO-d_6) δ: 165.7, 148.6, 134.4, 132.5, 131.6, 127.8, 128.7, 127.6, 118.8, 43.8; HRMS (ESI) calcd. for $C_{21}H_{19}N_2O_5S_2$ $[M-H]^-$: 443.0741, found: 443.0741.

***N',N'*-bis(4-Nitrophenyl)benzohydrazide (2l).** Yellow solid; mp: 287-288 ℃; ^{1}H NMR (400 MHz, DMSO-d_6) δ: 11.82 (s, 1H), 8.24 (d, *J* = 9.2 Hz, 4H), 7.98 (d, *J* = 7.2 Hz, 2H), 7.66 (d, *J* = 7.3 Hz, 1H), 7.58 (t, *J* = 7.5 Hz, 2H), 7.47 (d, *J* = 9.2 Hz, 4H); ^{13}C NMR (100 MHz, DMSO-d_6) δ: 165.7, 149.7, 142.3, 132.6, 131.4, 128.8, 127.6, 125.5, 119.1; HRMS (ESI) calcd. for $C_{19}H_{13}N_4O_5$ $[M-H]^-$: 377.0891, found: 377.0898.

***N',N'-dip*-Tolylbenzohydrazide (2m).** White solid; mp: 190-191 ℃; ^{1}H NMR (400 MHz, $CDCl_3$) δ: 8.21 (s, 1H), 7.86-7.82 (m, 2H), 7.55 (t, *J* = 7.4 Hz, 1H), 7.45 (t, *J* = 7.5 Hz, 2H), 7.08 (s, 8H), 2.30 (s, 6H); ^{13}C NMR (100 MHz, $CDCl_3$) δ: 166.4, 143.9, 132.7, 132.4, 132.1, 129.8, 128.8, 127.3, 119.6, 20.7; HRMS (ESI) calcd. for $C_{21}H_{19}N_2O$ $[M-H]^-$: 315.1503, found: 315.1504.

***N',N'-dim*-Tolylbenzohydrazide (2n).** White solid; mp: 173-174 ℃; ^{1}H NMR (400 MHz, $CDCl_3$) δ: 8.21 (s, 1H), 7.86 (d, *J* = 7.3 Hz, 2H), 7.56 (t, *J* = 7.4 Hz, 1H), 7.47 (t, *J* = 7.5 Hz, 2H), 7.17 (t, *J* = 7.7 Hz, 2H), 7.05-6.98 (m, 4H), 6.86 (d, *J* = 7.5 Hz, 2H), 2.30 (s, 6H); ^{13}C NMR (100 MHz, $CDCl_3$) δ: 166.4, 146.0, 139.1, 132.7, 132.2, 129.0, 128.8, 127.3, 123.9, 120.3, 116.8, 21.6; HRMS (ESI) calcd. for $C_{21}H_{19}N_2O$ $[M-H]^-$: 315.1503, found: 315.1515.

***N',N'-dio*-Tolylbenzohydrazide (2o).** White solid; mp: 213-214 ℃; ^{1}H NMR (400 MHz, $CDCl_3$) δ: 7.99 (s, 1H), 7.79 (d, *J* = 7.3 Hz, 2H), 7.52 (d, *J* = 7.5 Hz, 1H), 7.44 (t, *J* = 7.6 Hz, 2H), 7.19 (d, *J* = 7.2 Hz, 2H), 7.13 (t, *J* = 7.0 Hz, 2H), 7.05 (t, *J* = 7.0 Hz, 4H), 2.18 (s, 6H); ^{13}C NMR (100 MHz, $CDCl_3$) δ: 165.0, 145.8, 132.9, 132.6, 131.9, 131.6, 128.8, 127.1, 126.5, 124.7, 121.5, 18.6; HRMS (ESI) calcd. for $C_{21}H_{19}N_2O$ $[M-H]^-$: 315.1503, found: 315.1517.

