JOC The Journal of Organic Chemistry

Article

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Tandem Approach to Benzothieno- and Benzofuropyridines from *o*-Alkynyl Aldehydes via Silver-Catalyzed 6-*endo*-*dig* Ring Closure

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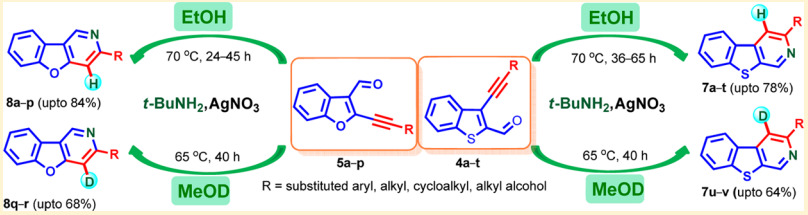
Supporting Information



ABSTRACT: An operationally simple silver-catalyzed tandem strategy for the synthesis of benzothienopyridines **7a−t** and benzofuropyridines **8a−p** by the reaction of *o*-alkynyl aldehyde **4a−t** and **5a−p** with *tert*-butylamine **6** under mild reaction conditions is described. The present methodology provides a facile conversion of easily accessible *o*-alkynyl aldehydes into medicinally useful heterocycles in good to excellent yields under mild and environmentally friendly reaction conditions with excellent regioselectivity. The developed chemistry has been successfully extended for the selective synthesis of C-4 deuterated benzothienopyridines **7u−v** and benzofuropyridines **8q−r**. The role of the ethanolic proton in the reaction was validated by deuterium-labeling experiments.

INTRODUCTION

Nitrogen- and sulfur-containing fused heterocycles are an important class of compounds because of their presence in a variety of pharmaceuticals, natural products, drug-like scaffolds, as well as organic materials.[1] Among them, the reduced and oxidized forms of benzothienopyridines exhibit a wide range of biological activities including as an appetite depressant (Figure 1, i)[2] and anticonflict activity (Figure 1, ii).[3] In recent years, benzothienopyridines have received considerable attention due to the development of D−π−*A* dye-sensitized solar cells (Figure 1, iii).[4] As a privileged fragment, the benzofuropyridine skeleton is another important heterocycle and displays wide application in pharmaceutical research. Their derivatives have shown topoisomerase inhibitor activity (Figure 1, iv),[5] analgesics,[6] antibacterial,[7,8b] anxiolytics (Figure 1, v),[8] Eg5 kinesin inhibitors,[9] and phosphodiesterase activity.[10] Apart from the significant biological activity, those compounds were identified as host materials for green and blue phosphorescent organic light emitting diodes (PHOLEDs).[11]

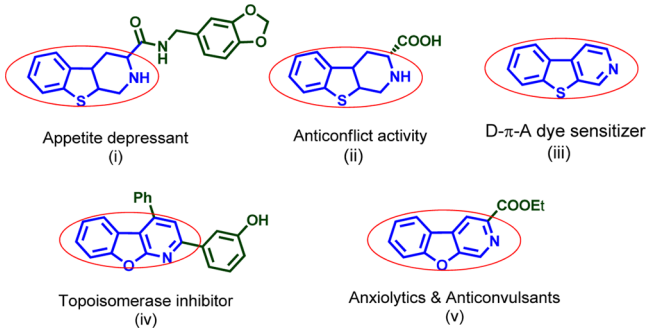


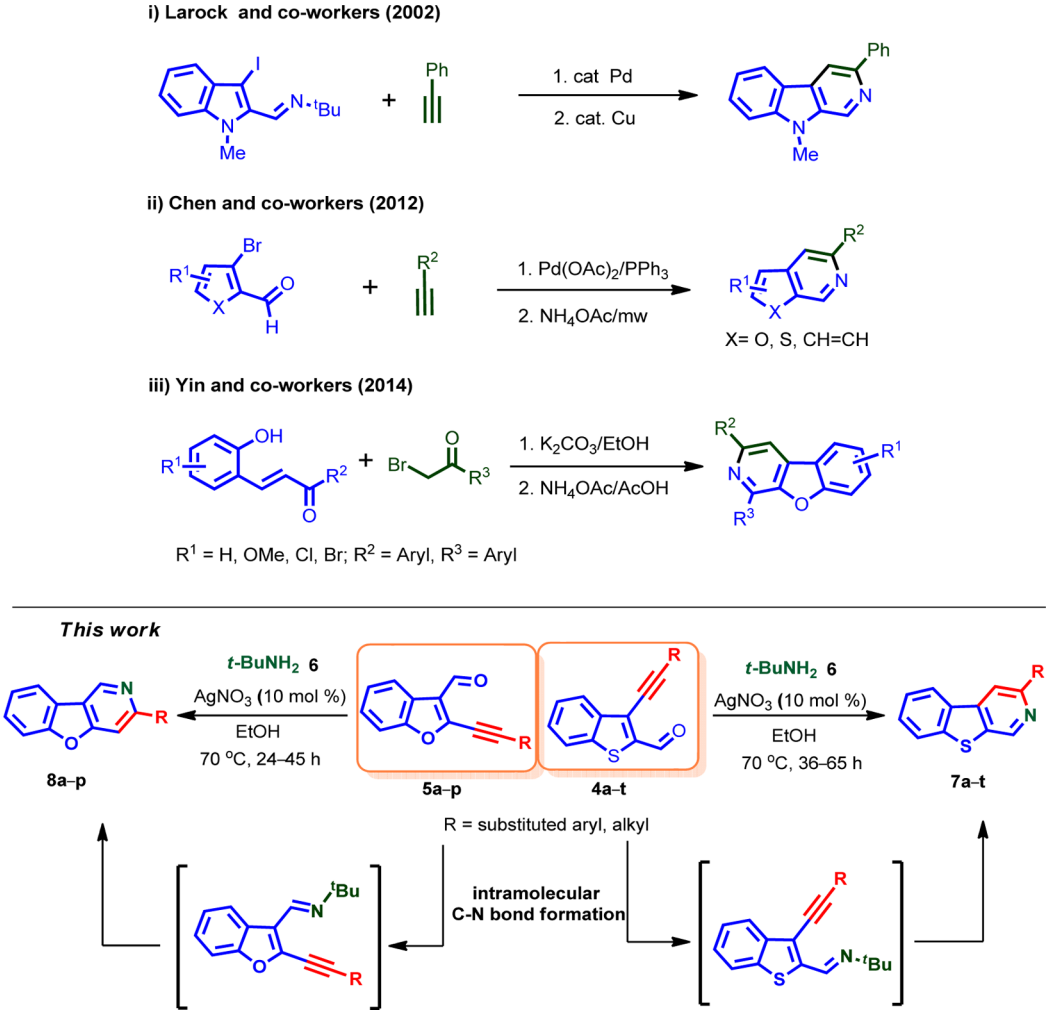
Figure 1. Significant examples of biologically active benzothienopyridine and benzofuropyridine cores.

Over the past few decades, transition-metal-catalyzed organic transformations using alkyne substrates have emerged as one of the most widely used protocols for the synthesis of a wide variety of heterocyclic/carbocyclic compounds and natural-product-like frameworks toward C−C and C−N bond formations[12] because of the exceptional ability of transition metals to trigger the π systems at low catalyst loading as well as tolerance toward various functional groups. Among them, silver-catalyzed[13] tandem cyclization[14,15] has gained considerable attention in the past decade because these reactions can

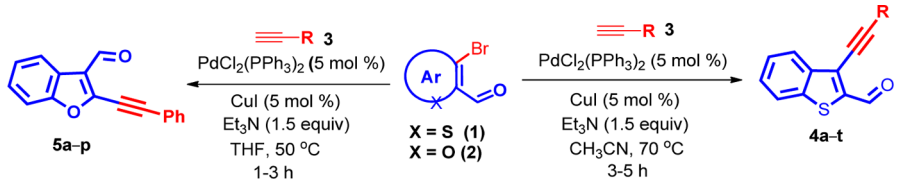
Received: July 16, 2015
Published: October 12, 2015

DOI: 10.1021/acs.joc.5b01647
J. Org. Chem. 2015, 80, 10548−10560

Scheme 1. Designed Tandem Approach for the Synthesis of Benzothienopyridines and Benzofuropyridines



Scheme 2. Synthesis of 3-Aryl/alkylethynyl-benzothiophene-2-carbaldehydes and 2-Aryl/alkylethynyl-benzofuran-3-carbaldehydes



quickly synthesize the complex molecules from simple starting materials.

Previously, tetrahydrobenzothieno[2,3-*c*]pyridines and dihydrobenzothieno[2,3-*c*]pyridines were synthesized using Pictet–Spengler[16] and Bischler–Napieralski reactions.[17] In 2002 Larock and co-workers[18] reported a well-designed synthesis of *β*-carbolines starting from 3-iodo-1-methyl-1*H*-indole-2-carbaldehyde via formation of imine intermediate followed by reaction with alkynes under palladium catalysis (Scheme 1, i). In 2012 Chen and co-workers[19] reported the palladium-catalyzed tandem synthesis of isoquinolines, thieno-pyridines, and furopyridines by the reaction of *o*-haloaldehydes with a variety of alkynes under microwave irradiation (Scheme 1, ii). Recently, Yin and co-workers[20] reported a metal-free approach for the synthesis of substituted benzofuropyridines by reaction of (*E*)-4-(2-hydroxyphenyl)but-3-en-2-ones with *α*-bromo ketones (Scheme 1, iii).

Application of tandem/domino/cascade reactions in the synthesis of heterocycles/carbocycles and natural-products-like scaffolds using *o*-alkynyl aldehydes or *o*-haloaldehydes has been highlighted recently. Larock,[21] Yamamoto,[22] Wu,[23] and others[24] have made significant contributions in this direction using alkyne substrate. In a continuation of our interest in the synthesis of heterocyclic scaffolds[25] using *o*-alkynylaldehydes, herein we report the synthesis of benzothienopyridines[26] and benzofuropyridines from their corresponding *o*-alkynylaldehyde in one-pot operation using environmentally friendly reaction conditions.

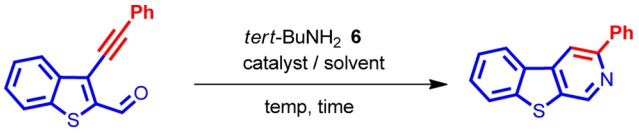
DOI: 10.1021/acs.joc.5b01647
J. Org. Chem. 2015, 80, 10548–10560

RESULTS AND DISCUSSION

Synthesis of 3-Aryl/alkylethynyl-benzothiophene-2-carbaldehydes and 2-Aryl/alkylethynyl-benzofuran-3-carbaldehydes. Starting substrates 3-aryl/alkylethynyl-benzothiophene-2-carbaldehydes **4a−t** and 2-aryl/alkylethynyl-benzofuran-3-carbaldehydes **5a−p** required for examining the scope and generality of this designed chemistry were readily prepared by the standard Sonogashira coupling of *o*-haloaldehydes **1** and **2** with commercially available terminal alkynes **3a−t** (Scheme 2).[27]

To identify the optimal reaction conditions, a variety of catalyst and solvents was examined in the reaction of 3-(phenylethynyl) benzo[*b*]thiophene-2-carbaldehyde **4a** with *tert*-butylamine **6**. Initially we carried out the reaction of **4a** (0.5 mmol) with 0.52 mmol of *tert*-butylamine **6** using 10 mol % AgOTf in 2.0 mL of dichloroethane at 25 °C for 12 h; the desired product **7a** was obtained in 5% yield (Table 1, entry 1).

