Prayogik Rasayan

Copper Catalyzed 5-*endo*-dig Cyclization Cascade of 2-(2-Enynyl)pyridines with Boronic Acids: Access to Hetero-arylated Unsymmetrical Triarylmethanes

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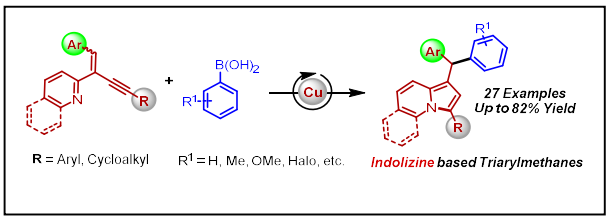
Abstract

An efficient protocol for the synthesis of 1,3-disubstituted indolizine-containing unsymmetrical triarylmethane derivatives has been developed through a copper catalyzed 5-*endo*-dig cyclization of 2-(2-enynyl)pyridines followed by nucleophilic addition of organoboronic acids. A variety of substituted organoboronic acids and 2-(2-enynyl)-pyridines were subjected to react under the optimal reaction conditions, and the respective indolizine-based unsymmetrical triarylmethanes were obtained in moderate to good yields.



Keywords: Triarylmethanes (TRAMs), Indolizine, Nitrogen-heterocycles, Cascade cyclization, Copper catalysis, Boronic acids

1. Introduction

Indolizine is a versatile *N*-containing heterocyclic compound characterized by its unique bicyclic structure, which consists of a fused pyrrole and pyridine ring. This structure not only imparts indolizine with a distinctive chemical profile but also contributes to its wide-ranging biological and material applications.[1] This structural moiety is highly regarded by synthetic chemists due to its frequent occurrence in a variety of natural alkaloids,[2] agrochemicals,[3] and other biologically active synthetic compounds.[4] Notably, many natural and synthetic derivatives of indolizine have shown significant therapeutic potential, such as antibacterial,[5] anticancer,[6] antitubercular,[7] anti-inflammatory,[8] and antifungal properties,[9] etc. (Figure 1). Apart from these, indolizine derivatives have also been explored as drugs in treating neurodegenerative diseases, cardiovascular conditions, and metabolic disorders.[10] This diversity in their biological activity is attributed to the ability of the indolizine nucleus to interact with various biological targets which could affect multiple biological pathways, including enzyme inhibition, receptor modulation, and cell signalling interference.[11] This versatility makes them valuable in drug discovery and development. Besides their pharmaceutical applications, these compounds have also found applications in material science, serving as fluorescent probes, dyes for dye-sensitized solar cells, and as components in organic light-emitting diodes (OLEDs).[12] Moreover, indolizine-based materials are being investigated for their potential in cell labelling and biomarkers, sensors, light-emitting devices, and as components in advanced nanomaterials.[13]

Similarly, triarylmethanes (TRAMs), particularly, the unsymmetrical ones, have emerged as important and integral scaffolds in many pharmaceuticals and biologically active molecules.[14] Several of them exhibit important therapeutic applications and are being explored as anti-breast cancer, anti-viral, anti-inflammatory and anti-TB agents (Figure 1).[14a,15]

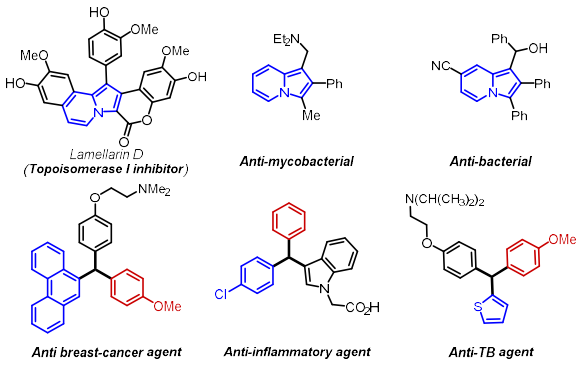
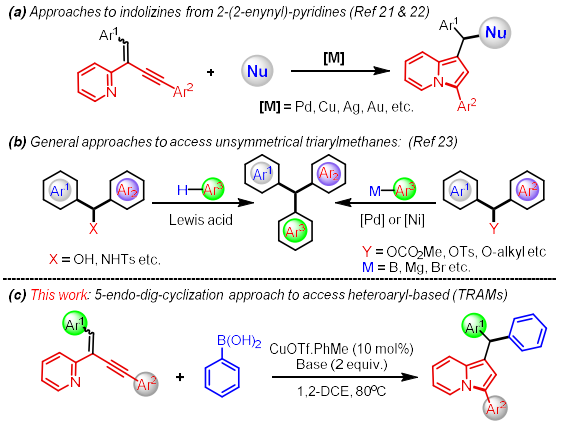


Figure 1: Representative examples of indolizine- and unsymmetrical triarylmethanes (TRAMs)-based bioactive molecules.

Besides the medicinal applications, molecules possessing triarylmethane motifs have also found remarkable applications in various other fields, such as in the dye industry, materials science and some triarylmethane

derivatives have been utilized as metal ion sensors and fluorescent probes.[16]

Due to the significant importance of indolizine as well as triarylmethane derivatives, spanning from fundamental chemistry to broad spectrum of practical applications in medicine and material science, have gained significant attention as valuable synthetic targets and attracted the synthetic community towards the development of different synthetic approaches to access indolizine derivatives, including transition metal-catalyzed annulation/coupling reactions, radical cyclization/cross-coupling reactions, and some metal free approaches as well.[17] The most common protocols for the synthesis of indolizines involve metal-catalyzed transformations of propargylic pyridines,[18] pyridinium salts,[19] or pyrrole derivatives[20] as the starting materials. Recently, another different approach has been developed to access highly substituted indolizine derivatives through a metal-catalyzed 5-*endo*-dig cyclization of 2-(2-enynyl)-pyridines utilizing a wide range of nucleophiles (a, Scheme 1).[21,22] Likewise, the dominant approaches for the synthesis of symmetrical and unsymmetrical triarylmethanes involve either a Lewis acid/Brønsted acid mediated Friedel-Crafts reaction or a transition metal catalyzed cross coupling reaction of diarylmethanol derivatives with relevant aryl coupling partners, and other miscellaneous processes, including metal catalyzed direct arylation of diarylmethanes, have also been reported (b, scheme 1).[23]



Scheme 1: Common Approaches Toward Indolizines and triarylmethanes and Our Approach to Indolizines-based Unsymmetrical Triarylmethanes.

While working on the development of new protocols to access indolizine containing diaryl- and triarylmethane derivatives,[22] very recently, our research group reported a copper-catalyzed protocol to access heterocycles-based unsymmetrical triarylmethanes, containing both indolizine and chromone scaffolds in the same molecule.[22a] Apart from this, our group also developed a couple of protocols to access highly-substituted indolizine derivatives through a metal-catalyzed [3+2]-annulation of 2-pyridinyl-substituted *p*-quinone methides (*p*-QMs) with terminal alkynes[24a] or *N, N*-dimethyl enaminones.[24b] In line with this, we believed that it could be possible to access indolizine-containing unsymmetrical triarylmethanes by reacting 2-(2-enynyl)pyridines with organoboronic acids as a cheap and readily available starting materials (c, Scheme 1).