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PAPER

***N',N'*-bis(3,5-*di*Methylphenyl)benzohydrazide (2p).** White solid; mp: 205-206 ℃; ^{1}H NMR (400 MHz, $CDCl_3$) δ: 8.18 (s, 1H), 7.90-7.84 (m, 2H), 7.57 (t, *J* = 7.4 Hz, 1H), 7.48 (t, *J* = 7.5 Hz, 2H), 6.82 (s, 4H), 6.69 (s, 2H), 2.26 (s, 12H); ^{13}C NMR (100 MHz, $CDCl_3$) δ: 166.3, 146.1, 138.9, 132.7, 132.1, 128.8, 127.3, 124.9, 117.5, 21.5; HRMS (ESI) calcd. for $C_{23}H_{23}N_2O$ $[M+H]^+$: 345.1961, found: 345.1942.

***N',N'*-bis(3,4-*di*Methylphenyl)benzohydrazide (2q).** White solid; mp: 192-193 ℃;^{1}H NMR (400 MHz, $CDCl_3$) δ: 8.15 (s, 1H), 7.89-7.83 (m, 2H), 7.55 (t, *J* = 7.4 Hz, 1H), 7.47 (t, *J* = 7.5 Hz, 2H), 7.04 (d, *J* = 8.1 Hz, 2H), 6.99 (s, 2H), 6.93 (d, *J* = 8.1 Hz, 2H), 2.21 (d, *J* = 4.0 Hz, 12H); ^{13}C NMR (100 MHz, $CDCl_3$) δ: 166.3, 144.3, 137.4, 132.9, 132.1, 131.2, 130.3, 128.8, 127.3, 121.0, 117.1, 20.0, 19.0; HRMS (ESI) calcd. for $C_{23}H_{25}N_2O$ $[M+H]^+$: 345.1961, found: 345.1945.

***N',N'*-bis(6-Chloropyridin-2-yl)benzohydrazide (2r).** Off-white solid; mp: 198-199 ℃; ^{1}H NMR (400 MHz, DMSO-d_6) δ: 11.41 (s, 1H), 8.01-7.96 (m, 2H), 7.87-7.81 (m, 2H), 7.65 (t, *J* = 7.4 Hz, 1H), 7.57 (t, *J* = 7.4 Hz, 2H), 7.52 (d, *J* = 8.2 Hz, 2H), 7.18 (d, *J* = 7.6 Hz, 2H); ^{13}C NMR (100 MHz, DMSO-d_6) δ: 166.3, 154.7, 147.5, 141.3, 132.2, 132.1, 128.6, 127.6, 118.1, 111.9; HRMS (ESI) calcd. for $C_{17}H_{11}Cl_2N_4O$ $[M-H]^-$: 357.0315, found: 357.0317.

4-Methoxy-*N',N'-di*phenylbenzohydrazide (2t). Off-white solid; mp: 197-198 ℃; ^{1}H NMR (400 MHz, $CDCl_3$) δ: 8.28 (s, 1H), 7.83 (d, *J* = 8.7 Hz, 2H), 7.32-7.24 (m, 4H), 7.20 (d, *J* = 7.8 Hz, 4H), 7.02 (t, *J* = 7.2 Hz, 2H), 6.94 (d, *J* = 8.7 Hz, 2H), 3.86 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ: 166.1, 162.8, 145.9, 129.2, 124.6, 122.9, 119.5, 114.0, 55.5; HRMS (ESI) calcd. for $C_{20}H_{17}N_2O_2$ $[M-H]^-$: 317.1296, found: 317.1304.

4-Hydroxy-*N',N'-di*phenylbenzohydrazide (2u). Off-white solid; mp: 207-208 ℃; ^{1}H NMR (400 MHz, DMSO-d_6) δ: 10.95 (s, 1H), 7.82 (d, *J* = 7.2 Hz, 2H), 7.29 (t, *J* = 7.1 Hz, 4H), 7.14 (d, *J* = 7.6 Hz, 4H), 6.97 (t, *J* = 7.1 Hz, 2H), 6.85 (d, *J* = 7.1 Hz, 2H); ^{13}C NMR (100 MHz, DMSO-d_6) δ: 165.4, 160.9, 145.9, 129.5, 129.0, 123.0, 121.9, 118.6, 115.1; HRMS (ESI) calcd. for $C_{19}H_{17}N_2O_2$ $[M+H]^+$: 305.1285, found: 305.1279.