Table 1. Optimization of the Reaction Conditions[a]



4a **7a**

entry	cat. (mol %)	solvent	temp (°C)	time (h)	yield (%)[b]
1	AgOTf/10	$C_2H_4Cl_2$	25	12	5
2	AgOTf/10	$C_2H_4Cl_2$	70	18	30
3	AgOTf/10	$C_2H_4Cl_2$	70	36	48
4	$AgNO_3$/10	$C_2H_4Cl_2$	70	36	55
5	$AgNO_3$/10	MeOH	65	36	60
6	$AgNO_3$/10	EtOH	70	36	72
7	$AgNO_3$/20	EtOH	70	36	65
8	$AgNO_3$/10	EtOH	70	24	60
9	$AgNO_3$/10	H_2O	70	24	30
10	$AgNO_3$/10	DMSO	100	36	35
11	$AuCl_3$/10	EtOH	70	36	53
12	AuCl/10	EtOH	70	36	60
13	Ag_2O/10	EtOH	70	36	35
14	$PdCl_2$/10	EtOH	70	36	28
15	$Cu(OTf)_2$/10	EtOH	70	36	20
16		EtOH	70	36	nr

[a]Reactions were performed using 0.5 mmol of **4a** and *tert*-butylamine **6** (0.52 mmol) and catalyst in 2.0 mL of solvent. [b]Isolated yield.

When increasing the reaction time from 12 to 18 h and the temperature from 25 to 70 °C, the desired product **7a** was obtained in higher yield (Table 1, entries 2 and 3). When $AgNO_3$ was used as catalyst, a significant improvement in the yield of the product **7a** was observed because silver has superior alkynophilicity due to π coordination with the carbon−carbon triple bond (entry 4).[28] Interesting use of MeOH as solvent provided the product **7a** selectively in 60% yield (entry 5). However, when reaction was performed using ecofriendly solvent EtOH at 70 °C for 36 h, the desired product **7a** was obtained in 72% yield (entry 6). No significant effect on the yield of product **7a** was observed by increasing the catalyst loading (entry 7). A decrease in the reaction time from 36 to 24 h gave the product **7a** in lower yield (entry 8). When the reactions were carried out in water and DMSO, the desired product **7a** was obtained in 30% and 35% yields, respectively (entries 9 and 10). Use of other catalyst $AuCl_3$, AuCl, Ag_2O, $PdCl_2$, and $Cu(OTf)_2$ was found to be inferior for the reaction (entries 11−15). However, when the reaction was performed in the absence of catalyst, we failed to obtain the desired product **7a** (entry 16).

Synthesis of Substituted Benzo[4,5]thieno[2,3-*c*]-pyridine. The scope and generality of the reaction was examined by employing a variety of *o*-alkynylbenzo[*b*]-thiophene-2-carbaldehydes **4a−t** with *tert*-butylamine **6** for the synthesis of a diverse library of 3-aryl/alkylbenzo[4,5]-thieno[2,3-*c*]pyridine **7a−t** (Table 2). The substrates **4b−g** bearing an electron-donating substituent such as Me, Et, *n*-Bu, *t*-Bu, OMe, and NMe_2 at para position to the triple bond of the phenyl ring showed the capability to trigger the 6-*endo-dig* cyclization[29] and provided the respective desired products **7a−g** in good yields. However, substrates **4h** and **4i** bearing an electron-releasing substituent on the ortho and meta position of the phenyl ring afforded the desired product **7h** and **7i** comparatively in similar yields. Substrate **4j** bearing an electron-rich heterocycle thiophene on reaction with amine **6** proved to be favorable for the reaction and afforded the desired product **7j** in 71% yield. Substrate **4k**, bearing an OCF_3 at the para position of the phenyl ring, provided the product **7k** in 69% yield. Reaction of substrate **4l** bearing two OMe groups at the 3 and 5 position of the phenyl ring provided the product **7l** in 68% yield. Exploring the reaction with substrate **4m** bearing an electron-withdrawing $-CF_3$ group at the para position of the phenyl ring retarded the reaction, and product **7m** was obtained in 65% yield after running the reaction for 55 h.

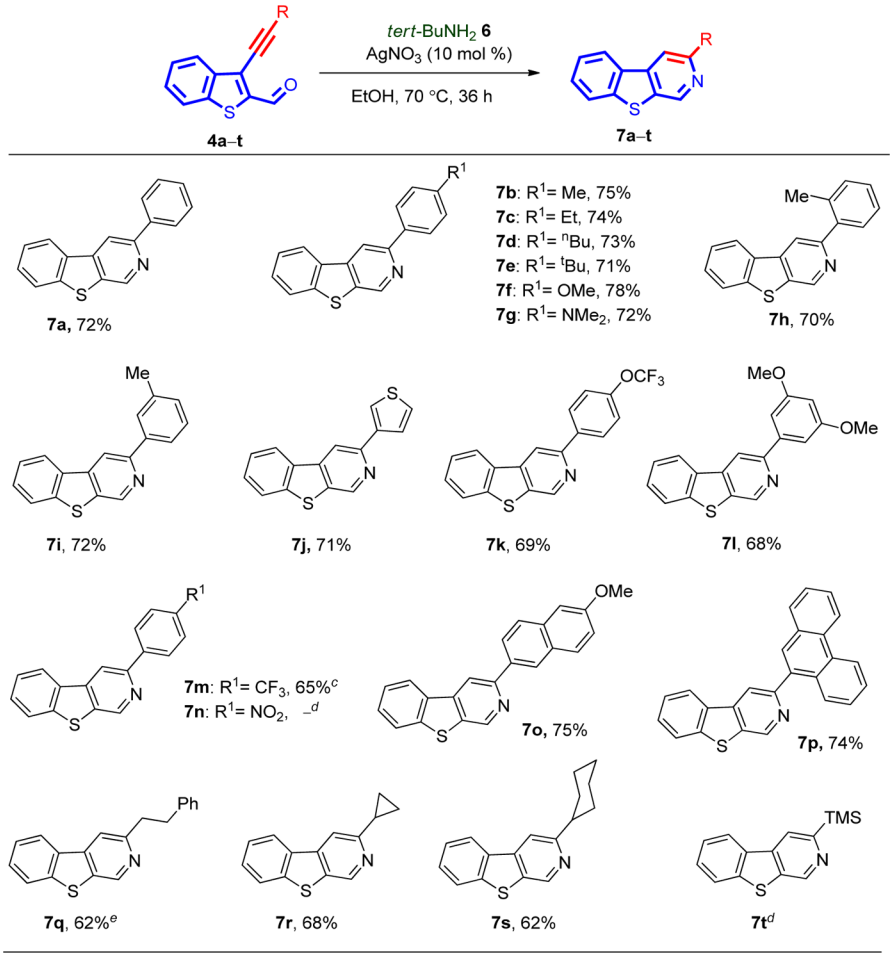
Further exploring the reaction of 3-((4-nitrophenyl)ethynyl)-benzo[*b*]thiophene-2-carbaldehyde (**4n**), bearing a strong electron-withdrawing nitro group at the para position of the phenyl ring attached to alkyne, fails to afford the desired product **7n**. *o*-Alkynylaldehydes **4o** and **4p** bearing −OMe-substituted naphthyl and phenanthrene groups, respectively on the alkyne fruitfully provided the desired products **7o** and **7p** in 75% and 74% yields, respectively. After obtaining successful results with aromatic alkynes we further explored the developed protocol with aliphatic alkynes **4q−s**; the reaction proceeded well and provided the desire products **7q−s** in moderate to good yields; however, an inseparable complex mixture was obtained when TMS-substituted alkyne **4t** was reacted with *tert*-butylamine **6**. All synthesized products were fully characterized by ^{1}H NMR, ^{13}C NMR, HRMS, and finally X-ray crystallographic studies of compound **7i**.[30]

Synthesis of Substituted Benzofuro[3,2-*c*]pyridines. The benzofuropyridine nucleus represents an important class of heterocyclic compounds which shows a wide range of significant biological and pharmaceutical properties.[31] After successful synthesis of a variety of medicinally useful benzothienopyridines and to gain further insight into the reaction, we continued our study by examining various oxygen-containing substrates **5a−p** with *tert*-butylamine **6**, which furnished differently substituted benzofuro[3,2-*c*]pyridines **8a−p** (Table 3). We observed that reaction of alkynes **5a−p** with *tert*-butylamine **6** provided the desired products **8a−p** in good yield and less reaction time (36 vs 24 h) in comparison to benzothienopyridines **7a−t** (compare Table 2 vs Table 3).

Reaction of *o*-alkynylaldehydes **5a** with *tert*-butylamine **6** using optimized reaction conditions provided the desired product **8a** in 74% yield in 24 h (Table 3). *o*-Alkynylaldehydes **5b−g** bearing an electron-releasing substituent on the phenyl ring attached to the alkyne provided the respective desired

DOI: 10.1021/acs.joc.5b01647
J. Org. Chem. 2015, 80, 10548−10560

Table 2. Silver-Catalyzed Tandem Synthesis of Benzothienopyridines[a]



[a]Reactions were performed using 0.5 mmol of *o*-alkynylaldehydes **4a–t**, *tert*-butylamine **6** (0.52 mmol), and $AgNO_3$ (10 mol %) in 2.0 mL of EtOH at 70 °C for 36 h. [b]Isolated yield. [c]Time = 55 h. [d]Inseparable complex mixtures. [e]Time = 65 h.

products **8b–g** in good to excellent yields. For substrate **5h** bearing a strong electron-donating group such as the thienyl group as R, the reaction proceeded well and afforded the product **8h** in 81% yield; however, reaction of **5i** with an OCF_3 group at the para position of the phenyl ring provided the product **8i** in 74% yield. Reaction of *o*-alkynylaldehyde **5j–k** with an electron-withdrawing group (*m*-OMe and 3,5 di-OMe) on the phenyl ring afforded the desired products **8j–k** in 72% and 70% yields, respectively. Substrate **5l** with a phenoxymethyl group successfully provided the desired product **8l** in 64% yield; however, alkyl-substituted *o*-alkynylaldehydes **5m** and **5n** gave the desired products **8m** and **8n** in 62% and 66% yields, respectively, after running the reaction for 45 h. TMS-substituted alkyne **5o** failed to provide the desired product **8o**. When we carried out the reaction of 2-(6-hydroxyhex-1-yn-1-yl)benzofuran-3-carbaldehyde **5p** with *tert*-butylamine **6** the desired product **8p** was obtained in 55% yield (Table 3).

Encouraged by the above results, we explored the reaction with the regioisomer of *o*-alkynylaldehydes; the tandem cyclization of 3-ethynylbenzofuran-2-carbaldehyde **5q** and **5r** with *tert*-butylamine **6** provided the fused products 3-arylbenzofuro [2,3-*c*]pyridine **9a** and **9b** in 75% and 80% yields, respectively (Scheme 3).