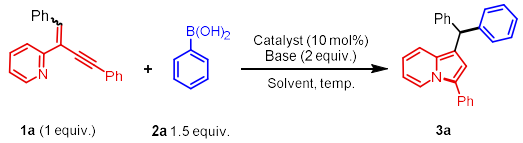
2. Result and discussion:

To optimize the reaction conditions, we chose 2-(2-enynyl)pyridine **1a** and readily available phenylboronic acid **2a** as model substrates, and the results from the optimization studies are as shown in Table 1. The preliminary experiment was performed with CuI as the catalyst and KO^{t}Bu as the base in MeCN solvent at room temperature, but no product formation was seen as the starting material was decomposed into many unidentified complex mixtures in 12 hours (Table 1, entry 1). To our pleasure, when the reaction temperature was increased to 70 °C, the desired product **3a** was obtained in 52% yield within 6 hours (Table 1, entry 2). Then the reaction was performed in 1,2-DCE as the solvent at 70 °C, the desired product was isolated in 58% yield in just 2 hours (Table 1, entry 3). When the reaction was performed with K_3PO_4 as the base, a slight increase in the yield of **3a** (62%) was observed (Table 1, entry 4). Encouraged by this result, further optimization studies were performed using K_3PO_4 as the base in different other solvents such as 1,4-dioxane, DMF, etc. (Table 1, entries 5 to 7) however, the yield of **3a** was inferior as compared to the reactions in 1,2-DCE. Further, the reaction was conducted with other copper-based catalysts such as $Cu(OAc)_2$, $Cu(OTf)_2$, CuBr, etc. (Table 1, entries 8 to 11) and it was found that the reaction with Cu(OTf).PhMe yielded the desired product **3a** in 68% isolated yield after 2 hours (Table 1, entry 11). A considerable improvement in the yield of **3a** was observed when the reaction temperature was raised to 80 °C, and in that case the product was obtained in 78% yield (Table 1, entry 12). Fascinated with these results, we further optimized the reaction conditions using different inorganic and organic bases such as K_2CO_3, $NaHCO_3$, NEt_3, etc. However, in those cases no improvement in the yield **3a** was observed (Table 1, entries 13 to 15). Only trace amount of the product formation was seen when $PdCl_2$ was used as the catalyst even after 24 hours (Table 1, entry 16). The reaction was also performed with various silver salts such as $AgOCOCF_3$ and $AgSbF_6$, as well as with $Bi(OTf)_3$ as a catalyst, but these salts were proven to be ineffective for this transformation as the starting material was decomposed to a complex mixture in those cases (Table 1, entries 17-19). No product formation was seen in the absence of the catalyst, which indicates that a catalyst is required to drive this transformation (Table 1, entry 20).

With the optimized reaction conditions in hands, the generality of this transformation was investigated using different substituted phenylboronic acids **2a-n** and 2-(2-enynyl)pyridine **1a**. A wide range of arylboronic acids containing different substituents on the phenyl ring were subjected to react under the optimized reaction condition and in all those cases, the corresponding products **3a-m** were isolated in moderate to good yields (Scheme 2). The reaction worked well with arylboronic acids substituted with electron-rich groups **2b-g**, and the respective products **3b-g** were isolated in moderate to good yields (68-82%). Halogen-substituted boronic acids **2h-j** also reacted efficiently with **1a**,

and the corresponding products **3h-j** were obtained in the range of 42-74% isolated yields. Aryl boronic acids **2k** and **2l** substituted with an electron-withdrawing –CF_3 group, also underwent the reaction smoothly affording the product **3k** and **3l** in 44 and 45% yield respectively. The reaction of **1a** with a bulky naphthalene-based boronic acid **2m** produced the product **3m** in 51% yield.The reaction also worked well with cyclohexyl boronic acids **2n**, however, the yield was low in that case as the products **3n** was isolated only in 34% yield.

Table 1: Optimization Study[a]

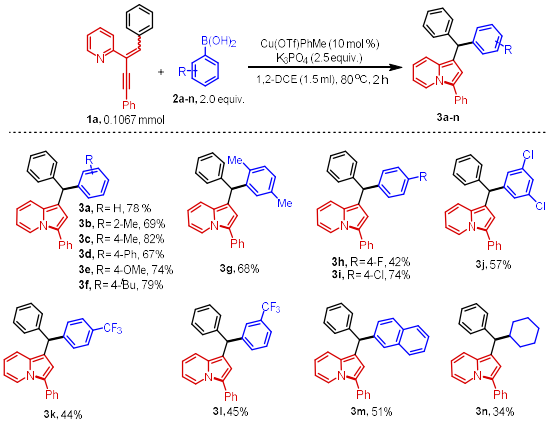


1a (1 equiv.) 2a 1.5 equiv. 3a

Entry	Catalyst	Base	Solvent	Temp [°C]	Time [h]	Yield (%)[b]
1	CuI	KOtBu	MeCN	RT	12	ND
2	CuI	KOtBu	MeCN	70	6	52
3	CuI	KOtBu	1,2-DCE	70	2	58
4	CuI	K_3PO_4	1,2-DCE	70	2	62
5	CuI	K_3PO_4	PhMe	70	12	60
6	CuI	K_3PO_4	1,4-Dioxane	70	36	42
7	CuI	K_3PO_4	DMF	70	12	16
8	$Cu(OAc)_2$	K_3PO_4	1,2-DCE	70	24	36
9	$Cu(OTf)_2$	K_3PO_4	1,2-DCE	70	2	65
10	Cu(OTf). PhMe	K_3PO_4	1,2-DCE	70	2	68
11	CuBr	K_3PO_4	1,2-DCE	70	3	44
12[c]	**Cu(OTf). PhMe**	**K_3PO_4**	**1,2-DCE**	**80**	**2**	**78**
13	Cu(OTf). PhMe	K_2CO_3	1,2-DCE	80	6	63
14	Cu(OTf). PhMe	$NaHCO_3$	1,2-DCE	80	6	42
15	Cu(OTf). PhMe	NEt_3	1,2-DCE	80	12	36
16	$PdCl_2$	K_3PO_4	1,2-DCE	80	24	Trace
17	AgOCO CF_3	K_3PO_4	1,2-DCE	80	24	ND
18	$AgSbF_6$	K_3PO_4	1,2-DCE	80	24	ND
19	$Bi(OTf)_3$	K_3PO_4	1,2-DCE	80	24	ND
20	. . .	K_3PO_4	1,2-DCE	80	24	NR

[a]Reaction conditions: All the reactions were carried out with 0.1067 mmol (30 mg) of **1a**, 1.5 equiv. of boronic acid, 2.0 equiv. of base and 10 mol % of catalyst in (1.5 ml solvent). [b]Isolated yields; [c]2.0 equiv. of boronic acid, 2.5 equiv. of base (K_3PO_4) with respect to **1a** and 10 mol % catalyst at 80 °C was found to be optimal. ND = Not detected. NR = No reaction.

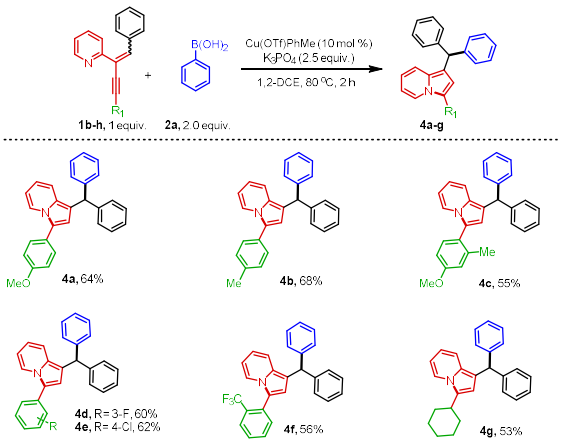
Scheme 2: Substrate scope with different aryl boronic acids[b]



[a]Reaction conditions: All the reactions were carried out with 0.1067 mmol (30 mg) of **1a**, 2.0 equiv. of bobonic acids (**2a-n**) and 2.5 equiv. K_3PO_4 in (1.5 ml 1,2-DCE solvent). [b]Yields reported are isolated yields.