4-Bromo-*N',N'-di*phenylbenzohydrazide (2v). Off-white solid; mp: 206-207 ℃; ^{1}H NMR (400 MHz, $CDCl_3$) δ: 8.36 (s, 1H), 7.71 (d, *J* = 8.5 Hz, 2H), 7.58 (d, *J* = 8.5 Hz, 2H), 7.28 (m, 4H), 7.18 (d, *J* = 7.7 Hz, 4H), 7.04 (t, *J* = 7.3 Hz, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ: 165.8, 145.7, 132.0, 131.2, 129.3, 128.9, 127.0, 123.2, 119.5; HRMS (ESI) calcd. for $C_{19}H_{16}BrN_2O$ $[M+H]^+$: 367.0441, found: 367.0441.

4-Amino-*N',N'-di*phenylbenzohydrazide (2w). White solid; mp: 225-226 ℃; ^{1}H NMR (400 MHz, DMSO-d_6) δ: 10.72 (s, 1H), 7.66 (d, *J* = 8.5 Hz, 2H), 7.27 (t, *J* = 7.9 Hz, 4H), 7.13 (d, *J* = 7.8 Hz, 4H), 6.95 (t, *J* = 7.3 Hz, 2H), 6.58 (d, *J* = 8.6 Hz, 2H), 5.75 (s, 2H); ^{13}C NMR (100 MHz, DMSO-d_6) δ: 166.2, 152.9, 146.6, 129.6, 129.4, 122.2, 119.3, 119.1, 113.1; HRMS (ESI) calcd. for $C_{19}H_{16}N_3O$ $[M-H]^-$: 302.1299, found: 302.1307.

4-Nitro-*N',N'-di*phenylbenzohydrazide (2x). Yellow solid; mp: 204-205 ℃; ^{1}H NMR (400 MHz, DMSO-d_6) δ: 11.51 (s, 1H), 8.37 (d, *J* = 8.8 Hz, 2H), 8.17 (d, *J* = 8.9 Hz, 2H), 7.35-7.28 (m, 4H), 7.17 (d, *J* = 7.7 Hz, 4H), 7.02 (t, *J* = 7.3 Hz, 2H); ^{13}C NMR (100 MHz, DMSO-d_6) δ: 164.3, 149.5, 145.5, 138.1, 129.1, 129.0, 123.7, 122.4, 118.8; HRMS (ESI) calcd. for $C_{19}H_{14}N_3O_3$ $[M-H]^-$: 332.1041, found: 332.1051.

3-Nitro-*N',N'-di*phenylbenzohydrazide (2y). Light yellow solid; mp: 207-208 ℃; ^{1}H NMR (400 MHz, $CDCl_3$) δ: 8.67 (s, 1H), 8.58 (s, 1H), 8.40 (d, *J* = 8.2 Hz, 1H), 8.21 (d, *J* = 7.8 Hz, 1H), 7.65 (t, *J* = 8.0 Hz, 1H), 7.31-7.26 (m, 4H), 7.18 (d, *J* = 7.7 Hz, 4H), 7.05 (t, *J* = 7.3 Hz, 2H); ^{13}C NMR (100 MHz, DMSO-d_6) δ: 163.8, 147.9, 145.6, 133.9, 133.8, 130.4, 129.1, 126.6, 122.4, 122.2, 118.9; HRMS (ESI) calcd. for $C_{19}H_{16}N_3O_3$ $[M+H]^+$: 334.1186, found: 334.1187.