Competitive Study. In order to understand the regio- and chemoselectivity of the reaction, we designed two sets of experiments (Scheme 4). In the first set of experiments we performed a comparison of the reactivity between two nucleophiles (amine vs alcohol). We carried out the reaction of substrate **5a** with *tert*-butylamine (**6**) and *tert*-butanol (**10**) in DCE at 70 °C for 24 h; product **8a** was obtained in 70% yield; however, 1-(*tert*-butoxy)-3-phenyl-1*H*-pyrano[4,3-*b*]-benzofuran (**11**) was not obtained. The possible reason for the formation of product **8a** over product **11** could be due to preferential formation of imine intermediate **Y** over hemiacetal intermediate **Z** (Scheme 4, i).[32]

It is apparent that products **7a–t** synthesized from substrate **4a–t** required a longer reaction time in comparison to products **8a–p/9a–b** synthesized from substrate **5a–r**. To validate the reactivity behavior of the substrates, we performed a control experiment. We carried out reaction between substrates **4a** (1.0 equiv) and **5q** (1.0 equiv) with *tert*-butylamine (1.2 equiv) using optimized reaction conditions for 36 h (Scheme 4, ii). These results show that the benzofuropyridine **9a** was obtained in 70% yield; however, product **7a** was observed in a trace amount. This result indicates that substrate benzofuran-2-carbaldehyde (**5q**) is more reactive in comparison to substrate benzothiophene-2-carbaldehyde (**4a**). The above observation could be explained on the basis of the reactivity behavior of *o*-alkynylaldehydes. In the case of 3-(arylethynyl)benzo[*b*]-thiophene-2-carbaldehydes (**4**), the presence of an electron-rich thiophene ring system (+R effect)[25c] decreases the reactivity of the aldehydic group as well as intramolecular

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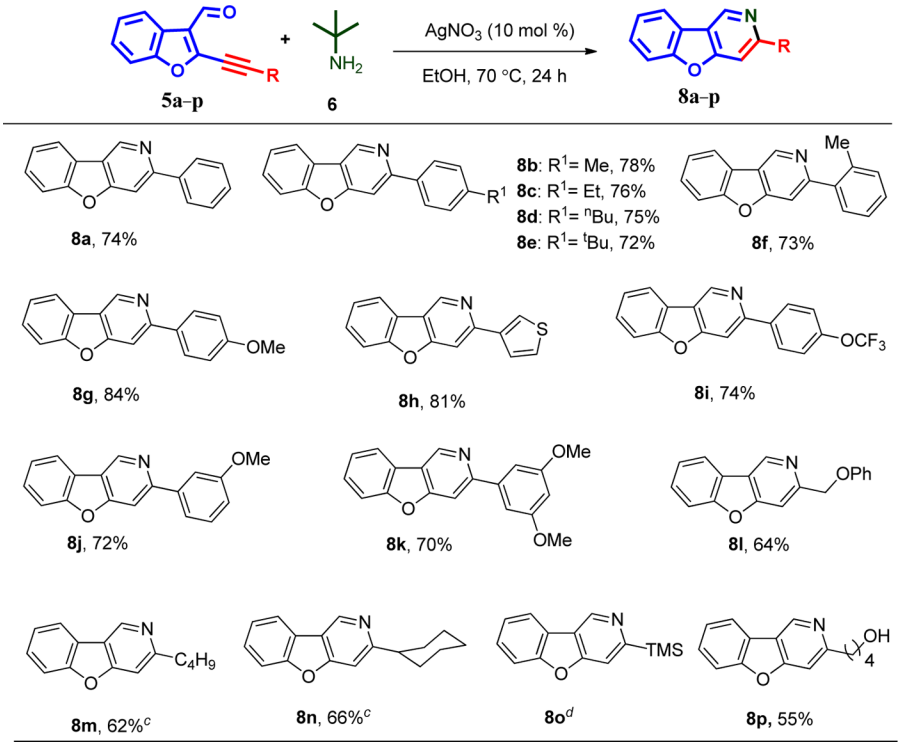
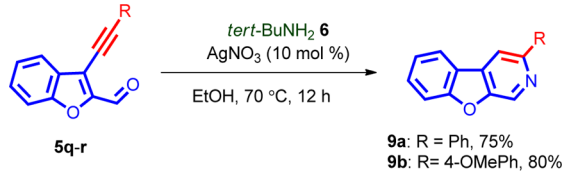
Table 3. Silver-Catalyzed Tandem Synthesis of Benzofuropyridines[a]



[a]Reactions were performed using 0.5 mmol of *o*-alkynylaldehydes **5a–p**, amine **6** (0.52 mmol), and $AgNO_3$ (10 mol %) in 2.0 mL of EtOH at 70 °C for 24 h. [b]Isolated yield. [c]Time = 45 h. [d]Inseparable complex mixtures.

Scheme 3. Silver-Catalyzed Tandem Synthesis of Benzofuropyridines[a]



attack of imine on alkyne, whereas in case of 3-(arylethynyl)-benzofuran-2-carbaldehydes (**5**) the presence of a comparatively less electron-rich furan ring system (due to the −I effect) increases the relative reactivity of the aldehydic group of **5**, which facilitates formation of the key intermediate imine (Scheme 4, ii). The reaction of 2-(phenylethynyl)benzofuran-3-carbaldehyde (**5a**, 1.0 equiv) and 3- phenylethynyl)benzofuran-2-carbaldehyde (**5q**, 1.0 equiv) with *tert*-butylamine (1.2 equiv) using optimized reaction conditions for 24 h provided the fused product **9a** in 65% yield; however, the product **8a** was obtained in only 10% yield. The higher reactivity of substrate **5q** over **5a** is due to the −I effect of the oxygen (Scheme 4, iii).

Synthesis of Deuterated Compounds. In recent years synthesis of deuterated compounds and deuterated drugs has gained significant attention in the pharmaceutical industry because of the medicinal value and their application in the study of metabolism of drugs and toxic substances in the animals.[33] To further extend the scope of the developed chemistry, we synthesized deuterated benzothienopyridine **7u** and **7v** and benzofuropyridine **8q–r** from respective starting substrates in moderate to good yields using MeOD as solvent as well as a source of deuterium under silver catalysis (Scheme 5). This study also supports our proposed mechanism and role of ethanol as a solvent in the reaction.

On the basis of the above control experiments, a plausible mechanism for the formation of products **7a–v** and **8a–r** is described in Scheme 6. The reaction of *o*-alkynyl aldehyde **4** and **5** with *tert*-butylamine **6** will form imine intermediates **P** and **P′**. Under silver catalysis intramolecular attack of imine nitrogen on alkyne will generate quinolinium intermediate **Q** and **Q′**. Subsequently, deuteration/protonation (from MeOD or ethanol) followed by elimination of isobutylene[34] with the help of methoxide ion will result in the formation of products **7** and **8** via formation of intermediate **R, R′** and **S, S′**.

CONCLUSION

In conclusion, we developed a versatile and environmentally benign tandem protocol which provided a broad range of functionalized benzothienopyridines and benzofuropyridines in good to excellent yield from easily accessible starting substrates with excellent regioselectivity. This developed chemistry has been successfully extended for the selective synthesis of C-4 deuterated benzothienopyridines and benzofuropyridines. Selective formation of C-4 deuterated products further supports the proposed mechanism as well as the role of alcohol (solvent) in the reaction. Alkynes bearing electron-releasing, electron-withdrawing, alkyl, acyl, and thienyl groups successfully provided the desired products in good yields. Substrates 2-(phenylethynyl)benzofuran-3-carbaldehydes **5a–p** were found to be more reactive in comparison to 3-(phenylethynyl)benzo-[*b*]thiophene-2-carbaldehydes **4a–t**, as validated by the control experiments. Developed tandem approach is general and operationally simple and expands the synthetic utility of *o*-alkynyl aldehydes for the synthesis of a variety of

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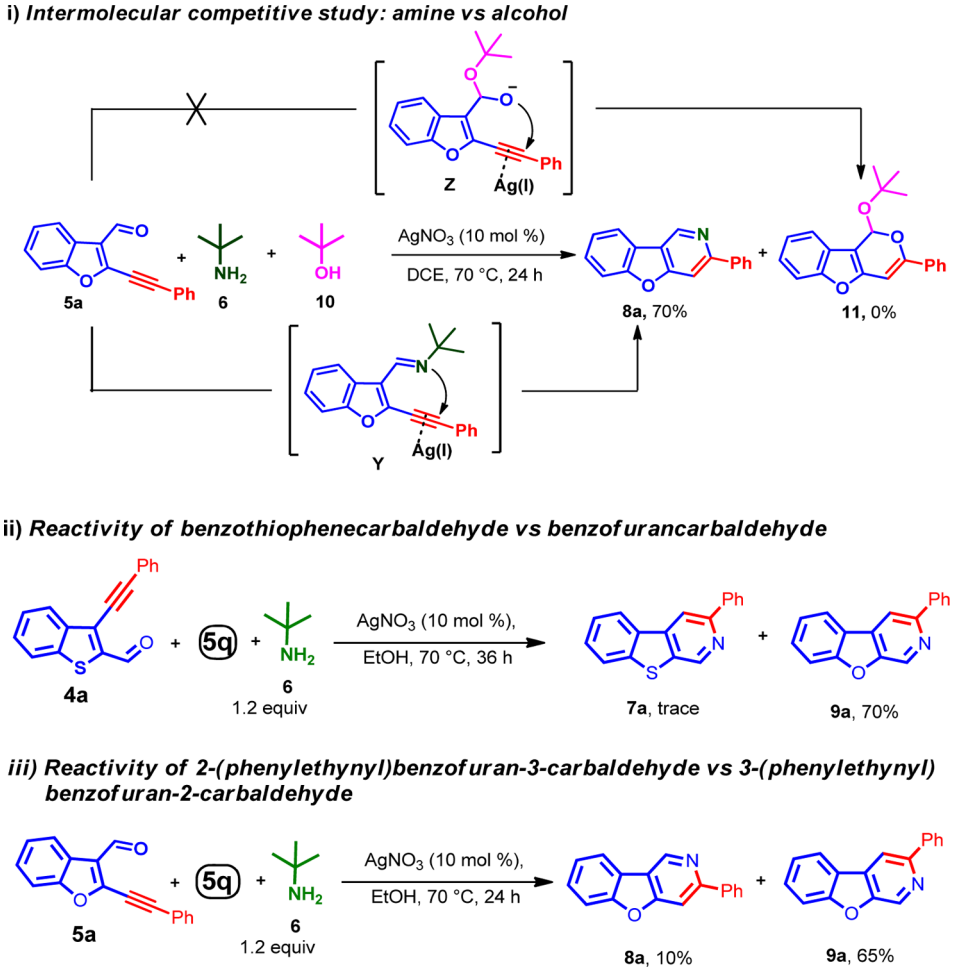
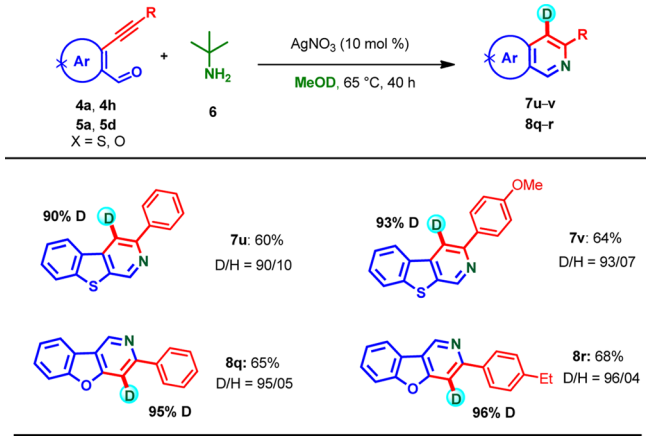
Scheme 4. Competitive Study



Scheme 5. Synthesis of C-4 Deuterated Benzothieno- and Benzofuropyridines



benzothienopyridines and benzofuropyridines which are of great importance in medicinal chemistry.

EXPERIMENTAL SECTION

General Information and Method. Nuclear magnetic resonance spectra were recorded in $CDCl_3$, ^1H NMR (400 MHz) and ^{13}C NMR (100 MHz), at ambient temperature. Chemical shifts (δ) for all protons are reported in parts per million (ppm) and were measured relative to the residual $CHCl_3$ resonance as an internal reference in the deuterated solvent. Chemical shifts were reported as parts per million (δ in ppm) using tetramethylsilane (TMS) as internal standard or by reference to proton resonances resulting from incomplete deuteration of the NMR solvent. The following abbreviations were used to describe the multiplicities: when appropriate s = singlet, d = doublet, t = triplet, q = quartet, m = multiplet, dd = doublet of doublet. Reactions were monitored using thin-layer chromatography on commercially prepared silica gel plates and visualized by either UV irradiation or by staining with I_2. Chemical yields are referred to the pure isolated substances. Chromatographic purification of the label compounds was accomplished by column chromatography using 100–200 mesh size silica gels.