Next, we went on to investigate the substrate scope with 2-(2-enynyl) pyridines **1b-h** having different aryl substituents (both electron-rich and electron-poor) at the alkyne part and, to our delight, in all those cases, the expected products **4a-f** were obtained in the range of 55-68% yield under the optimized reaction conditions (Scheme 3). The 2-(2-enynyl) pyridine **1h**, substituted with a cyclohexyl group furnished the product **4g** in 53% yield.

Scheme 3: Substrate scope with different 2-(2-enynyl)pyridines[b]

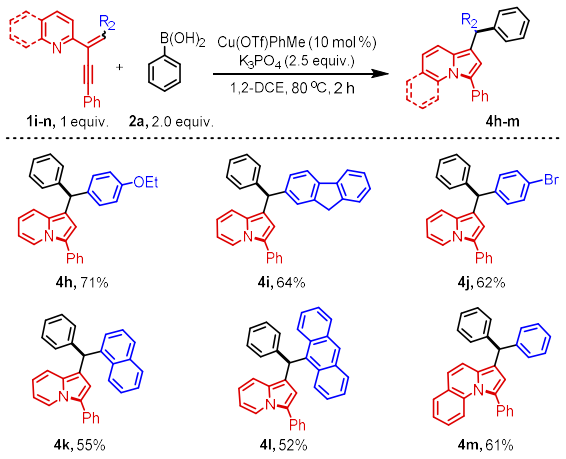


[a]Reaction conditions: All the reactions were carried out with 0.086 – 0.104 mmol (30 mg) of **1b-h**, 2.0 equiv. of bobonic

acid **2a** and 2.5 equiv. K_3PO_4 in (1.5 ml 1,2-DCE solvent). [b]Yields reported are Isolated yields.

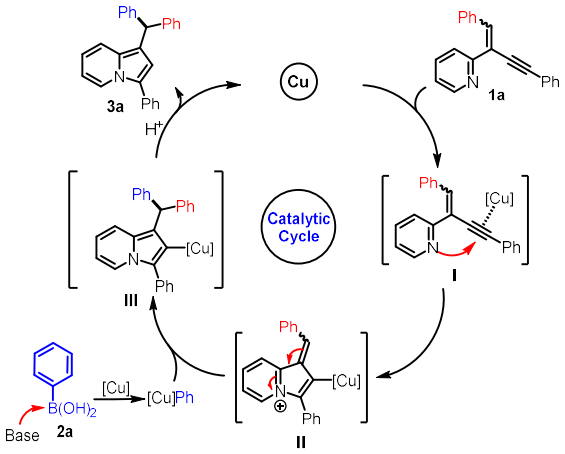
Then, the substrate scope studies were also elaborated to other 2-(2-enynyl) pyridines (**1i-m**) having different aryl substituents at the alkene part with phenyl boronic acid **2a** and in all those cases the respective products **4h-l** was isolated in (52-71%) yield. 2-(2-enynyl)pyridine **1i** substituted with an electron-rich (-OEt) group and 2-(2-enynyl)pyridine **1j** containing a fluorene substituent reacted smoothly to afford the corresponding products **4h** and **4i** in 71% and 64% yield respectively. 2-2(enynyl)pyridine **1k**, substituted with a bromo-group provided the product **4j** in 62% yield. The reaction also worked well with 2-2(enynyl)pyridine **1l** and **1m**, having bulky substituents such as naphthalene and anthracene at the alkene part, and the products **4k** and **4l** were obtained in 55% and 52% respectively. 2-2(enynyl)quinoline **1n** derived from quinaldic acid afforded the product **4m** in 61% yield. Scheme 4 reveals the substrate scope of this protocol with 2-(2-enynyl) pyridines having different substituents at the alkene part.

Scheme 4: Substrate scope with 2-(2-enynyl) pyridines having different substituents at the alkene part[b]



[a]Reaction conditions: All the reactions were carried out with 0.079 – 0.092 mmol (30 mg) of **1i-n**, 2.0 equiv. of bobonic acid **2a** and 2.5 equiv. K_3PO_4 in (1.5 mL of 1,2-DCE solvent). [b]Yields reported are Isolated yields.

Based on the outcome of this methodology and previous literature reports,[21,22] a plausible mechanism for this transformation was proposed, as shown in (Scheme 5). We propose that the reaction begins with the activation of the alkyne part of 2-(2-enynyl)pyridines **1a** by the copper catalyst to generate intermediate **I**, which undergoes 5-*endo*-dig-cyclization to produce the intermediate indolizinium salt **II**, in which the exocyclic alkene-part becomes relatively more electrophilic due to the generation of the positive charge on the nitrogen atom. Subsequently, remote nucleophilic addition of the aryl nucleophile from aryl-Cu complex (generated from the reaction of Cu catalyst with boronic acid **2a** under basic conditions) to the exocyclic olefinic center of intermediate **II** generates another intermediate **III**, which upon protodemetallation affords the final product **3a** along with the regeneration of the catalyst.



Scheme 5: Proposed Mechanism

3. Conclusions

In conclusion, we have developed an efficient protocol for the synthesis of 1,3-disubstituted indolizine containing unsymmetrical triarylmethane derivatives through a copper-catalyzed 5-*endo*-dig cyclization of 2-(2-enynyl)pyridines followed by remote nucleophilic addition of organoboronic acids. The generality of this transformation was examined using a wide range of boronic acid and 2-(2-enynyl) pyridines, and the respective indolizine-based unsymmetrical triarylmethanes were obtained in moderate to good yields. This transformation was also found to be compatible to access pyrrolo-[1,2-*a*]-quinoline based unsymmetrical triarylmethanes which are another class of bio-active compounds. Considering the importance of indolizine as well as unsymmetrical triarylmethanes from medicinal chemistry to material science, we believe that these new class of heteroaryl-based triarylmethanes may find some applications in the future.

4. Experimental Section

General Information: All reactions were carried out in an oven dried round bottom flask. All the solvents were distilled before use and stored under argon atmosphere. Most of the reagents, starting materials were purchased from commercial sources and used as such. Melting points were recorded on SMP20 melting point apparatus and are uncorrected. ^1H, ^{13}C and ^{19}F spectra were recorded in $CDCl_3$ and DMSO-d_6 (400, 100 and 376 MHz respectively) on Bruker FT–NMR spectrometer. Chemical shift (δ) values are reported in parts per million relative to TMS and the coupling constants (J) are reported in Hz. High resolution mass spectra were recorded on Waters Q–TOF Premier–HAB213 spectrometer. FT-IR spectra were recorded on a Perkin-Elmer FTIR spectrometer. Thin layer chromatography was performed on Merck silica gel 60 F_{254} TLC pellets and visualised by UV irradiation and KMnO4 stain. Column chromatography was carried out

through silica gel (100–200 mesh) using EtOAc/hexane as an eluent.

General procedure for the addition of boronic acids to 2-(2-enynyl)pyridines:

Anhydrous 1,2-DCE solvent (1.5 mL) was added to the mixture of 2-(2-enynyl)pyridine (30 mg, 0.1067 mmol, 1.0 equiv.), boronic acid (2.0 equiv.), K_3PO_4 (2.5 equiv.) and Cu(OTf).PhMe (10 mol %) under nitrogen atmosphere in an oven-dried round bottom flask and the resulting suspension was stirred at 80 °C in a pre-heated oil bath until the 2-(2-enynyl)pyridine was completely consumed (based on TLC analysis). The reaction mixture was concentrated under reduced pressure and the residue was purified through a silica gel chromatography, using EtOAc/Hexane mixture as an eluent, to get the pure indolizine based unsymmetrical triarylmethanes.