***N',N'-di*Phenylacetohydrazide (2z).** White solid; mp: 191-192 ℃; ^{1}H NMR (400 MHz, DMSO-d_6) δ: 10.45 (s, 0.86H), 9.92 (s, 0.13H), 7.37-7.32 (m, 0.71H), 7.30-7.25 (m, 3.52H), 7.09-7.04 (m, 4H), 6.97 (t, *J* = 7.3 Hz, 2H), 1.93 (s, 2.47H), 1.90 (s, 0.52H); ^{13}C NMR (100 MHz, DMSO-d_6) δ: 174.5, 168.7, 146.3, 145.8, 129.3, 129.0, 122.9, 122.0, 119.1, 118.7, 20.5, 19.5; HRMS (ESI) calcd. for $C_{14}H_{15}N_2O$ $[M+H]^+$: 227.1179, found: 227.1177.

2,2,2-*tri*Fluoro-*N',N'*-diphenylacetohydrazide (2aa). white solid; mp: 194-195 ℃;^{1}H NMR (400 MHz, $CDCl_3$) δ: 8.44 (s, 1H), 7.36-7.29 (m, 4H), 7.14-7.07 (m, 6H); ^{13}C NMR (100 MHz, DMSO-d_6) δ: 156.2, 155.9, 144.8, 129.4, 123.2, 119.1, 117.3, 114.4; HRMS (ESI) calcd. for $C_{14}H_{10}F_3N_2O$ $[M-H]^-$: 279.0751, found: 279.0761.

***tert*-Butyl 2,2-*di*phenylhydrazinecarboxylate (2ab).** White solid; mp: 121-122 ℃; ^{1}H NMR (400 MHz, $CDCl_3$) δ: 7.32-7.24 (m, 4H), 7.14 (d, *J* = 7.8 Hz, 4H), 7.01 (t, *J* = 7.3 Hz, 2H), 6.83 (s, 1H), 1.40 (d, *J* = 70.2 Hz, 9H); ^{13}C NMR (100 MHz, $CDCl_3$) δ: 155.0, 146.3, 129.1, 122.8, 119.3, 81.3, 28.3; HRMS (ESI) calcd. for $C_{17}H_{19}N_2O_2$ $[M-H]^-$: 283.1452, found: 283.1463.

***tert*-Butyl 2,2-bis(4-chlorophenyl)hydrazinecarboxylate (2ac).** White solid; mp: 127-128 ℃; ^{1}H NMR (400 MHz, $CDCl_3$) δ: 7.25-7.22 (m, 4H), 7.05 (d, *J* = 8.8 Hz, 4H), 6.83 (s, 1H), 1.48 (s, 6H), 1.32 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ: 154.8, 144.6, 129.2, 128.2, 120.6, 81.7, 28.2; HRMS (ESI) calcd. for $C_{17}H_{17}Cl_2N_2O_2$ $[M-H]^-$: 351.0673, found: 351.0687.

***N'*-(4-Nitrophenyl)-*N'*-*m*-tolylbenzohydrazide (2ad).** Brown solid; mp: 182-183 ℃; ^{1}H NMR (400 MHz, $CDCl_3$) δ: 8.53 (s, 1H), 8.10-8.05 (m, 2H), 7.89-7.84 (m, 2H), 7.60 (t, *J* = 7.4 Hz, 1H), 7.49 (t, *J* = 7.6 Hz, 2H), 7.34-7.23 (m, 3H), 7.13 (d, *J* = 7.4 Hz, 1H), 6.93-6.88 (m, 2H), 2.36 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ: 166.1, 152.1, 143.1, 140.4, 140.2, 132.8, 131.6, 129.8, 129.0, 128.3, 127.3, 125.9, 125.7, 122.3, 113.3, 21.4; HRMS (ESI) calcd. for $C_{20}H_{17}N_3O_3Na$ $[M+Na]^+$: 370.1162, found: 370.1142.