General Procedure for the Synthesis of Starting Materials 4 and 5. The starting materials **4** and **5** were prepared by the Sonogashira coupling reaction[27] of corresponding 2-bromobenzofurancarbaldehyde and bromobenzothiophenecarbaldehyde with terminal alkynes using the reported procedure and confirmed by comparison of its physical and spectral data (^1H NMR, ^{13}C NMR, and HRMS), and infrared spectra were recorded on a FTIR spectrophotometer. The structure and purity of known starting materials **4a**, **4b**, **4e**, **4f**, **4j**, **4m**, **4s**, **4t**, and **5a** were confirmed by comparison of their physical and spectral data (^1H NMR and ^{13}C NMR) with those reported in the literature.[35]

*3-((4-Ethylphenyl)ethynyl)benzo[b]thiophene-2-carbaldehyde (**4c**).* The product was obtained as yellow needles (223.5 mg, 77%): mp 116–118 °C; ^1H NMR (400 MHz, $CDCl_3$) δ 10.39 (s, 1H), 8.07 (d, J = 8.4 Hz, 1H), 7.80 (d, J = 7.6 Hz, 1H), 7.50–7.42 (m, 4H), 7.18 (d, J = 7.6 Hz, 2H), 2.63 (q, J = 7.6 Hz, 2H), 1.99 (t, J = 7.6 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 184.6, 146.2, 143.1, 141.0, 139.4, 132.0, 128.8, 128.2, 125.5, 125.1, 123.3, 119.0, 99.4, 80.0, 28.9, 15.3;

DOI: 10.1021/acs.joc.5b01647
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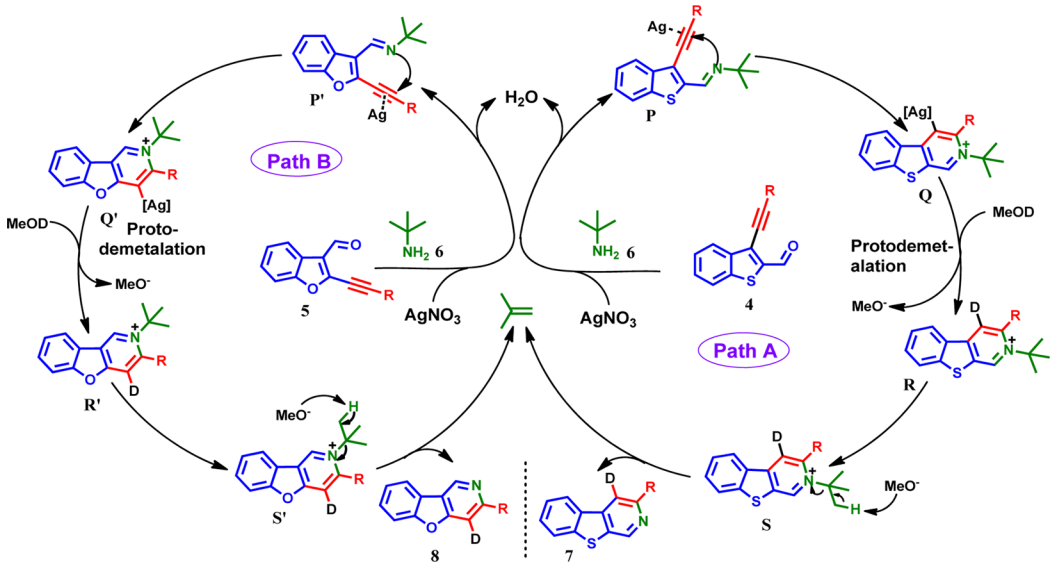
Scheme 6. Plausible Mechanism



FTIR (Zn−Se ATR, cm^{-1}) 2961, 2919, 2193, 1663, 833; HRMS (ESI) calcd for $[C_{19}H_{14}OS]$ requires $[M + H]^+$ 291.0844, found 291.0861.

3-((4-Butylphenyl)ethynyl)benzo[b]thiophene-2-carbaldehyde ***(4d)***. The product was obtained as a brown oil (238.8 mg, 75%); ^1H NMR (400 MHz, $CDCl_3$) δ 10.38 (s, 1H), 8.08−8.06 (m, 1H), 7.81−7.78 (m, 1H), 7.49−7.41 (m, 4H), 7.17−7.15 (m, 2H), 2.58 (t, J = 7.7 Hz, 2H), 1.58−1.51 (m, 2H), 1.34−1.25 (m, 2H), 0.86 (t, J = 7.4 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 184.6, 145.0, 143.0, 141.0, 139.4, 131.90, 131.87, 128.79, 128.76, 128.1, 125.5, 125.1, 123.3, 118.9, 99.5, 80.0, 35.7, 33.3, 22.3, 13.9; FTIR (Zn−Se ATR, cm^{-1}) 2955, 2861, 2202, 1668, 838; HRMS (ESI) calcd for $[C_{21}H_{18}OS]$ requires $[M]^+$ 318.1078, found $[M]^+$ 318.1078.

3-((4-(Dimethylamino)phenyl)ethynyl)benzo[b]thiophene-2-carbaldehyde ***(4g)***. The product was obtained as a pale yellow needles (250.1 mg, 82%): mp 126−130 °C; ^1H NMR (400 MHz, $CDCl_3$) δ 10.36 (s, 1H), 8.06 (d, J = 7.6 Hz, 1H), 7.76 (d, J = 7.7 Hz, 1H), 7.46−7.37 (m, 4H), 6.60 (d, J = 8.40 Hz, 2H), 2.94 (s, 6H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 184.7, 150.8, 141.6, 141.1, 139.4, 133.3, 129.2, 128.7, 125.3, 125.1, 123.2, 111.7, 108.0, 101.4, 79.4, 40.1; FTIR (Zn−Se ATR, cm^{-1}) 2923, 2852, 2193, 1655, 1267, 816; HRMS (ESI) calcd for $[C_{19}H_{15}NOS]$ requires $[M]^+$ 305.0874, found 305.0875.

3-(o-Tolylethynyl)benzo[b]thiophene-2-carbaldehyde ***(4h)***. The product was obtained as yellow needles (210.0 mg, 76%): mp 128−134 °C; ^1H NMR (400 MHz, $CDCl_3$) δ 10.38 (s, 1H), 8.05 (d, J = 7.6 Hz, 1H), 7.78 (d, J = 7.6 Hz, 1H), 7.52 (d, J = 7.6 Hz, 1H), 7.48−7.41 (m, 2H), 7.26−7.20 (m, 2H), 7.17−7.13 (m, 1H), 2.51 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 184.4, 143.1, 141.0, 140.5, 139.3, 132.4, 129.8, 129.6, 128.8, 128.0, 125.9, 125.6, 124.9, 123.3, 121.7, 98.0, 84.3, 21.0; FTIR (Zn−Se ATR, cm^{-1}) 2923, 2844, 2189, 1655; HRMS (ESI) calcd for $[C_{18}H_{12}OS]$ requires $[M]^+$ 276.0609, found 276.0609.

3-(m-Tolylethynyl)benzo[b]thiophene-2-carbaldehyde ***(4i)***. The product was obtained as yellow needles (201.7 mg, 73%): mp 121−128 °C; ^1H NMR (400 MHz, $CDCl_3$) δ 10.34 (s, 1H), 8.05−8.03 (m, 1H), 7.77−7.75 (m, 1H), 7.46−7.40 (m, 2H), 7.38−7.34 (m, 2H), 7.21 (t, J = 7.3 Hz, 1H), 7.15−7.13 (m, 1H), 2.30 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 184.4, 143.1, 140.9, 139.3, 138.3, 132.4, 130.4, 129.0, 128.8, 128.4, 127.8, 125.5, 124.9, 123.2, 121.6, 99.3, 80.1, 21.2; FTIR (Zn−Se ATR, cm^{-1}) 2921, 2854, 2199, 1666, 688, 801; HRMS (ESI) calcd for $[C_{18}H_{12}OS]$ requires $[M]^+$ 276.0609, found $[M]^+$ 276.0608.

3-((4-(Trifluoromethoxy)phenyl)ethynyl)benzo[b]thiophene-2-carbaldehyde ***(4k)***. The product was obtained as yellow needles (245.8 mg, 71%): mp 90−94 °C; ^1H NMR (400 MHz, $CDCl_3$) δ 10.37 (s, 1H), 8.06 (d, J = 7.3 Hz, 1H), 7.82 (d, J = 7.3 Hz, 1H), 7.60 (d, J = 8.8 Hz, 2H), 7.52−7.44 (m, 2H), 7.21−7.18 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 184.2, 149.8, 143.8, 141.0, 139.3, 133.5, 128.9, 127.1, 125.7, 124.9, 123.4, 121.1, 120.6, 119.0, 97.3, 81.3; FTIR (Zn−Se ATR, cm^{-1}) 2923, 2202, 1663, 1200, 854; HRMS (ESI) calcd for $[C_{18}H_9F_3O_2S]$ requires $[M + Na]^+$ 369.0173, found 369.0166.

3-((3,5-Dimethoxyphenyl)ethynyl)benzo[b]thiophene-2-carbaldehyde ***(4l)***. The product was obtained as yellow needles (238.5 mg, 74%): mp 140−144 °C; ^1H NMR (400 MHz, $CDCl_3$) δ 10.38 (s, 1H), 8.08−8.06 (m, 1H), 7.80 (d, J = 7.3 Hz, 1H), 7.50−7.42 (m, 2H), 6.70 (d, J = 2.4 Hz, 2H), 6.4 (t, J = 2.4 Hz, 1H), 3.76 (s, 6H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 184.5, 160.7, 143.5, 141.0, 139.3, 128.8, 127.6, 125.6, 125.0, 123.3, 123.0, 109.6, 102.8, 99.0, 80.0, 55.5; FTIR (Zn−Se ATR, cm^{-1}) 2961, 2919, 2210, 1663, 1259, 796, 758; HRMS (ESI) calcd for $[C_{19}H_{14}O_3S]$ requires $[M]^+$ 322.0664, found 322.0664.

3-((4-Nitrophenyl)ethynyl)benzo[b]thiophene-2-carbaldehyde ***(4n)***. The product was obtained as brown needles (208.9 mg, 68%): mp 116−118 °C; ^1H NMR (400 MHz, $CDCl_3$) δ 10.39 (s, 1H), 8.25−8.22 (m, 2H), 8.07 (d, J = 7.3 Hz, 1H), 7.85 (d, J = 8.0 Hz, 1H), 7.74−7.71 (m, 2H), 7.54−7.47 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 183.9, 147.7, 144.7, 141.0, 139.1, 133.4, 132.7, 129.1, 128.6, 125.9, 124.8, 123.9, 123.7, 123.4, 96.3, 85.1; FTIR (Zn−Se ATR, cm^{-1}) 2933, 2333, 1694, 1510, 1310; HRMS (ESI) calcd for $[C_{17}H_9NO_3S]$ requires $[M]^+$ 307.0303, found 307.0301.

3-((6-Methoxynaphthalen-2-yl)ethynyl)benzo[b]thiophene-2-carbaldehyde ***(4o)***. The product was obtained as yellow needles (273.6 mg, 80%): mp 150−154 °C; ^1H NMR (400 MHz, $CDCl_3$) δ 10.44 (s, 1H), 8.15−8.12 (m, 1H), 8.03 (s, 1H), 7.83−7.81 (m, 1H), 7.69 (d, J = 8.7 Hz, 2H), 7.56−7.54 (m, 1H), 7.50−7.46 (m, 2H), 7.14−7.12 (m, 1H), 7.08−7.07 (m, 1H), 3.87 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 184.6, 158.9, 143.1, 141.1, 139.4, 134.8, 132.2, 129.5, 128.8, 128.7, 128.4, 128.1, 127.2, 125.6, 125.1, 123.3, 119.8, 116.6, 105.9, 99.9, 80.3, 55.4; FTIR (Zn−Se ATR, cm^{-1}) 2961, 2923, 2193,1655, 1263; HRMS (ESI) calcd for $[C_{22}H_{14}O_2S]$ requires $[M]^+$ 342.0715, found 342.0715.

3-(Phenanthren-9-ylethynyl)benzo[b]thiophene-2-carbaldehyde ***(4p)***. The product was obtained as yellow needles (311.7 mg, 86%): mp 170−174 °C; ^1H NMR (400 MHz, $CDCl_3$) δ 10.53 (s, 1H), 8.65−8.62 (m, 1H), 8.61−8.58 (m, 1H), 8.43−8.41 (m, 1H), 8.21−8.19 (m, 1H), 8.11 (s, 1H), 7.84−7.81 (m, 2H), 7.69−7.65 (m, 2H), 7.63−7.61 (m, 1H), 7.57−7.53 (m, 1H), 7.51−7.47 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 184.4, 143.5, 141.1, 139.4, 133.4, 130.9, 130.7, 130.6, 130.1, 128.9, 128.8, 128.2, 127.7, 127.43, 127.41, 127.2, 126.5, 125.8, 125.1, 123.4, 123.0, 122.7, 118.3, 97.5, 84.8; FTIR (Zn−Se ATR, cm^{-1}) 2923, 2197, 1668; HRMS (ESI) calcd for $[C_{25}H_{14}OS]$ requires $[M]^+$ 362.0765, found 362.0765.