*1-benzhydryl-3-phenylindolizine (**3a**):*

The reaction was performed at 0.1067 mmol scale of **1a**; R_f = 0.8 (5% EtOAc in hexane); green gummy solid (30.1 mg, 78% yield); ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.28 (d, J = 7.1 Hz, 1H), 7.54 (d, J = 8.0 Hz, 2H), 7.43 (t, J = 7.6 Hz, 2H); 7.32 – 7.30 (m, 3H), 7.29 – 7.26 (m, 6H), 7.22 (t, J = 6.9 Hz, 2H)), 7.17 (d, J = 9.04 Hz, 1H), 6.60 – 6.55 (m, 1H), 6.54 (s, 1H), 6.46 (t, J = 6.92 Hz, 1H)), 5.78 (s, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 144.8, 132.6, 130.8, 129.1, 129.0, 128.4, 128.0, 127.0, 126.2, 124.5, 122.3, 118.1, 116.5, 116.4, 115.5, 110.8, 48.7; FT-IR (thin film, neat): 3028, 1612, 1452, 1250, 736, 696 cm^{-1}; HRMS (ESI): m/z calcd for $C_{27}H_{22}N$ $[M+H]^+$: 360.1752; found : 360.1758.

*3-phenyl-1-[phenyl(o-tolyl)methyl]indolizine (**3b**):*

The reaction was performed at 0.1067 mmol scale of **1a**; R_f = 0.8 (5% EtOAc in hexane); green gummy solid (27.6 mg, 69% yield); ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.30 (d, J = 7.2 Hz, 1H), 7.54 (d, J = 7.6 Hz, 2H), 7.43 (t, J = 7.6 Hz, 2H); 7.31 – 7.28 (m, 3H), 7.24 – 7.17 (m, 4H)), 7.15 – 7.10 (m, 3H), 7.04 (d, J = 7.1 Hz, 1H), 6.59 – 6.55 (m, 1H), 6.48 – 6.45 (m, 2H), 5.90 (s, 1H), 2.32 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 144.2, 143.0, 136.4, 132.6, 130.8, 130.4, 129.3, 129.1, 129.0, 128.4, 127.9, 127.0, 126.3, 126.1, 125.9, 124.4, 122.4, 118.1, 116.3, 116.0, 115.9, 110.8, 45.2, 20.0; FT-IR (thin film, neat): 2926, 1601, 1478, 1259, 748, 683 cm^{-1}; HRMS (ESI): m/z calcd for $C_{28}H_{24}N$ $[M+H]^+$: 374.1909; found : 374.1924.

*3-phenyl-1-[phenyl(p-tolyl)methyl]indolizine (**3c**):*

The reaction was performed at 0.1067 mmol scale of **1a**; R_f = 0.8 (5% EtOAc in hexane); pale yellow solid (32.7 mg, 82% yield); m. p. = 118 – 120 ºC; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.28 (d, J = 7.2 Hz, 1H), 7.55 (d, J = 7.8 Hz, 2H), 7.44 (t, J = 7.6 Hz, 2H), 7.31 (d, J = 7.4 Hz, 2H), 7.28 – 7.26 (m, 3H) 7.22 (d, J = 6.9 Hz, 1H), 7.19 – 7.15 (m, 3H)), 7.11 (d, J = 7.9 Hz, 2H), 6.59 – 6.55 (m, 1H), 6.54 (s, 1H), 6.45 (t, J = 6.76 Hz, 1H), 5.74 (s, 1H), 2.34 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 145.0, 141.8, 135.7, 132.6, 130.8, 129.09, 129.08, 129.0 (2C), 128.4, 127.9, 126.9, 126.2, 124.4, 122.3, 118.2, 116.7, 116.3, 115.5, 110.8, 48.3, 21.2; FT-IR (thin film, neat): 2928, 1624, 1482, 1263, 753, 687 cm^{-1}; HRMS (ESI): m/z calcd for $C_{28}H_{24}N$ $[M+H]^+$: 374.1909; found : 374.1916.

*1-{[1,1'-biphenyl]-4-yl(phenyl)methyl}-3-phenylindolizine (**3d**):*

The reaction was performed at 0.1067 mmol scale of **1a**; R_f = 0.6 (5% EtOAc in hexane); pale yellow gummy solid (31.3 mg, 67% yield); ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.31 (d, J = 5.9 Hz, 1H), 7.63 (d, J = 7.4 Hz, 2H), 7.58 – 7.55 (m, 4H); 7.47 – 7.43 (m, 4H), 7.37 – 7.30 (m, 8H), 7.26 – 7.22 (m, 2H), 6.62 – 7.59 (m, 2H), 6.48 (t, J = 6.8 1H), 5.82 (s, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 144.7, 143.9, 141.1, 139.0, 132.6, 130.9, 129.5, 129.1, 129.0, 128.8, 128.5, 127.9, 127.2, 127.1(2C), 127.0, 126.3, 124.6, 122.4, 118.1, 116.5, 116.4, 115.5, 110.8, 48.4; FT-IR (thin film, neat): 2926, 1610, 1486, 1259, 756, 687 cm^{-1}; HRMS (ESI): m/z calcd for $C_{33}H_{26}N$ $[M+H]^+$: 436.2065; found : 436.2054.

*1-[(4-methoxyphenyl)(phenyl)methyl]-3-phenylindolizine (**3e**):*

The reaction was performed at 0.1067 mmol scale of **1a**; R_f = 0.5 (5% EtOAc in hexane); pale yellow gummy solid (31.1 mg, 74% yield); ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.29 (d, J = 7.12 Hz, 1H), 7.56 – 7.54 (m, 2H), 7.44 (t, J = 7.6 Hz, 2H), 7.33 – 7.29 (m, 3H), 7.28 – 7.26 (m, 2H), 7.24 – 7.20 (m, 2H), 7.18 – 7.16 (m, 2H), 6.87 – 6.84 (m, 2H), 6.60 – 6.56 (m, 1H), 6.54 (s, 1H), 6.46 (t, J = 7.9 Hz, 1H), 5.73 (s, 1H), 3.80 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 158.0, 145.1, 137.0, 132.6, 130.8, 130.0, 129.1, 129.0, 128.4, 127.9, 127.0, 126.2, 124.4, 122.3, 118.2, 116.8, 116.3, 115.5, 113.7, 110.8, 55.4, 47.9; FT-IR (thin film, neat): 2834, 1512, 1436, 1248, 736, 674 cm^{-1}; HRMS (ESI): m/z calcd for $C_{28}H_{24}NO$ $[M+H]^+$: 390.1858; found : 390.1874.

*1-{[4-(tert-butyl)phenyl](phenyl)methyl}-3-phenylindolizine (**3f**):*

The reaction was performed at 0.1067 mmol scale of **1a**; R_f = 0.6 (5% EtOAc in hexane); pale yellow gummy solid (35.2 mg, 79% yield); ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.27 (d, J = 7.2 Hz, 1H), 7.55 (d, J = 7.8 Hz, 2H), 7.44 (t, J = 7.4 Hz, 2H), 7.32 – 7.26 (m, 7H), 7.21 – 7.18 (m, 4H), 6.59 – 6.55 (m, 2H)), 6.45 (t, J = 6.8 Hz, 1H), 5.74 (s, 1H), 1.32 (s, 9H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 148.9, 145.1, 141.6, 132.7, 130.8, 129.1, 129.0, 128.6, 128.3, 127.9, 126.9, 126.1, 125.2, 124.4, 122.3, 118.2, 116.8, 116.3, 115.5, 110.8, 48.2, 34.5, 31.6; FT-IR (thin film, neat): 2964, 1606, 1258, 1388, 752, 699 cm^{-1}; HRMS (ESI): m/z calcd for $C_{31}H_{30}N$ $[M+H]^+$: 416.2378; found : 416.2364.