Typical procedure for the Cu(II)-catalyzed cross-coupling of *N'*-aryl acylhydrazines with arylboronic acids: A mixture of aryl acylhydrazine (0.2 mmol), arylboronic acid (0.24 mmol) and $Cu(OAc)_2 \cdot H_2O$ (0.02 mmol) in dioxane (2.0 mL) was stirred at room temperature for 24-48 h. After completion of the reaction (indicated by TLC), the mixture was quenched by saturated NaCl

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solution, extracted with EtOAc, and dried over Na_2SO_4. The crude product was purified by flash column chromatography to provide the corresponding products **7a-l.**

***N′*-(4-Methoxyphenyl)-*N′*-phenylbenzohydrazide (7a).** White solid; mp: 185-186 ℃; ^{1}H NMR (400 MHz, $CDCl_3$) δ: 8.25 (s, 1H), 7.84 (d, *J* = 7.2 Hz, 2H), 7.55 (t, *J* = 7.4 Hz, 1H), 7.45 (t, *J* = 7.6 Hz, 2H), 7.33 (d, *J* = 8.9 Hz, 2H), 7.25-7.20 (m, 2H), 6.96 (d, *J* = 7.9 Hz, 2H), 6.89 (dd, *J* = 7.3, 5.1 Hz, 3H), 3.81 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ: 166.5, 157.2, 147.1, 138.8, 132.7, 132.2, 129.1, 128.8, 127.3, 125.4, 120.9, 115.6, 114.7, 55.5; HRMS (ESI) calcd. for $C_{20}H_{17}N_2O_2$ [M-H]$^-$: 317.1296, found: 317.1294.

***N′*-Phenyl-*N′*-*p*-tolylbenzohydrazide (7b).** White solid; mp: 171-172 ℃; ^{1}H NMR (400 MHz, $CDCl_3$) δ: 8.28 (s, 1H), 7.85 (d, *J* = 7.3 Hz, 2H), 7.55 (t, *J* = 7.3 Hz, 1H), 7.46 (t, *J* = 7.6 Hz, 2H), 7.28-7.23 (m, 2H), 7.19 (d, *J* = 8.4 Hz, 2H), 7.11 (dd, *J* = 8.1, 3.7 Hz, 4H), 6.97 (t, *J* = 7.3 Hz, 1H), 2.32 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ: 166.4, 146.4, 143.3, 133.6, 132.6, 132.2, 129.9, 129.1, 128.8, 127.3, 122.0, 121.3, 117.8, 20.8; HRMS (ESI) calcd. for $C_{20}H_{17}N_2O$ [M-H]$^-$: 301.1346, found: 301.1343.

***N′*-(4-Chlorophenyl)-*N′*-phenylbenzohydrazide (7c).** White solid; mp: 172-173 ℃; ^{1}H NMR (400 MHz, $CDCl_3$) δ: 8.36 (s, 1H), 7.86-7.82 (m, 2H), 7.57 (dd, *J* = 10.6, 4.3 Hz, 1H), 7.46 (t, *J* = 7.6 Hz, 2H), 7.33-7.28 (m, 2H), 7.24-7.19 (m, 4H), 7.13-7.04 (m, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ: 166.6, 145.4, 144.6, 132.4, 132.2, 129.3, 129.1, 128.8, 127.6, 127.3, 123.6, 120.3, 120.0; HRMS (ESI) calcd. for $C_{19}H_{14}ClN_2O$ [M-H]$^-$: 321.0800, found: 321.0800.

***N′*-Phenyl-*N′*-*m*-tolylbenzohydrazide (7d).** White solid; mp: 168-169 ℃; ^{1}H NMR (400 MHz, $CDCl_3$) δ: 8.26 (s, 1H), 7.86 (d, *J* = 7.4 Hz, 2H), 7.57 (t, *J* = 7.4 Hz, 1H), 7.47 (t, *J* = 7.6 Hz, 2H), 7.30 (d, *J* = 8.5 Hz, 2H), 7.22-7.16 (m, 3H), 7.07-7.01 (m, 3H), 6.87 (d, *J* = 7.4 Hz, 1H), 2.30 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ: 166.4, 146.0, 145.8, 139.1, 132.6, 132.2, 129.2, 129.1, 128.8, 127.3, 124.2, 122.8, 120.5, 119.3, 117.0, 21.6; HRMS (ESI) calcd. for $C_{19}H_{17}N_2O$ [M-H]$^-$: 301.1346, found: 301.1348.