3-(4-Phenylbut-1-yn-1-yl)benzo[b]thiophene-2-carbaldehyde ***(4q)***. The product was obtained as a pale yellow oil (216.3 mg, 74%); ^1H NMR (400 MHz, $CDCl_3$) δ 10.08 (s, 1H), 7.78−7.72 (m, 2H),

DOI: 10.1021/acs.joc.5b01647
J. Org. Chem. 2015, 80, 10548−10560

7.41 (t, J = 8.0 Hz, 1H), 7.34 (t, J = 6.6 Hz, 1H), 7.29−7.18 (m, 5H), 2.94 (t, J = 8.08 Hz, 2H), 2.83 (t, J = 7.3 Hz, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 184.8, 143.3, 141.0, 139.9, 139.7, 128.6, 128.5, 126.6, 125.3, 125.1, 123.1, 99.9, 73.1, 34.6, 21.9; FTIR (Zn−Se ATR, cm^{-1}) 2923, 2852, 2222, 1655; HRMS (ESI) calcd for $[C_{19}H_{14}OS]$ requires $[M]^+$ 290.0765, found 290.0765.

3-(Cyclopropylethynyl)benzo[b]thiophene-2-carbaldehyde (**4r**). The product was obtained as yellow needles (162.9 mg, 72%): mp 117−121 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 10.22 (s, 1H), 7.93 (d, J = 7.3 Hz, 1H), 7.75 (d, J = 8.8 Hz, 1H), 7.45−7.36 (m, 2H), 1.57−1.51 (m, 1H), 0.98−0.92 (m, 2H), 0.90−0.85 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 184.7, 143.1, 141.0, 139.7, 128.9, 128.6, 125.3, 125.0, 123.1, 104.5, 67.3, 9.4, 0.6; FTIR (Zn−Se ATR, cm^{-1}) 2923, 2852, 2218, 1655; HRMS (ESI) calcd for $[C_{14}H_{10}OS]$ requires $[M + H]^+$ 227.0531, found 227.0550.

2-(p-Tolylethynyl)benzofuran-3-carbaldehyde (**5b**). The product was obtained as light brown needles (226.4 mg, 87%): mp 84−88 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 10.34 (s, 1H), 8.18 (d, J = 6.8 Hz, 1H), 7.54−7.49 (m, 3H), 7.44−7.36 (m, 2H), 7.23 (d, J = 7.6 Hz, 2H), 2.40 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 185.6, 154.6, 148.3, 141.0, 132.0, 129.5, 127.0, 125.1, 123.5, 123.4, 122.4, 117.3, 111.2, 101.4, 21.7; FTIR (Zn−Se ATR, cm^{-1}) 2919, 2827, 2202, 1672, 808; HRMS (ESI) calcd for $[C_{18}H_{12}O_2]$ requires $[M + H]^+$ 261.0916, found 261.0932.

2-((4-Ethylphenyl)ethynyl)benzofuran-3-carbaldehyde (**5c**). The product was obtained as yellow needles (235.9 mg, 86%): mp 74−78 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 10.24 (s, 1H), 8.08 (d, J = 6.8 Hz, 1H), 7.46 (d, J = 7.6 Hz, 2H), 7.41−7.39 (m, 1H), 7.35−7.27 (m, 2H), 7.16 (d, J = 7.6 Hz, 2H), 2.60 (q, J = 7.6 Hz, 2H), 1.16 (t, J = 7.64 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 185.5, 154.5, 148.3, 147.2, 132.1, 128.3, 127.0, 125.1, 123.5, 123.4, 122.4, 117.5, 111.2, 101.4, 28.9, 15.2; FTIR (Zn−Se ATR, cm^{-1}) 2961, 2916, 2197, 1676, 837; HRMS (ESI) calcd for $[C_{19}H_{14}O_2]$ requires $[M + H]^+$ 275.1072, found 275.1098.

2-((4-Butylphenyl)ethynyl)benzofuran-3-carbaldehyde (**5d**). The product was obtained as a yellow oil (266.0 mg, 88%); ^{1}H NMR (400 MHz, $CDCl_3$) δ 10.27 (s, 1H), 8.10 (d, J = 7.6 Hz, 1H), 7.47 (d, J = 7.6 Hz, 2H), 7.42 (d, J = 8.4 Hz, 1H), 7.39−7.29 (m, 2H), 7.16 (d, J = 7.6 Hz, 2H), 2.58 (t, J = 7.6 Hz, 2H), 1.58−1.50 (m, 2H), 1.33−1.24 (m, 2H), 0.86 (t, J = 6.9 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 185.6, 154.6, 148.3, 146.0, 132.1, 128.8, 127.0, 125.1, 123.5, 123.4, 122.4, 117.5, 111.2, 101.5, 35.7, 33.2, 22.3, 13.9; FTIR (Zn−Se ATR, cm^{-1}) 2961, 2932, 2206, 1672, 846; HRMS (ESI) calcd for $[C_{21}H_{18}O_2]$ requires $[M + H]^+$ 303.1385, found 303.1405.

2-((4-(tert-Butyl)phenyl)ethynyl)benzofuran-3-carbaldehyde (**5e**). The product was obtained as light yellow needles (263.0 mg, 87%): mp 121−125 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 10.26 (s, 1H), 8.09 (d, J = 6.8 Hz, 1H), 7.50−7.48 (m, 2H), 7.43−7.41 (m, 1H), 7.37−7.34 (m, 3H), 7.33−7.28 (m, 1H), 1.26 (s, 9H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 185.6, 154.6, 154.0, 148.3, 131.9, 127.0, 125.8, 125.1, 123.5, 123.4, 122.4, 117.3, 111.2, 101.4, 35.0, 31.0; FTIR (Zn−Se ATR, cm^{-1}) 2963, 2207, 1678, 835; HRMS (ESI) calcd for $[C_{21}H_{18}O_2]$ requires $[M + H]^+$ 303.1385, found 303.1405.

2-(o-Tolylethynyl)benzofuran-3-carbaldehyde (**5f**). The product was obtained as brown needles (218.6 mg, 84%): mp 118−122 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 10.36 (s, 1H), 8.18 (d, J = 8.4 Hz, 1H), 7.60−7.58 (m, 1H), 7.51−7.49 (m, 1H), 7.44−7.33 (m, 3H), 7.29−7.22 (m, 2H), 2.56 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 185.3, 154.6, 148.1, 141.1, 132.4, 130.3, 129.8, 127.0, 125.9, 125.1, 123.6, 123.3, 122.3, 120.2, 111.2, 100.1, 80.8, 20.7; FTIR (Zn−Se ATR, cm^{-1}) 2957, 2819, 2197, 1680, 737; HRMS (ESI) calcd for $[C_{18}H_{12}O_2]$ requires $[M + H]^+$ 261.0916, found 261.0931.

2-((4-Methoxyphenyl)ethynyl)benzofuran-3-carbaldehyde (**5g**). The product was obtained as yellow needles (248.6 mg, 90%): mp 122−126 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 10.24 (s, 1H), 8.08 (d, J = 7.64 Hz, 1H), 7.50−7.47 (m, 2H), 7.41−7.39 (m, 1H), 7.34−7.27 (m, 2H), 6.84 (d, J = 6.84 Hz, 2H), 3.76 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 185.5, 161.2, 154.4, 148.5, 133.8, 126.8, 125.0, 123.4, 123.2, 122.3, 114.3, 112.2, 111.1, 101.5, 76.3, 55.4; FTIR (Zn−Se ATR, cm^{-1}) 2957, 2836, 2197, 1663, 829; HRMS (ESI) calcd for $[C_{18}H_{12}O_3]$ requires $[M + H]^+$ 277.0865, found 277.0881.

2-(Thiophen-3-ylethynyl)benzofuran-3-carbaldehyde (**5h**). The product was obtained as brown needles (206.8 mg, 82%): mp 113−117 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 10.25 (s, 1H), 8.10 (d, J = 7.6 Hz, 1H), 7.68 (d, J = 3.0 Hz, 1H), 7.43−7.41 (m, 1H), 7.37−7.35 (m, 1H), 7.33−7.29 (m, 2H), 7.21 (d, J = 4.5 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 185.5, 154.6, 148.0, 132.1, 129.6, 127.1, 126.3, 125.2, 123.7, 123.4, 122.4, 119.6, 111.2, 96.2; FTIR (Zn−Se ATR, cm^{-1}) 2961, 2206, 1668; HRMS (ESI) calcd for $[C_{15}H_8O_2S]$ requires $[M + H]^+$ 253.0323, found 253.0352.

2-((4-(Trifluoromethoxy)phenyl)ethynyl)benzofuran-3-carbaldehyde (**5i**). The product was obtained as yellow needles (250.9 mg, 76%): mp 92−94 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 10.22 (s, 1H), 8.06 (d, J = 7.6 Hz, 1H), 7.54 (d, J = 9.1 Hz, 2H), 7.39−7.35 (m, 1H), 7.34−7.24 (m, 2H), 7.16 (d, J = 8.4 Hz, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 185.2, 154.7, 150.3, 147.3, 133.7, 127.2, 125.3, 125.2, 124.1, 123.2, 122.4, 121.0, 119.0, 111.2, 99.1, 77.8; FTIR (Zn−Se ATR, cm^{-1}) 2965, 2210, 1672, 1154; HRMS (ESI) calcd for $[C_{18}H_9F_3O_3]$ requires $[M + H]^+$ 331.0582, found 331.0598.

2-((3-Methoxyphenyl)ethynyl)benzofuran-3-carbaldehyde (**5j**). The product was obtained as brown needles (223.7 mg, 81%): mp 98−102 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 10.33 (s, 1H), 8.17 (d, J = 7.6 Hz, 1H), 7.51−7.49 (m, 1H), 7.44−7.38 (m, 2H), 7.36−7.30 (m, 1H), 7.25−7.22 (m, 1H), 7.13 (s, 1H), 7.02−7.00 (m, 1H), 3.83 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 185.4, 159.4, 154.6, 147.8, 129.8, 127.1, 125.1, 124.6, 123.8, 123.3, 122.4, 121.2, 117.0, 116.5, 111.2, 100.8, 77.3, 55.3; FTIR (Zn−Se ATR, cm^{-1}) 2923, 2852, 2206, 1672, 1284, 683, 875; HRMS (ESI) calcd for $[C_{18}H_{12}O_3]$ requires $[M + H]^+$ 277.0865, found 277.0885.

2-((3,5-Dimethoxyphenyl)ethynyl)benzofuran-3-carbaldehyde (**5k**). The product was obtained as yellow needles (244.8 mg, 80%): mp 100−104 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 10.33 (s, 1H), 8.16 (d, J = 7.6 Hz, 1H), 7.50−7.48 (m, 1H), 7.44−7.35 (m, 2H), 6.75 (s, 2H),6.55−6.54 (m, 1H), 3.81 (s, 6H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 185.4, 160.6, 154.6, 147.8, 127.1, 125.2, 123.9, 123.3, 122.4, 121.5, 111.2, 109.7, 103.7, 101.0, 76.5, 55.5; FTIR (Zn−Se ATR, cm^{-1}) 2921, 2854, 2203, 1683; HRMS (ESI) calcd for $[C_{19}H_{14}O_4]$ requires $[M + H]^+$ 307.0970, found 307.0989.