*1-[(2,5-dimethylphenyl)(phenyl)methyl]-3-phenylindolizine (**3g**):*

The reaction was performed at 0.1067 mmol scale of **1a**; R_f = 0.6 (5% EtOAc in hexane); pale yellow gummy solid (28.3 mg, 68% yield); ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.31 (d, J = 7.1 Hz, 1H), 7.58 – 7.56 (m, 2H), 7.45 (t, J = 7.4 Hz, 2H), 7.33 – 7.29 (m, 3H), 7.24 – 7.22 (m, 3H), 7.15 (d, J = 9.0 Hz, 1H), 7.09 (d, J = 7.6 Hz, 1H), 6.97 (d, J = 7.6 Hz, 1H), 6.88 (s, 1H), 6.58 (t, J = 7.0 Hz, 1H), 6.48 – 6.45 (m, 2H), 6.00 (s, 1H), 2.29 (s, 3H), 2.24 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 144.4, 142.7, 135.2, 133.2, 132.6, 130.9, 130.3, 129.7, 129.3, 129.0, 128.3, 127.9, 127.0, 126.9, 126.1, 124.4, 122.3, 118.1, 116.3, 116.1, 115.9, 110.7, 45.1, 21.4, 19.6; FT-IR (thin film, neat): 2921, 1614, 1492, 1305, 737, 658 cm^{-1}; HRMS (ESI): m/z calcd for $C_{29}H_{26}N$ $[M+H]^+$: 388.2065; found : 388.2058.

*1-[(4-fluorophenyl)(phenyl)methyl]-3-phenylindolizine (**3h**):*

The reaction was performed at 0.1067 mmol scale of **1a**; R_f = 0.8 (5% EtOAc in hexane); green gummy solid (17.1 mg, 42% yield); ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.28 (d, J = 7.2 Hz, 1H), 7.54 – 7.52 (m, 2H), 7.44 (t, J = 7.6 Hz, 2H), 7.30 (t, J = 7.4 Hz, 3H), 7.24 – 7.19 (m, 5H), 7.14 (d, J = 9.0 Hz, 1H), 6.98 (t, J = 8.6 Hz, 2H), 6.58 (t, J = 6.4 Hz, 1H), 6.49 – 6.45 (m, 2H), 5.74 (s, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 161.5 (d, $J_{C\text{-}F}$ = 242.6 Hz), 144.6, 140.5 (d, $J_{C\text{-}F}$ = 3.1 Hz), 132.5, 130.7,

130.5 (d, J_{C-F} = 7.8 Hz), 129.0, 128.5, 127.9, 127.1, 126.4, 124.6, 122.4, 118.0, 116.6, 116.3, 115.3, 115.2, 115.0, 110.9, 48.0; $^{19}F\{^{1}H\}$ NMR (376 MHz, $CDCl_3$) δ −117.30; FT-IR (thin film, neat): 3064, 1614, 1582, 1256, 842, 738 cm^{-1}; HRMS (ESI): m/z calcd for $C_{27}H_{21}FN$ $[M+H]^+$: 378.1658; found : 378.1642.

*1-[(4-chlorophenyl)(phenyl)methyl]-3-phenylindolizine (**3i**):*

The reaction was performed at 0.1067 mmol scale of **1a**; R_f = 0.7 (5% EtOAc in hexane); pale yellow solid (31.3 mg, 74% yield); m. p. = 114 – 116 ºC; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.27 (d, *J* = 7.1 Hz, 1H), 7.53 (d, *J* = 7.6 Hz, 2H), 7.43 (t, *J* = 7.3 Hz, 2H), 7.32 – 7.26 (m, 4H), 7.24 – 7.22 (m, 4H), 7.17 (d, J = 7.7 Hz, 2H), 7.13 (d, *J* = 9.0 Hz, 1H), 6.58 (t, *J* = 7.4 Hz, 1H), 6.48 – 6.44 (m, 2H), 5.72 (s, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 144.3, 143.4, 132.4, 132.0, 130.8, 130.5, 129.0, 128.5, 128.0, 127.1, 126.5, 124.6, 122.4, 118.0, 116.6, 115.9, 115.3, 110.9, 48.1; FT-IR (thin film, neat): 3062, 1496, 1305, 1204, 847 cm^{-1}; HRMS (ESI): m/z calcd for $C_{27}H_{21}ClN$ $[M+H]^+$: 394.1363; found : 394.1377.

*1-[(3,5-dichlorophenyl)(phenyl)methyl]-3-phenylindolizine (**3j**):*

The reaction was performed at 0.1067 mmol scale of **1a**; R_f = 0.6 (5% EtOAc in hexane); green gummy solid (26.3 mg, 57% yield); ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.27 (d, *J* = 7.1 Hz, 1H), 7.55 – 7.53 (m, 2H), 7.44 (t, *J* = 7.4 Hz, 2H), 7.32 (t, *J* = 6.8 Hz, 3H), 7.24 – 7.21 (m, 4H), 7.16 – 7.13 (m, 3H), 6.62 (t, *J* = 7.2 Hz, 1H), 6.50 – 6.48 (m, 2H), 5.70 (s, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 148.4, 143.2, 134.9, 132.3, 130.8, 129.1, 129.0, 128.7, 128.0, 127.6, 127.2, 126.8, 126.6, 124.9, 122.5, 117.7, 117.0, 115.1, 114.7, 111.0, 48.2; FT-IR (thin film, neat): 3060, 1492, 1305, 1253, 1154, 867, 737 cm^{-1}; HRMS (ESI): m/z calcd for $C_{27}H_{20}Cl_2N$ $[M+H]^+$: 428.0973; found : 428.0978.

*3-phenyl-1-{phenyl[4-(trifluoromethyl)phenyl]methyl}indolizine (**3k**):*

The reaction was performed at 0.1067 mmol scale of **1a**; R_f = 0.6 (5% EtOAc in hexane); pale yellow solid (20.2 mg, 44% yield); m. p. = 132 – 134 ºC; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.28 (d, *J* = 7.2 Hz, 1H), 7.56 – 7.53 (m, 4H), 7.44 (t, *J* = 7.6 Hz, 2H), 7.38 – 7.36 (m, 2H), 7.33 – 7.30 (m, 3H), 7.25 (t, *J* = 4.9 Hz, 3H), 7.15 (d, *J* = 9.0 Hz, 1H), 6.61 (t, *J* = 6.5 Hz, 1H), 6.50 – 6.46 (m, 2H), 5.81 (s, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 148.9, 143.8, 132.4, 130.8, 129.4, 129.08, 129.06, 128.6, 128.4, 128.0, 127.2, 126.6, 125.4 (q, J_{C-F} = 3.7 Hz), 124.8, 124.5 (q, J_{C-F} = 270 Hz), 122.5, 117.9, 116.8, 115.4, 115.3, 111.0, 48.6; $^{19}F\{^{1}H\}$ NMR (376 MHz, $CDCl_3$) δ −62.23; FT-IR (thin film, neat): 2934, 1428, 1332, 1259, 1126, 867, 756, 642 cm^{-1}; HRMS (ESI): m/z calcd for $C_{28}H_{21}F_3N$ $[M+H]^+$: 428.1626; found : 428.1634.