***N′*-(3-Chlorophenyl)-*N′*-phenylbenzohydrazide (7e).** White solid; mp: 159-160 ℃; ^{1}H NMR (400 MHz, $CDCl_3$) δ: 8.35 (s, 1H), 7.87-7.83 (m, 2H), 7.57 (t, *J* = 7.4 Hz, 1H), 7.47 (t, *J* = 7.6 Hz, 2H), 7.31 (dd, *J* = 10.6, 4.2 Hz, 4H), 7.15 (dd, *J* = 16.0, 7.8 Hz, 2H), 7.10 (dd, *J* = 4.4, 2.3 Hz, 1H), 6.98 (dd, *J* = 8.3, 1.5 Hz, 1H), 6.96-6.92 (m, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ: 166.6, 147.4, 144.9, 134.9, 132.4, 132.1, 130.1, 129.4, 128.8, 127.3, 124.5, 121.9, 121.5, 117.5, 115.7; HRMS (ESI) calcd. for $C_{19}H_{14}ClN_2O$ [M-H]$^-$: 321.0800, found: 321.0805.

***N′*-(Naphthalen-2-yl)-*N′*-phenylbenzohydrazide (7f).** White solid; mp: 217-218 ℃; ^{1}H NMR (400 MHz, $CDCl_3$) δ: 8.46 (s, 1H), 7.91-7.86 (m, 2H), 7.75 (t, *J* = 7.9 Hz, 2H), 7.66 (d, *J* = 8.0 Hz, 1H), 7.59-7.54 (m, 2H), 7.46 (t, *J* = 7.6 Hz, 2H), 7.43-7.35 (m, 3H), 7.34-7.26 (m, 4H), 7.10-7.04 (m, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ: 166.5, 145.9, 143.5, 134.2, 132.4, 132.3, 130.2, 129.3, 129.0, 128.8, 127.6, 127.3, 127.2, 126.4, 124.5, 123.3, 120.4, 119.7, 115.3; HRMS (ESI) calcd. for $C_{23}H_{17}N_2O$ [M-H]$^-$: 337.1346, found: 337.1352.

***N′*-(4-Bromophenyl)-*N′*-(4-methoxyphenyl)benzohydrazide (7g).** White solid; mp: 211-212 ℃; ^{1}H NMR (400 MHz, $CDCl_3$) δ: 8.27 (s, 1H), 7.83 (d, *J* = 7.4 Hz, 2H), 7.56 (t, *J* = 7.3 Hz, 1H), 7.46 (t, *J* = 7.6 Hz, 2H), 7.31 (dd, *J* = 15.6, 8.9 Hz, 4H), 6.89 (d, *J* = 8.8 Hz, 2H), 6.80 (d, *J* = 8.8 Hz, 2H), 3.81 (s, 3H); ^{13}C NMR (100 MHz, DMSO-d_6) δ: 165.6, 156.8, 146.7, 137.8, 132.4, 132.0, 131.5, 128.6, 127.4, 125.4, 116.2, 114.6, 110.5, 55.3; HRMS (ESI) calcd. for $C_{20}H_{16}BrN_2O_2$ [M-H]$^-$: 395.0401, found: 395.0397.

***N′*-(4-Methoxyphenyl)-*N′*-*p*-tolylbenzohydrazide (7h).** Off-white solid; mp: 200-201 ℃; ^{1}H NMR (400 MHz, $CDCl_3$) δ: 8.21 (s, 1H), 7.86-7.81 (m, 2H), 7.55 (t, *J* = 7.4 Hz, 1H), 7.45 (t, *J* = 7.5 Hz, 2H), 7.28-7.23 (m, 2H), 7.05 (d, *J* = 8.3 Hz, 2H), 6.93 (d, *J* = 8.5 Hz, 2H), 6.88-6.84 (m, 2H), 3.79 (s, 3H), 2.28 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ: 166.4, 156.6, 144.7, 139.4, 132.8, 132.1, 131.0, 129.7, 128.8, 127.2, 123.9, 117.1, 114.6, 55.5, 20.6; HRMS (ESI) calcd. for $C_{21}H_{19}N_2O_2$ [M-H]$^-$: 331.1452, found: 331.1452.