2-(3-phenoxyprop-1-yn-1-yl)benzofuran-3-carbaldehyde (**5l**). The product was obtained as a yellow oil (212.5 mg, 77%);^{1}H NMR (400 MHz, $CDCl_3$) δ 10.11 (s, 1H), 8.13 (d, J = 7.64 Hz, 1H), 7.46−7.39 (m, 2H), 7.38−7.32 (m, 3H), 7.05−7.01 (m, 3H), 5.03 (s, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 185.3, 157.2, 154.6, 146.5, 129.6, 127.4, 125.3, 124.8, 123.0, 122.5, 122.1, 114.9, 111.3, 96.0, 74.9, 56.1; FTIR (Zn−Se ATR, cm^{-1}) 3062, 2854, 2356, 1672; HRMS (ESI) calcd for $[C_{18}H_{12}O_3]$ requires $[M]^+$ 277.0865, found 277.0881.

2-(Hex-1-yn-1-yl)benzofuran-3-carbaldehyde (**5m**). The product was obtained as a brown oil (162.7 mg, 72%); ^{1}H NMR (400 MHz, $CDCl_3$) δ 10.14 (s, 1H), 8.06 (d, J = 7.6 Hz, 1H),7.39−7.37 (m, 1H), 7.33−7.25 (m, 2H), 2.51(t, J = 6.8 Hz, 2H), 1.64−1.57 (m, 2H), 1.49−1.40 (m, 2H), 0.90 (t, J = 6.8 Hz, 3H) ^{13}C NMR (100 MHz, $CDCl_3$) δ 185.8, 154.2, 148.8, 126.7, 125.0, 123.3, 123.2, 122.2, 111.1, 103.9, 69.1, 29.9, 22.0, 19.5, 13.5; FTIR (Zn−Se ATR, cm^{-1}) 2956, 2868, 2229, 1676; HRMS (ESI) calcd for $[C_{15}H_{14}O_2]$ requires $[M + H]^+$ 227.1072, found 227.1092.

2-(Cyclohexylethynyl)benzofuran-3-carbaldehyde (**5n**). The product was obtained as a brown oil (176.6 mg, 70%); ^{1}H NMR (400 MHz, $CDCl_3$) δ 10.13 (s, 1H), 8.06−8.04 (m, 1H), 7.40−7.36 (m, 1H), 7.33−7.31 (m, 1H), 7.30−7.25 (m, 1H), 2.72−2.67 (m, 1H), 1.86−1.84 (m, 2H), 1.71−1.69 (m, 2H), 1.57−1.46 (m, 2H), 1.37−1.30 (m, 4H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 185.9, 154.1, 149.0, 126.7, 125.0, 123.1, 122.2, 111.1, 107.6, 93.2, 69.1, 31.7, 29.8, 25.6, 24.6; FTIR (Zn−Se ATR, cm^{-1}) 2930, 2856, 2196, 1707; HRMS (ESI) calcd for $[C_{17}H_{16}O_2]$ requires $[M + H]^+$ 253.1229, found 253.1242.

2-((Trimethylsilyl)ethynyl)benzofuran-3-carbaldehyde (**5o**). The product was obtained as a brown oil (174.4 mg, 72%); ^{1}H NMR (400 MHz, $CDCl_3$) δ 10.22 (s, 1H), 8.15−8.08 (m, 1H), 7.48−7.40 (m, 2H), 7.38−7.33 (m, 2H), 0.33 (s, 9H); ^{13}C NMR (100 MHz, $CDCl_3$)

DOI: 10.1021/acs.joc.5b01647
J. Org. Chem. 2015, 80, 10548−10560

δ 185.5, 154.3, 147.3, 127.2, 126.0, 125.1, 124.3, 122.4, 121.6, 109.2, 91.2, -0.59; FTIR (Zn−Se ATR, cm^{-1}) 2962, 2830, 2158, 1681; HRMS (ESI) calcd for $[C_{14}H_{14}O_2Si]$ requires $[M + H]^+$ 243.0841, found 243.0861.

*2-(6-Hydroxyhex-1-yn-1-yl)benzofuran-3-carbaldehyde (**5p**).* The product was obtained as light yellow oil (150.0 mg, 62%); ^1H NMR (400 MHz, $CDCl_3$) δ 10.12 (s, 1H), 8.04 (d, *J* = 8.40 Hz, 1H), 7.36 (d, *J* = 7.6 Hz, 1H), 7.32−7.22 (m, 2H), 3.64 (t, *J* = 6.1 Hz, 2H), 2.55 (t, *J* = 6.8 Hz, 2H), 1.93 (br s, 1H), 1.73−1.67 (m, 4H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 186.6, 164.5, 154.0, 125.3, 124.5, 121.5, 119.7, 111.1, 97.9, 69.4, 61.7, 34.0, 24.8, 18.6; FTIR (Zn−Se ATR, cm^{-1}) 3441, 2943, 2873, 2207, 1664 1262; HRMS (ESI) calcd for $[C_{15}H_{14}O_3]$ requires $[M + H]^+$ 243.1021, found 243.1041.

*3-(Phenylethynyl)benzofuran-2-carbaldehyde (**5q**).* The product was obtained as yellow needles (221 mg, 90%): mp 94−98 °C; ^1H NMR (400 MHz, $CDCl_3$) δ 10.01 (s, 1H), 7.78 (d, *J* = 8.4 Hz, 1H), 7.55−7.51 (m, 2H), 7.49−7.44 (m, 2H), 7.33−7.29 (m, 4H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 177.9, 155.3, 152.4, 131.9, 130.0, 129.5, 128.6, 127.4, 124.5, 122.5, 121.7, 115.8, 112.8, 100.0, 76.7; FTIR (Zn−Se ATR, cm^{-1}) 2920, 2824, 2207, 1675; HRMS (ESI) calcd for $[C_{17}H_{10}O_2]$ requires $[M + H]^+$ 247.0759 found 247.0781.

*3-((4-Methoxyphenyl)ethynyl)benzofuran-2-carbaldehyde (**5r**).* The product was obtained as yellow needles (253 mg, 92%): mp 88−92 °C; ^1H NMR (400 MHz, $CDCl_3$) δ 10.11 (s, 1H), 7.88 (d, *J* = 7.6 Hz, 1H), 7.59−7.56 (m, 4H), 7.42−7.38 (m, 1H), 6.94 (d, *J* = 8.4 Hz, 2H), 3.86 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 178.0, 160.6, 155.4, 152.2, 133.6, 130.0, 127.5, 124.4, 123.0, 122.6, 114.3, 112.8, 111.5, 100 5, 76.1, 55.4; FTIR (Zn−Se ATR, cm^{-1}) 2958, 2836, 2197, 1665, 830; HRMS (ESI) calcd for $[C_{17}H_{17}NS]$ requires $[M + H]^+$ 277.0865 found 277.0884.

General Procedure for the Synthesis of Substituted Benzothienopyridine 7a−t and 8a−p. In a oven-dried round-bottom flask, a solution of 3-(arylethynyl)benzo[*b*]thiophene-2-carbaldehyde **4a−t** and **5a−p** (0.5 mmol), 2.0 mL of EtOH, $AgNO_3$ (10 mol %), and *tert*-butylamine **6** (0.52 mmol) were added under inert atmosphere. The resulting reaction mixture was heated at 70 °C for 24−65 h. Progression of the reaction was monitored by TLC analysis; after complete consumption of starting material, the reaction was cooled to room temperature. The reaction mixture was diluted with ethyl acetate (10 mL) and water (15 mL) and then filtered through a plug of Celite. The layers were separated, and the organic layer was washed with aqueous saturated brine solution and dried over Na_2SO_4. Organic layer was concentrated under reduced pressure. The crude material so obtained was purified by column chromatography on silica gel (100−200) (hexane:ethyl acetate; 98/02). The structure and purity of known starting materials were confirmed by comparison of their physical and spectral data (^1H NMR, ^{13}C NMR, and HRMS), and infrared spectra were recorded on a FTIR spectrophotometer. The structure and purity of known final product **7a** were confirmed by comparison of their physical and spectral data (^{1} H NMR and ^{13}C NMR) with those reported in the literature.[36]

*3-(p-Tolyl)benzo[4,5]thieno[2,3-c]pyridine (**7b**).* The product was obtained as dark yellow needles (103.26 m g, 75%): mp 118−122 °C; ^1H NMR (400 MHz, $CDCl_3$) δ 9.11 (s, 1H), 8.31 (s, 1H), 8.23 (d, *J* = 7.8 Hz, 1H), 7.93 (d, *J* = 7.8 Hz, 2H), 7.85 (d, *J* = 7.8 Hz, 1H), 7.54−7.50 (m, 1H), 7.48−7.44 (m, 1H), 7.26 (d, *J* = 7.8 Hz, 2H), 2.36 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 152.6, 144.2, 142.7, 141.4, 138.6, 136.7, 134.2, 133.9, 129.5, 129.0, 126.8, 124.8, 123.3, 122.8, 112.1, 21.2 ; FTIR (Zn−Se ATR, cm^{-1}) 2923, 2857, 1597, 816; HRMS (ESI) calcd for $[C_{18}H_{13}NS]$ requires $[M]^+$ 275.0769, found 275.0769.

*3-(4-Ethylphenyl)benzo[4,5]thieno[2,3-c]pyridine (**7c**).* The product was obtained as yellow needles (107.0 mg, 74%): mp 119−124 °C; ^1H NMR (400 MHz, $CDCl_3$) δ 9.05 (s, 1H), 8.24−8.22 (m, 1H), 8.15−8.14 (m, 1H), 7.92 (d, *J* = 8.4 Hz, 2H), 7.78−7.75 (m, 1H), 7.47−7.44 (m, 1H), 7.41−7.37 (m, 1H), 7.24 (d, *J* = 7.6 Hz, 2H), 2.62 (q, *J* = 7.6 Hz, 2H), 1.19 (t, *J* = 7.6 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 152.7, 144.9, 144.2, 142.7, 141.4, 137.0, 134.2, 133.9, 129.0, 128.3, 126.9, 124.8, 123.3, 122.8, 112.0, 28.6, 15.5; FTIR (Zn−Se ATR, cm^{-1}) 2969, 2932, 1601, 846; HRMS (ESI) calcd for $[C_{19}H_{15}NS]$ requires $[M + H]^+$ 290.1003, found 290.1023.

*3-(4-Butylphenyl)benzo[4,5]thieno[2,3-c]pyridine (**7d**).* The product was obtained as yellow needles (115.7 mg, 73%): mp 117−121 °C; ^1H NMR (400 MHz, $CDCl_3$) δ 9.08 (s, 1H), 8.27 (s, 1H), 8.18 (d, *J* = 7.3 Hz 1H), 7.93 (d, *J* = 8.2 Hz, 2H), 7.81 (d, *J* = 7.8 Hz, 1H), 7.51−7.46 (m, 1H), 7.44−7.40 (m, 1H), 7.24 (d, *J* = 8.2 Hz, 2H), 2.60 (t, *J* = 7.3 Hz, 2H), 1.61−1.53 (m, 2H), 1.35−1.26 (m, 2H), 0.86 (t, *J* = 7.8 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 152.7, 144.2, 143.6, 142.7, 141.4, 136.9, 133.9, 129.0, 128.9, 126.8, 124.8, 123.3, 122.8, 112.1, 35.4, 33.6, 22.3, 14.0; FTIR (Zn−Se ATR, cm^{-1}) 2923, 2857, 1601, 833; HRMS (ESI) calcd for $[C_{21}H_{19}NS]$ requires $[M]^+$ 317.1238, found 317.1238

*3-(4-(tert-Butyl)phenyl)benzo[4,5]thieno[2,3-c]pyridine (**7e**).* The product was obtained as yellow oil (112.5 mg, 71%); ^1H NMR (400 MHz, $CDCl_3$) δ 9.08 (s, 1H), 8.26 (s, 1H), 8.17 (d, *J* = 7.3 Hz, 1H), 7.94 (d, *J* = 8.6 Hz, 2H), 7.79 (d, *J* = 8.2 Hz, 1H), 7.49−7.39 (m, 4H), 1.30 (s, 9H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 152.6, 151.8, 144.2, 142.7, 141.4, 136.7, 134.2, 133.9, 129.0, 126.6, 125.8, 124.8, 123.3, 122.8, 112.2, 34.6, 31.3; FTIR (Zn−Se ATR, cm^{-1}) 2961, 2927, 1597, 837; HRMS (ESI) calcd for $[C_{21}H_{19}NS]$ requires $[M]^+$ 317.1238, found 317.1239.