*3-phenyl-1-{phenyl[3-(trifluoromethyl)phenyl]methyl}indolizine (**3l**):*

The reaction was performed at 0.1067 mmol scale of **1a**; R_f = 0.6 (5% EtOAc in hexane); pale yellow gummy solid (20.6 mg, 45% yield); ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.29 (d, *J* = 7.2 Hz, 1H), 7.56 – 7.54 (m, 3H), 7.51 – 7.45 (m, 3H), 7.43 – 7.39 (m, 2H), 7.34 – 7.31 (m, 3H), 7.26 – 7.24 (m, 3H), 7.17 (d, *J* = 9.0 Hz, 1H), 6.61 (t, *J* = 6.9 Hz, 1H), 6.50 – 6.44 (m, 2H), 5.83 (s, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 145.8, 143.9, 132.52, 132.50, 132.4, 130.8, 130.7, 130.5 (q, J_{C-F} = 274 Hz), 129.0, 128.8, 128.6, 128.0, 127.2, 126.6, 125.8 (q, J_{C-F} = 3.7 Hz), 124.8, 123.2 (q, J_{C-F} = 3.7 Hz), 122.4, 117.8, 116.8, 115.4, 115.2, 111.0, 48.5; $^{19}F\{^{1}H\}$ NMR (376 MHz, $CDCl_3$) δ −62.31; FT-IR (thin film, neat): 2934, 1324, 1253, 1121, 867, 762 cm^{-1}; HRMS (ESI): m/z calcd for $C_{28}H_{21}F_3N$ $[M+H]^+$: 428.1626; found : 428.1647.

*1-[naphthalen-2-yl(phenyl)methyl]-3-phenylindolizine (**3m**):*

The reaction was performed at 0.1067 mmol scale of **1a**; R_f = 0.6 (5% EtOAc in hexane); pale yellow gummy solid (22.5 mg, 51% yield); ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.29 (d, *J* = 7.1 Hz, 1H), 7.82 – 7.80 (m, 1H), 7.78 – 7.72 (m, 2H), 7.64 (s, 1H), 7.55 – 7.53 (m, 2H), 7.44 – 7.40 (m, 5H), 7.31 – 7.29 (m, 5H), 7.25 (dd, *J* = 8.6, 4.2 Hz, 1H), 7.20 (d, *J* = 9.0 Hz, 1H), 6.58 – 6.54 (m, 2H), 6.46 (t, *J* = 7.0 Hz, 1H), 5.93 (s, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 144.6, 142.4, 133.6, 132.5, 132.3, 130.9, 129.2, 129.0, 128.4, 128.05, 128.00, 127.96, 127.92, 127.7, 127.2, 127.0, 126.3, 126.0, 125.5, 124.5, 122.4, 118.2, 116.5, 116.2, 115.6, 110.8, 48.8; FT-IR (thin film, neat): 3056, 1602, 1347, 1264, 847, 732 cm^{-1}; HRMS (ESI): m/z calcd for $C_{31}H_{24}N$ $[M+H]^+$: 410.1909; found : 410.1921.

*1-[cyclohexyl(phenyl)methyl]-3-phenylindolizine (**3n**):*

The reaction was performed at 0.1067 mmol scale of **1a**; R_f = 0.6 (5% EtOAc in hexane); green gummy solid (13.4 mg, 34% yield); ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.23 (d, *J* = 7.1 Hz, 1H), 7.61 – 7.59 (m, 2H), 7.48 (t, *J* = 7.6 Hz, 3H), 7.39 – 7.36 (m, 2H), 7.32 – 7.26 (m, 3H), 6.15 (t, *J* = 7.2 Hz, 1H), 6.93 (s, 1H), 6.62 (t, *J* = 7.1 Hz, 1H), 6.41 (t, *J* = 6.6 Hz, 1H), 3.84 (d, *J* = 10.4 Hz, 1H), 2.15 (q, *J* = 10.8, 21.6 Hz, 1H), 1.72 – 1.46 (m, 6H), 1.32 – 1.11 (m, 4H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 145.5, 145.4, 132.8, 129.0, 128.6, 128.5, 128.4, 128.2, 127.9, 126.9, 125.8, 125.7, 122.3, 117.8, 112.7, 110.5, 49.8, 42.9, 32.4, 26.8, 26.6; FT-IR (thin film, neat): 2956, 1658, 1496, 1362, 703 cm-1; HRMS (ESI): m/z calcd for $C_{27}H_{28}N$ $[M+H]^+$: 366.2222; found : 366.2208.

*1-benzhydryl-3-(4-methoxyphenyl)indolizine (**4a**):*

The reaction was performed at 0.0964 mmol scale of **1b**; R_f = 0.5 (5% EtOAc in hexane); pale yellow gummy solid (24.2 mg, 64% yield); ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.17 (d, *J* = 7.1 Hz, 1H), 7.45 (d, *J* = 7.6 Hz, 2H), 7.31 – 7.30 (m, 2H), 7.28 – 7.26 (m, 6H), 7.23 – 7.19 (m, 2H), 7.16 (d, *J* = 9.0 Hz, 1H), 7.98 (d, *J* = 7.7 Hz, 2H), 6.54 (t, *J* = 7.2 Hz, 1H), 6.47 (s, 1H), 6.43 (t, *J* = 13.4 Hz, 1H), 5.77 (s, 1H), 3.84 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 158.8, 144.9, 130.3, 129.5, 129.1, 128.4, 126.2, 125.1, 124.2, 122.3, 118.1, 116.1, 116.0, 115.0, 114.4, 110.6, 55.5, 48.7; FT-IR (thin film, neat): 2834, 1523, 1364, 1249, 1186, 863, 736 cm^{-1}; HRMS (ESI): m/z calcd for $C_{28}H_{24}NO$ $[M+H]^+$: 390.1858; found : 390.1852.

*1-benzhydryl-3-(p-tolyl)indolizine (**4b**):*

The reaction was performed at 0.1016 mmol scale of **1c**; R_f = 0.6 (5% EtOAc in hexane); pale yellow solid (26.0 mg, 68% yield); m. p. = 122 – 124 ºC; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.23 (d, *J* = 7.1 Hz, 1H), 7.42 (d, *J* = 7.6 Hz, 2H), 7.31 – 7.27 (m, 4H), 7.26 – 7.24 (m, 5H), 7.23 – 7.18 (m, 3H), 7.15 (d, *J* = 9.0 Hz, 1H), 6.55 (t, *J* = 6.5 Hz, 1H), 6.49 (s, 1H), 6.43 (t, *J* = 6.9 Hz, 1H), 5.75 (s, 1H), 2.39 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 144.8, 136.8, 130.6, 129.7, 129.1, 128.4 (2C), 127.9, 126.2, 124.5, 122.4, 118.1, 116.3, 116.2, 115.2, 110.7, 48.7, 21.4; FT-IR (thin film, neat): 2926, 1486, 1358, 1264, 749 cm^{-1}; HRMS (ESI): m/z calcd for $C_{28}H_{24}N$ $[M+H]^+$: 374.1909; found : 374.1915.

*1-benzhydryl-3-(4-methoxy-2-methylphenyl)indolizine (**4c**):*

The reaction was performed at 0.0922 mmol scale of **1d**; R_f = 0.4 (5% EtOAc in hexane); pale yellow solid (20.6 mg, 55% yield); m. p. = 124 – 126 ºC; ^{1}H NMR (400 MHz, $CDCl_3$) δ

7.53 (d, *J* = 7.0 Hz, 1H), 7.33 – 7.31 (m, 2H), 7.29 (brs, 5H), 7.28 – 7.21 (m, 4H), 7.17 (d, *J* = 9.0 Hz, 1H), 6.89 (s, 1H), 6.82 (d, *J* = 8.4 Hz, 1H), 6.55 (t, *J* = 7.0 Hz, 1H), 6.42 – 6.39 (m, 2H), 5.82 (s, 1H), 3.86 (s, 3H), 2.12 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) *δ* 159.6, 145.1, 139.9, 132.5, 129.4, 129.1, 128.3, 126.1, 124.2, 123.2, 122.7, 117.8, 115.8, 115.64, 115.60, 115.3, 111.4, 110.2, 55.4, 48.8, 20.2; FT-IR (thin film, neat): 2934, 1606, 1364, 1243, 768, 739 cm^{-1}; HRMS (ESI): m/z calcd for $C_{29}H_{26}NO$ $[M+H]^+$: 404.2014; found : 404.1999.