***N′*-(4-Methoxyphenyl)-*N′*-(4-nitrophenyl)benzohydrazide (7i).** Yellow solid; mp: 212-213 ℃; ^{1}H NMR (400 MHz, $CDCl_3$) δ: 8.56 (s, 1H), 8.07-8.02 (m, 2H), 7.87-7.81 (m, 2H), 7.58 (t, *J* = 7.5 Hz, 1H), 7.49-7.40 (m, 4H), 6.96-6.92 (m, 2H), 6.81-6.76 (m, 2H), 3.83 (s, 3H); ^{13}C NMR (100 MHz, DMSO-d_6) δ: 165.4, 158.2, 153.0, 138.6, 135.9, 132.3, 131.9, 128.6, 127.6, 127.5, 125.7, 115.0, 112.1, 55.4; HRMS (ESI) calcd. for $C_{20}H_{16}N_3O_4$ [M-H]$^-$: 362.1146, found: 362.1144.

***N′*-(2-Methoxyphenyl)-*N′*-(4-methoxyphenyl)benzohydrazide (7j).** White solid; mp: 213-214 ℃; ^{1}H NMR (400 MHz, $CDCl_3$) δ: 8.59 (s, 1H), 7.85-7.80 (m, 2H), 7.60 (dd, *J* = 7.6, 1.6 Hz, 1H), 7.53 (dd, *J* = 10.5, 4.3 Hz, 1H), 7.45 (t, *J* = 7.4 Hz, 2H), 7.28 (d, *J* = 1.4 Hz, 1H), 7.04-6.99 (m, 2H), 6.76 (s, 4H), 3.84 (s, 3H), 3.74 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ: 166.6, 155.5, 153.9, 142.5, 133.3, 133.2, 131.9, 130.0, 128.7, 128.2, 127.3, 121.5, 115.2, 114.4, 112.5, 55.8, 55.7; HRMS (ESI) calcd. for $C_{21}H_{19}N_2O_3$ [M-H]$^-$: 347.1401, found: 347.1398.

4-Bromo-*N′*-(4-methoxyphenyl)-*N′*-phenylbenzohydrazide (7k). Off-white solid; mp: 195-196 ℃; ^{1}H NMR (400 MHz, $CDCl_3$) δ: 8.29 (s, 1H), 7.71-7.68 (m, 2H), 7.57 (d, *J* = 8.5 Hz, 2H), 7.32-7.28 (m, 2H), 7.23-7.19 (m, 2H), 6.92 (d, *J* = 8.0 Hz, 3H), 6.89-6.86 (m, 2H), 3.80 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ: 165.8, 157.3, 147.0, 138.6, 132.0, 131.3, 129.1, 128.9, 126.9, 125.4, 121.0, 115.6, 114.7, 55.5; HRMS (ESI) calcd. for $C_{20}H_{16}BrN_2O_2$ [M-H]$^-$: 395.0401, found: 395.0396.

***tert*-Butyl 2-(4-methoxyphenyl)-2-phenylhydrazinecarboxylate (7l).** Off-white solid; mp: 141-142 ℃; ^{1}H NMR (400 MHz, $CDCl_3$) δ: 7.22 (dd, *J* = 8.6, 7.4 Hz, 4H), 6.97-6.86 (m, 6H), 6.76 (s, 0.70H), 6.53 (s, 0.30H), 3.81 (s, 3H), 1.48 (s, 6H), 1.37 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ: 157.0, 155.0, 147.6, 139.2, 128.9, 125.1, 124.4, 120.5, 115.5, 114.6, 55.51, 28.3; HRMS (ESI) calcd. for $C_{18}H_{21}N_2O_3$ [M-H]$^-$: 313.1558, found: 313.1560.

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