*3-(4-Methoxyphenyl)benzo[4,5]thieno[2,3-c]pyridine (**7f**).* The product was obtained as yellow needles (113.6 g, 78%): mp 116−120 °C; ^1H NMR (400 MHz, $CDCl_3$) δ 9.08 (s, 1H), 8.26 (s, 1H), 8.22 (d, *J* = 8.4 Hz, 1H), 7.99 (d, *J* = 8.3 Hz, 2H), 7.84 (d, *J* = 7.6 Hz, 1H), 7.52 (t, *J* = 7.6 Hz, 1H), 7.45 (t, *J* = 7.6 Hz, 1H), 6.97 (d, *J* = 9.1 Hz, 2H), 3.81 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 160.2, 152.4, 144.2, 142.8, 141.4, 133.9, 133.8, 132.2, 129.0, 128.2, 124.8, 123.4, 122.8, 114.2, 111.7, 55.4; FTIR (Zn−Se ATR, cm^{-1}) 2923, 2840, 1601, 1242, 833; HRMS (ESI) calcd for $[C_{18}H_{13}NOS]$ requires $[M + H]^+$ 292.0796, found 292.0810.

*4-(Benzofuro[3,2-c]pyridin-3-yl)-N,N-dimethylaniline (**7g**).* The product was obtained as yellow needles (109.4 mg, 72%): mp 131−135 °C; ^1H NMR (400 MHz, $CDCl_3$) δ 9.10 (s, 1H), 8.26−8.21 (m, 2H), 8.01 (d, *J* = 9.1 Hz, 2H), 7.85 (d, *J* = 8.2 Hz, 1H), 7.54−7.51 (m, 1H), 7.48−7.44 (m, 1H), 6.82 (d, *J* = 9.1 Hz, 2H), 3.00 (s, 6H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 152.9, 150.8, 143.9, 142.7, 141.3, 134.0, 132.9, 128.8, 127.7, 127.4, 124.6, 123.2, 122.7, 112.3, 110.8, 40.3; FTIR (Zn−Se ATR, cm^{-1}) 2923, 2848, 1597, 1259, 804; HRMS (ESI) calcd for $[C_{19}H_{16}N_2S]$ requires $[M]^+$ 304.1034, found 304.1035.

*3-(o-Tolyl)benzo[4,5]thieno[2,3-c]pyridine (**7h**).* The product was obtained as yellow needles (96.2 mg, 70%): mp 115−119 °C; ^1H NMR (400 MHz, $CDCl_3$) δ 9.19 (s, 1H), 8.22−7.92 (m, 3H), 7.59−7.48 (m, 3H), 7.32−7.24 (m, 3H), 2.40 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 154.8, 143.9, 142.3, 141.3, 140.4, 136.0, 134.1, 133.8, 130.7, 129.8, 129.1, 128.2, 125.9, 124.9, 123.3, 122.9, 116.0, 20.4; FTIR (Zn−Se ATR, cm^{-1}) 2923, 2857, 1597, 741; HRMS (ESI) calcd for $[C_{18}H_{13}NS]$ requires $[M]^+$ 275.0769, found 275.0769.

*3-(m-Tolyl)benzo[4,5]thieno[2,3-c]pyridine (**7i**).* The product was obtained as yellow needles (99.0 mg, 72%): mp 118−122 °C; ^1H NMR (400 MHz, $CDCl_3$) δ 9.10 (s, 1H), 8.30 (s, 1H), 8.21 (d, *J* = 7.8 Hz, 1H), 7.86−7.78 (m, 3H), 7.53−7.49 (m, 1H), 7.46−7.42 (m, 1H), 7.35−7.31 (m, 1H), 7.18−7.16 (m, 1H), 2.40 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 152.8, 144.3, 142.8, 141.4, 139.5, 138.5, 134.4, 133.9, 129.4, 129.0, 128.7, 127.7, 124.8, 124.0, 123.3, 122.9, 112.5, 21.6; FTIR (Zn−Se ATR, cm^{-1}) 2933, 2867, 1601, 770; HRMS (ESI) calcd for $[C_{18}H_{13}NS]$ requires $[M]^+$ 275.0769, found 275.0770.

*3-(Thiophen-3-yl)benzo[4,5]thieno[2,3-c]pyridine (**7j**).* The product was obtained as light yellow needles (94.9 mg, 71%): mp 95−99 °C; ^1H NMR (400 MHz, $CDCl_3$) δ 9.05 (s, 1H), 8.22−8.20 (m, 2H), 7.93−7.91 (m, 1H), 7.85 (d, *J* = 8.0 Hz, 1H), 7.70−7.69 (m, 1H), 7.55−7.51 (m, 1H), 7.46 (t, *J* = 7.3 Hz, 1H), 7.39−7.37 (m, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 145.0, 144.2, 141.5, 134.0, 129.1, 128.6, 128.4, 127.9, 127.4, 127.0, 124.9, 123.4, 123.1, 122.9, 112.2; FTIR (Zn−Se ATR, cm^{-1}) 2919, 1597, HRMS (ESI) calcd for $[C_{15}H_9NS_2]$ requires $[M]^+$ 267.0176, found 267.0176.

*3-(4-(Trifluoromethoxy)phenyl)benzo[4,5]thieno[2,3-c]pyridine (**7k**).* The product was obtained as brown needles (119.1 mg, 69%): mp 117−119 °C; ^1H NMR (400 MHz, $CDCl_3$) δ 9.1 (s, 1H), 8.29 (s,

DOI: 10.1021/acs.joc.5b01647
J. Org. Chem. 2015, 80, 10548−10560

1H), 8.22 (d, J = 7.7 Hz, 1H), 8.06 (d, J = 8.6 Hz, 2H), 7.85 (d, J = 8.2 Hz, 1H), 7.56−7.51 (m, 1H), 7.49−7.45 (m, 1H), 7.30−7.27 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 151.3, 149.7, 144.6, 142.9, 141.6, 138.3, 135.0, 133.9, 129.4, 128.5, 125.1, 123.6, 123.0, 121.3, 119.3, 112.5; FTIR (Zn−Se ATR, cm^{-1}) 2919, 1601, 1263, 850; HRMS (ESI) calcd for $[C_{18}H_{10}F_3NOS]$ requires $[M]^+$ 345.0435, found 345.0434.

*3-(3,5-Dimethoxyphenyl)benzo[4,5]thieno[2,3-c]pyridine (**7l**).* The product was obtained as brown needles (109.2 mg, 68%): mp 159−163 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.12 (s, 1H), 8.30 (s, 1H), 8.22 (d, J = 7.6 Hz, 1H), 7.86 (d, J = 8.4 Hz, 1H), 7.54 (t, J = 7.6 Hz, 1H), 7.47 (t, J = 7.6 Hz, 1H), 7.24−7.22 (m, 2H), 6.52−6.51 (m, 1H), 3.87 (s, 6H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 161.2, 152.3, 144.1, 142.7, 141.7, 141.3, 134.8, 133.8, 129.1, 124.9, 123.3, 122.8, 112.6, 105.0, 100.9, 55.5; FTIR (Zn−Se ATR, cm^{-1}) 2959, 2925, 1590, 1259; HRMS (ESI) calcd for $[C_{19}H_{15}NO_2S]$ requires $[M + Na]^+$ 344.0721, found 344.0717.

*3-(4-(Trifluoromethyl)phenyl)benzo[4,5]thieno[2,3-c]pyridine (**7m**).* The product was obtained as brown needles (107.0 mg, 65%): mp 134−126 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.11 (s, 1H), 8.31 (s, 1H), 8.21 (d, J = 7.3 Hz, 1H), 8.13 (d, J = 8.2 Hz, 2H), 7.84 (d, J = 7.7 Hz, 1H), 7.68 (d, J = 8.2 Hz, 2H), 7.55−7.51 (m, 1H), 7.48−7.44 (m, 1H) ; ^{13}C NMR (100 MHz, $CDCl_3$) δ 150.9, 144.6, 142.8, 141.4, 135.4, 133.7, 129.3, 127.2, 125.7 (q, J = 3.8 Hz, 1C), 125.0, 123.4, 122.9, 112.7; FTIR (Zn−Se ATR, cm^{-1}) 2923, 1613, 1325, 1092; HRMS (ESI) calcd for $[C_{18}H_{10}F_3NS]$ requires $[M]^+$ 329.0486, found 329.0487.

*3-(6-Methoxynaphthalen-2-yl)benzo[4,5]thieno[2,3-c]pyridine (**7o**).* The product was obtained as yellow needles (128.0 mg, 75%): mp 134−138 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.12 (s, 1H), 8.43−8.39 (m, 2H), 8.23 (d, J = 7.9 Hz, 1H), 8.13−8.11 (m, 1H), 7.83 (d, J = 7.9 Hz, 1H), 7.79−7.76 (m, 2H), 7.52−7.48 (m, 1H), 7.46−7.42 (m, 1H), 7.11−7.09 (m, 2H), 3.85 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 161.1, 152.3, 144.1, 142.7, 141.7, 141.4, 134.8, 133.8, 129.1, 124.9, 123.3, 122.9, 112.6, 105.0, 100.9, 55.5; FTIR (Zn−Se ATR, cm^{-1}) 2925, 2858, 1603, 1095; HRMS (ESI) calcd for $[C_{22}H_{15}NOS]$ requires $[M]^+$ 341.0874, found 341.0874.

*3-(Phenanthren-9-yl)benzo[4,5]thieno[2,3-c]pyridine (**7p**).* The product was obtained as brown needles (133.5 mg, 74%): mp 161−165 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.32 (s, 1H), 8.78 (d, J = 8.2 Hz, 1H), 8.73 (d, J = 8.2 Hz, 1H), 8.30 (s, 1H), 8.21 (d, J = 7.3 Hz, 1H), 8.13 (d, J = 8.2 Hz, 1H), 7.95−7.93 (m, 3H), 7.70−7.66 (m, 2H), 7.63−7.54 (m, 3H), 7.50−7.46 (m, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 154.0, 144.2, 142.5, 141.4, 137.2, 134.6, 133.8, 131.4, 130.8, 130.6, 130.4, 129.2, 128.9, 128.6, 127.0, 126.8, 126.7, 126.6, 126.57, 124.9, 123.3, 123.0, 122.9, 122.5, 117.0; FTIR (Zn−Se ATR, cm^{-1}) 2921, 1590; HRMS (ESI) calcd for $[C_{25}H_{15}NS]$ requires $[M]^+$ 361.0925, found 361.0924.

*3-Phenethylbenzo[4,5]thieno[2,3-c]pyridine (**7q**).* The product was obtained as brown needles (89.7 mg, 62%): mp 88−92 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.00 (s, 1H), 8.07 (d, J = 7.8 Hz, 1H), 7.80 (d, J = 7.8 Hz, 1H), 7.69 (s, 1H), 7.50−7.46 (m, 1H), 7.42−7.38 (m, 1H), 7.25−7.16 (m, 4H), 7.13−7.11 (m, 1H), 3.21−3.17 (m, 2H), 3.09−3.05 (m, 2H) ; ^{13}C NMR (100 MHz, $CDCl_3$) δ 155.8, 144.0, 142.4, 141.6, 141.3, 133.7, 133.4, 128.9, 128.5, 128.4, 126.0, 124.7, 123.3, 122.8, 114.7, 40.1, 36.5; FTIR (Zn−Se ATR, cm^{-1}) 2923, 2852, 1601; HRMS (ESI) calcd for $[C_{19}H_{15}NS]$ requires $[M]^+$ 289.0925, found 289.0924.