*1-benzhydryl-3-(3-fluorophenyl)indolizine (**4d**):*

The reaction was performed at 0.1002 mmol scale of **1e**; R_f = 0.6 (5% EtOAc in hexane); pale yellow gummy solid (23.0 mg, 60% yield); ^{1}H NMR (400 MHz, $CDCl_3$) *δ* 8.29 (d, *J* = 7.2 Hz, 1H), 7.38 (t, *J* = 7.4 Hz, 1H), 7.34 – 7.30 (m, 5H), 7.28 – 7.22 (m, 7H), 7.19 (d, *J* = 9.0 Hz, 1H), 6.99 (t, *J* = 8.3 Hz, 1H), 6.61 (t, *J* = 7.2 Hz, 1H), 6.56 (s, 1H), 6.51 (t, *J* = 6.8 Hz, 1H), 5.78 (s, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) *δ* 163.3 (d, $J_{C\text{-}F}$ = 244.5 Hz), 144.6, 134.7 (d, $J_{C\text{-}F}$ = 33.1 Hz), 131.3, 130.5 (d, $J_{C\text{-}F}$ = 8.7 Hz), 130.2, 128.8 (d, $J_{C\text{-}F}$ = 66.7 Hz), 126.3, 123.3 (d, $J_{C\text{-}F}$ = 2.7 Hz), 123.2 (d, $J_{C\text{-}F}$ = 10.0 Hz), 122.3, 118.3, 116.9, 116.8, 115.9, 114.4 (d, $J_{C\text{-}F}$ = 21.9 Hz), 113.7 (d, $J_{C\text{-}F}$ = 21.1 Hz), 111.2, 48.7; ^{19}F{^{1}H} NMR (376 MHz, $CDCl_3$) *δ* −112.50; FT-IR (thin film, neat): 3058, 1612, 1583, 1367, 1256, 736, 630 cm^{-1}; HRMS (ESI): m/z calcd for $C_{27}H_{21}FN$ $[M+H]^+$: 378.1658; found : 378.1668.

*1-benzhydryl-3-(4-chlorophenyl)indolizine (**4e**):*

The reaction was performed at 0.0950 mmol scale of **1f**; R_f = 0.5 (5% EtOAc in hexane); pale yellow solid (23.3 mg, 62% yield); m. p. = 126 – 128 ºC; ^{1}H NMR (400 MHz, $CDCl_3$) *δ* 8.27 (d, *J* = 7.1 Hz, 1H), 7.53 (d, *J* = 7.6 Hz, 2H), 7.43 (t, *J* = 7.3 Hz, 2H), 7.32 – 7.26 (m, 4H), 7.24 – 7.22 (m, 4H), 7.17 (d, *J* = 7.7 Hz, 2H), 7.13 (d, *J* = 9.0 Hz, 1H), 6.58 (t, *J* = 7.4 Hz, 1H), 6.48 – 6.44 (m, 2H), 5.72 (s, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) *δ* 144.3, 143.4, 132.4, 132.0, 130.8, 130.5, 129.0, 128.5, 128.0, 127.1, 126.5, 124.6, 122.4, 118.0, 116.6, 115.9, 115.3, 110.9, 48.1; FT-IR (thin film, neat): 3060, 1494, 1309, 1204, 847, 739, 697 cm^{-1}; HRMS (ESI): m/z calcd for $C_{27}H_{21}ClN$ $[M+H]^+$: 394.1363; found : 394.1347.

*1-benzhydryl-3-[2-(trifluoromethyl)phenyl]indolizine (**4f**):*

The reaction was performed at 0.0859 mmol scale of **1g**; R_f = 0.6 (5% EtOAc in hexane); pale green gummy solid (20.6 mg, 56% yield); ^{1}H NMR (400 MHz, $CDCl_3$) *δ* 8.26 (d, *J* = 7.1 Hz, 1H), 7.62 – 7.58 (m, 3H), 7.53 – 7.47 (m, 3H), 7.46 – 7.39 (m, 2H), 7.34 – 7.31 (m, 2H), 7.28 (t, *J* = 7.4 Hz, 2H), 7.26 – 7.24 (m, 2H), 7.18 (d, *J* = 9.0 Hz, 1H), 6.66 (t, *J* = 7.6 Hz, 1H), 6.54 – 6.47 (m, 2H), 5.86 (s, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) *δ* 145.6, 132.5, 132.4 (q, $J_{C\text{-}F}$ = 2.9 Hz), 130.8, 130.5, 129.0, 128.8, 128.6 (q, $J_{C\text{-}F}$ = 276.4 Hz), 128.0, 127.2, 126.6, 126.4 (q, $J_{C\text{-}F}$ = 5.2 Hz), 124.8, 123.2, 122.4, 117.8, 116.8, 115.4, 111.0, 48.6; ^{19}F{^{1}H} NMR (376 MHz, $CDCl_3$) *δ* −60.13; FT-IR (thin film, neat): 2934, 1438, 1326, 1178, 866, 763 cm^{-1}; HRMS (ESI): m/z calcd for $C_{28}H_{21}F_3N$ $[M+H]^+$: 428.1626; found : 428.1642.

*1-benzhydryl-3-cyclohexylindolizine (**4g**):*

The reaction was performed at 0.1044 mmol scale of **1h**; R_f = 0.6 (5% EtOAc in hexane); pale green gummy solid (20.4 mg, 53% yield); ^{1}H NMR (400 MHz, $CDCl_3$) *δ* 7.76 (d, *J* = 6.6 Hz, 1H), 7.33 – 7.29 (m, 4H), 7.26 – 7.21 (m, 6H), 7.12 (d, *J* = 8.7 Hz, 1H), 6.52 – 6.45 (m, 2H), 6.27 (s, 1H), 5.77 (s, 1H), 2.84 – 2.80 (m, 1H), 2.09 (d, *J* = 9.6 Hz, 2H), 1.89 – 1.79 (m, 3H), 1.45 (q, *J* = 9.1 Hz, 4H) 1.35 – 1.30 (m, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) *δ* 145.2, 129.14, 129.10, 128.3 (2C), 126.1, 121.8, 118.0, 114.6, 114.5, 110.7, 109.8, 48.9, 35.4, 31.8, 26.7, 26.5; FT-IR (thin film, neat): 2953, 1656, 1494, 1256, 863, 724, cm^{-1}; HRMS (ESI): m/z calcd for $C_{27}H_{28}N$ $[M+H]^+$: 366.2222; found : 366.2234.

*1-[(4-ethoxyphenyl)(phenyl)methyl]-3-phenylindolizine (**4h**):*

The reaction was performed at 0.0922 mmol scale of **1i**; R_f = 0.4 (5% EtOAc in hexane); pale yellow gummy solid (26.5 mg, 71% yield); ^{1}H NMR (400 MHz, $CDCl_3$) *δ* 8.28 (d, *J* = 7.2 Hz, 1H), 7.56 – 7.53 (m, 2H), 7.44 (t, *J* = 7.5 Hz, 2H), 7.32 – 7.30 (m, 2H), 7.28 – 7.26 (m, 3H), 7.24 – 7.20 (m, 1H), 7.18 – 7.15 (m, 3H), 6.86 – 6.82 (m, 2H), 6.57 (ddd, *J* = 7.4, 6.4, 1.0 Hz, 1H), 6.53 (s, 1H), 6.45 (td, *J* = 7.3, 1.3 Hz, 1H), 5.72 (s, 1H), 4.02 (q, *J* = 7.0 Hz, 2H), 1.41 (t, *J* = 7.0 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) *δ* 157.4, 145.2, 136.8, 132.6, 130.8, 130.0, 129.1, 129.0, 128.4, 127.9, 126.9, 126.1, 124.4, 122.3, 118.2, 116.9, 116.3, 115.5, 114.3, 110.8, 63.5, 47.9, 15.1; FT-IR (thin film, neat): 2963, 1604, 1436, 1267, 754, 701 cm^{-1}; HRMS (ESI): m/z calcd for $C_{29}H_{26}NO$ $[M+H]^+$: 404.2014; found : 404.2027.

*1-[(9H-fluoren-2-yl)(phenyl)methyl]-3-phenylindolizine (**4i**):*

The reaction was performed at 0.0812 mmol scale of **1j**; R_f = 0.5 (5% EtOAc in hexane); pale yellow solid (23.4 mg, 64% yield); ^{1}H NMR (400 MHz, $CDCl_3$) *δ* 8.31 (d, *J* = 7.1 Hz, 1H), 7.77 (d, *J* = 7.5 Hz, 1H), 7.73 (d, *J* = 7.9 Hz, 1H); 7.57 (d, *J* = 7.6 Hz, 2H), 7.53 (d, *J* = 7.4 Hz, 1H); 7.46 – 7.43 (m, 3H), 7.37 (t, *J* = 7.4 Hz,1H), 7.35 – 7.26 (m, 8H), 7.21 (d, *J* = 9.1 Hz, 1H), 6.60 – 6.57 (m, 2H), 6.47 (t, *J* = 6.8 Hz,1H), 5.87 (s, 1H), 3.86 (s, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) *δ* 145.0, 143.7, 143.6, 143.5, 141.8, 140.0, 132.6, 130.9, 129.2, 129.0, 128.4, 127.9, 127.8, 127.0, 126.8, 126.5, 126.3, 125.7, 125.1, 124.5, 122.4, 119.8, 119.7, 118.2, 116.7, 116.4, 115.6, 110.8, 48.9, 37.1; FT-IR (thin film, neat): 2962, 1604, 1434, 1267, 846, 753, cm^{-1}; HRMS (ESI): m/z calcd for $C_{34}H_{26}N$ $[M+H]^+$: 448.2065; found : 448.2052.

*1-[(4-bromophenyl)(phenyl)methyl]-3-phenylindolizine (**4j**):*

The reaction was performed at 0.0833 mmol scale of **1k**; R_f = 0.5 (5% EtOAc in hexane); pale green gummy solid (22.7 mg, 62% yield); ^{1}H NMR (400 MHz, $CDCl_3$) *δ* 8.28 (d, *J* = 8.3 Hz, 1H), 7.54 (d, *J* = 7.7 Hz, 2H), 7.46 – 7.40 (m, 4H), 7.33 – 7.29 (m, 3H), 7.24 – 7.23 (m, 3H), 7.15 – 7.12 (m, 3H), 6.60 (t, *J* = 7.4 1H), 6.49 – 6.45 (m, 2H), 5.72 (s, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) *δ* 144.2, 143.9, 132.4, 131.5, 130.9, 130.8, 129.0 (2C), 128.5, 128.0, 127.1, 126.5, 124.6, 122.4, 120.1, 118.0, 116.7, 115.8, 115.3, 110.9, 48.2; FT-IR (thin film, neat): 3056, 1601, 1496, 1306, 737, 687 cm^{-1}; HRMS (ESI): m/z calcd for $C_{27}H_{21}BrN$ $[M+H]^+$: 438.0857; found : 438.0838.

*1-[naphthalen-1-yl(phenyl)methyl]-3-phenylindolizine (**4k**):*

The reaction was performed at 0.0905 mmol scale of **1l**; R_f = 0.5 (5% EtOAc in hexane); pale yellow gummy solid (20.5 mg, 55% yield); ^{1}H NMR (400 MHz, $CDCl_3$) *δ* 8.29 (d, *J* = 7.1 Hz, 1H), 7.82 – 7.80 (m, 1H), 7.78 – 7.72 (m, 2H), 7.64 (s, 1H), 7.55 – 7.53 (m, 2H), 7.44 – 7.40 (m, 5H), 7.31 – 7.29 (m, 5H), 7.25 (dd, *J* = 8.6, 4.2 Hz, 1H), 7.20 (d, *J* = 9.0 Hz, 1H), 6.58 – 6.54 (m, 2H), 6.46 (t, *J* = 7.0 Hz, 1H), 5.93 (s, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) *δ* 144.6, 142.4, 133.6, 132.5, 132.3, 130.9, 129.2, 129.0, 128.4, 128.05, 128.00, 127.96, 127.92, 127.7, 127.2, 127.0, 126.3, 126.0, 125.5, 124.5, 122.4, 118.2, 116.5, 116.2, 115.6, 110.8, 48.8; FT-IR (thin film, neat): 2923, 1600, 1487, 1336, 1254, 757, 687 cm^{-1}; HRMS (ESI): m/z calcd for $C_{31}H_{24}N$ $[M+H]^+$: 410.1909; found : 410.1917.

*1-[anthracen-9-yl(phenyl)methyl]-3-phenylindolizine (**4l**):*
The reaction was performed at 0.0786 mmol scale of ***1m***; R_f = 0.5 (5% EtOAc in hexane); pale yellow solid (19.0 mg, 52% yield); m. p. = 156 – 158 ºC; ^{1}H NMR (400 MHz, $CDCl_3$) *δ* 8.47 (s,1H), 8.37 (d, *J* = 8.9 Hz, 2H), 8.30 (d, *J* = 7.1 Hz, 1H); 8.03 (d, *J* = 8.4 Hz, 2H); 7.46 – 7.44 (m, 2H), 7.43 – 7.37 (m, 4H) 7.35 – 7.28 (m, 4H), 7.26 – 7.18 (m, 6H), 6.64 – 6.60 (m, 2H), 6.48 (t, *J* = 6.8 1H); ^{13}C NMR (100 MHz, $CDCl_3$) *δ* 145.1, 136.6, 132.5, 132.2, 131.5, 130.7, 129.3, 128.9, 128.4, 128.0, 127.5, 126.9, 125.8, 125.4, 124.8, 124.6, 122.5, 118.2, 116.7, 115.9, 114.5, 110.8, 41.9; FT-IR (thin film, neat): 3057, 1607, 1473, 1348, 1187, 863, 734 cm^{-1}; HRMS (ESI): m/z calcd for $C_{35}H_{26}N$ $[M+H]^+$: 460.2065; found : 460.2045.

*3-benzhydryl-1-phenylpyrrolo[1,2-a]quinoline (**4m**):*
The reaction was performed at 0.0905 mmol scale of **1n**; R_f = 0.5 (5% EtOAc in hexane); pale yellow solid (22.7 mg, 61% yield); ^{1}H NMR (400 MHz, $CDCl_3$) *δ* 7.58 (d, *J* = 7.7 Hz, 1H), 7.51 – 7.50 (m, 3H), 7.44 – 7.41 (m, 2H), 7.40 – 7.36 (m, 1H), 7.33 – 7.28 (m, 8H), 7.25 – 7.21 (m, 3H), 7.19 – 7.17 (m, 1H), 7.11 (t, *J* = 7.8 Hz, 1H), 6.92 (d, *J* =9.3, Hz, 1H); 6.38 (s, 1H), 5.80 (s, 1H); 13C NMR (100 MHz, $CDCl_3$) *δ* 144.7, 135.7, 134.4, 129.7, 129.4, 129.3, 129.2 (2C), 128.6, 128.5, 128.4, 127.6, 126.4, 126.3, 125.6, 123.4, 119.3, 118.7, 117.8, 117.6, 48.5; FT-IR (thin film, neat): 3059, 1599, 1448, 1327, 1257, 753 cm^{-1}; HRMS (ESI): m/z calcd for $C_{31}H_{24}N$ $[M+H]^+$: 410.1909; found : 410.1924.

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6. Notes

The authors declare no competing financial interest.

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