*3-Cyclopropylbenzo[4,5]thieno[2,3-c]pyridine (**7r**).* The product was obtained as brown needles (76.6 mg, 68%): mp 134−136 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.87 (s, 1H), 8.10 (d, J = 7.8 Hz, 1H), 7.79−7.74 (m, 2H), 7.49−7.37 (m, 2H), 2.15−2.09 (m, 1H), 1.04−0.94 (m, 4H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 157.5, 143.9, 142.2, 141.4, 133.6, 132.6, 128.8, 124.6, 123.2, 122.7, 113.0, 17.2, 9.8; FTIR (Zn−Se ATR, cm^{-1}) 2919, 2857, 1592; HRMS (ESI) calcd for $[C_{14}H_{11}NS]$ requires $[M]^+$ 225.0612, found 225.0612.

*3-Cyclohexylbenzo[4,5]thieno[2,3-c]pyridine (**7s**).* The product was obtained as a brown oil (82.8 mg, 62%); ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.98 (s, 1H), 8.15 (d, J = 7.6 Hz, 1H), 7.82−7.78 (m, 2H), 7.49 (t, J = 6.8 Hz, 1H), 7.42 (t, J = 7.6 Hz, 1H), 2.84−2.78 (m, 1H), 2.0−1.97 (m, 2H), 1.85−1.82 (m, 2H), 1.73−1.70 (m, 1H), 1.61−1.50 (m, 2H), 1.48−1.35 (m, 2H), 1.31−1.17 (m, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 161.3, 143.8, 142.5, 141.3, 133.9, 133.2, 128.8, 124.6, 123.2, 122.7, 112.6, 46.3, 33.4, 26.6, 26.1; FTIR (Zn−Se ATR, cm^{-1}) 2926, 2853, 1599; HRMS (ESI) calcd for $[C_{17}H_{17}NS]$ requires $[M + H]^+$ 268.1160 found 268.1172.

*3-Phenylbenzofuro[3,2-c]pyridine (**8a**).* The product was obtained as yellow needles (90.7 mg, 74%): mp 150−155 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.23 (s, 1H), 8.02−7.97 (m, 3H), 7.85 (s, 1H), 7.56 (d, J = 7.5 Hz, 1H), 7.48−7.43 (m, 3H), 7.39−7.34 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 162.2, 156.3, 156.1, 142.9, 139.4, 129.0, 128.8, 128.1, 127.1, 123.8, 121.6, 121.1, 120.3, 111.9, 103.9; FTIR (Zn−Se ATR, cm^{-1}) 2924, 2857, 1597; HRMS (ESI) calcd for $[C_{17}H_{11}NO]$ requires $[M + H]^+$ 246.0919, found 246.0931.

*3-(p-Tolyl)benzofuro[3,2-c]pyridine (**8b**).* The product was obtained as yellow needles (101.1 mg, 78%): mp 144−148 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.28 (s, 1H), 8.02 (d, J = 7.6 Hz, 1H), 7.97−7.95 (m, 2H), 7.87 (s, 1H), 7.61−7.59 (m, 1H), 7.55−7.49 (m, 1H), 7.43−7.39 (m, 1H), 7.31 (d, J = 7.6 Hz, 2H), 2.42 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 162.3, 156.3, 156.1, 142.8, 139.1, 136.6, 129.6, 128.0, 127.0, 123.8, 121.7, 121.1, 120.1, 111.9, 103.6, 21.3; FTIR (Zn−Se ATR, cm^{-1}) 2921, 2854, 1594, 814; HRMS (ESI) calcd for $[C_{18}H_{13}NO]$ requires $[M + H]^+$ 260.1075, found 260.1092.

*3-(4-Ethylphenyl)benzofuro[3,2-c]pyridine (**8c**).* The product was obtained as yellow needles (103.8 mg, 76%): mp 136−140 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.18 (s, 1H), 7.95−7.91 (m, 3H), 7.79 (s, 1H), 7.52 (d, J = 8.4 Hz, 1H), 7.45−7.40 (m, 1H), 7.33 (d, J = 7.6 Hz, 1H), 7.26 (d, J = 7.6 Hz, 2H), 2.64 (q, J = 7.6 Hz, 2H), 1.21 (t, J = 7.6 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 162.2 156.3, 156.2, 145.4, 142.9, 136.9, 128.4, 128.0, 127.1, 123.8, 121.7, 121.0, 120.0, 111.9, 103.5, 28.6, 15.5; FTIR (Zn−Se ATR, cm^{-1}) 2965, 2927, 1601, 833; HRMS (ESI) calcd for $[C_{19}H_{15}NO]$ requires $[M + H]^+$ 274.1232, found 274.1256.

*3-(4-Butylphenyl)benzofuro[3,2-c]pyridine (**8d**).* The product was obtained as yellow needles (113.0 mg, 75%): mp 111−114 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.18 (s, 1H), 7.94−7.90 (m, 3H), 7.79 (s, 1H), 7.52 (d, J = 8.4 Hz, 1H), 7.42 (t, J = 6.8 Hz, 1H), 7.32 (t, J = 6.8 Hz, 1H), 7.23 (d, J = 8.4 Hz, 2H), 2.60 (t, J = 7.2 Hz, 2H), 1.60−1.52 (m, 2H), 1.35−1.27 (m, 2H), 0.86 (t, J = 7.6 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 162.2, 156.2, 156.2, 144.0, 142.8, 136.8, 128.9, 128.0, 127.0, 123.8, 121.9, 121.0, 120.0, 111.8, 103.5, 35.4, 33.5, 22.3, 13.9; FTIR (Zn−Se ATR, cm^{-1}) 2952, 2932, 1597, 816; HRMS (ESI) calcd for $[C_{21}H_{19}NO]$ requires $[M + H]^+$ 302.1545, found 302.1562.

*3-(4-(tert-Butyl)phenyl)benzofuro[3,2-c]pyridine (**8e**).* The product was obtained as yellow needles (108.4 mg, 72%): mp 146−150 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.28 (s, 1H), 8.04−8.00 (m, 3H), 7.89 (s, 1H), 7.61 (d, J = 7.6 Hz, 1H), 7.54−7.49 (m, 3H), 7.43−7.39 (m, 1H), 1.37 (s, 9H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 162.3 156.3, 156.1, 152.3, 142.9, 136.6, 128.0, 126.8, 125.8, 123.8, 121.7, 121.1, 120.1, 111.9, 103.6, 35.2, 31.3; FTIR (Zn−Se ATR, cm^{-1}) 2957, 2935, 1592, 829; HRMS (ESI) calcd for $[C_{21}H_{19}NO]$ requires $[M + H]^+$ 302.1545, found 302.1568.

*3-(o-Tolyl)benzofuro[3,2-c]pyridine (**8f**).* The product was obtained as yellow needles (94.6 mg, 73%): mp 131−135 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.23 (s, 1H), 7.96 (d, J = 8.3 Hz, 1H), 7.56−7.53 (m, 2H), 7.47−7.41 (m, 2H), 7.35 (t, J = 6.8 Hz,1H), 7.27−7.24 (m, 3H), 2.35 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 161.4, 158.2, 156.1, 142.5, 140.4, 135.8, 130.8, 129.8, 128.3, 128.1, 125.9, 123.8, 121.5, 121.0, 119.8, 111.8, 107.5, 20.4; FTIR (Zn−Se ATR, cm^{-1}) 2952, 2927, 1605, 746; HRMS (ESI) calcd for $[C_{18}H_{13}NO]$ requires $[M + H]^+$ 260.1075, found 260.1098.

*3-(4-Methoxyphenyl)benzofuro[3,2-c]pyridine (**8g**).* The product was obtained as yellow needles (115.6 mg, 84%): mp 151−155 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.21 (s, 1H), 8.03−7.97 (m, 3H), 7.79 (s, 1H), 7.58−7.56 (m, 1H), 7.50−7.46 (m, 1H), 7.38 (t, J = 7.6 Hz, 1H), 7.01 (d, J = 8.4 Hz, 2H), 3.86 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 162.2, 160.4, 156.2, 155.7, 142.7, 132.0, 128.3, 127.8, 123.7, 121.7, 120.9, 119.7, 114.1, 111.8, 102.9, 55.3; FTIR (Zn−Se ATR, cm^{-1}) 2998, 2836, 1592, 1255, 837; HRMS (ESI) calcd for $[C_{18}H_{13}NO_2]$ requires $[M + H]^+$ 276.1025, found 276.1051.

DOI: 10.1021/acs.joc.5b01647
J. Org. Chem. 2015, 80, 10548−10560

*3-(Thiophen-3-yl)benzofuro[3,2-c]pyridine (**8h**).* The product was obtained as yellow needles (101.7 mg, 81%): mp 133−137 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.1 (s, 1H), 7.95−7.92 (m, 2H), 7.72 (s, 1H), 7.65 (d, J = 5.3 Hz 1H), 7.54−7.53 (m, 1H), 7.44 (t, J = 7.6 Hz, 1H), 7.37−7.34 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 162.1, 156.3, 151.9, 142.9, 142.0, 128.1, 126.5, 126.3, 123.9, 123.8, 121.7, 121.0, 120.1, 111.9, 103.6; FTIR (Zn−Se ATR, cm^{-1}) 2980, 1597; HRMS (ESI) calcd for [$C_{15}H_9NOS$] requires [M + H]$^+$ 252.0483, found 252.0510.

*3-(4-(Trifluoromethoxy)phenyl)benzofuro[3,2-c]pyridine (**8i**).* The product was obtained as yellow needles (121.8 mg, 74%): mp 150−154 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.18 (s, 1H), 8.03−8.00 (m, 2H), 7.95 (d, J = 7.6 Hz, 1H), 7.78 (s, 1H), 7.54−7.52 (m, 1H), 7.47−7.43 (m, 1H), 7.36−7.32 (m, 1H), 7.27−7.25 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 162.1, 156.4, 154.5, 149.8, 143.0, 138.0, 128.6, 128.3, 124.0, 121.4, 121.14, 121.11, 120.6, 119.2, 112.0, 103.9; FTIR (Zn−Se ATR, cm^{-1}) 2927, 1597, 1259, 1150, 846; HRMS (ESI) calcd for [$C_{18}H_{10}F_3NO_2$] requires [M + H]$^+$ 330.0742, found 330.0756.

*3-(3-Methoxyphenyl)benzofuro[3,2-c]pyridine (**8j**).* The product was obtained as yellow needles (99.1 mg, 72%): mp 147−151 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.27 (s, 1H), 8.03 (d, J = 8.40 Hz, 1H), 7.89 (s, 1H), 7.67 (s, 1H), 7.63−7.60 (m, 2H), 7.52 (t, J = 7.9 Hz, 1H), 7.41 (t, J = 7.6 Hz, 2H), 6.99 (dd, J = 8.4 and 6.1 Hz, 1H), 3.92 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 162.2, 160.0, 156.3, 155.8, 142.9, 140.9, 129.8, 128.1, 123.8, 121.6, 121.1, 120.4, 119.5, 115.1, 112.3, 111.9, 104.0, 55.4; FTIR (Zn−Se ATR, cm^{-1}) 2936, 2836, 1605, 1054, 750, 691; HRMS (ESI) calcd for [$C_{18}H_{13}NO_2$] requires [M + H]$^+$ 276.1025, found 276.1042.

*3-(3,5-Dimethoxyphenyl)benzofuro[3,2-c]pyridine (**8k**).* The product was obtained as yellow needles (109.9 mg, 72%): mp 156−160 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.18 (s, 1H), 7.95 (d, J = 7.6 Hz, 1H), 7.79 (s, 1H), 7.54−7.52 (m, 1H), 7.46−7.42 (m, 1H), 7.34 (t, J = 7.6 Hz, 1H), 7.17−7.16 (m, 2H), 3.81 (s, 6H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 162.2, 161.1, 156.4, 155.8, 142.7, 141.6, 128.2, 123.9, 121.6, 121.1, 120.6, 111.9, 105.2, 104.1, 101.4, 55.5; FTIR (Zn−Se ATR, cm^{-1}) 2950, 2890, 1650, 1110, 1050; HRMS (ESI) calcd for [$C_{19}H_{15}NO_3$] requires [M + H]$^+$ 306.1130, found 306.1152.

*3-(Phenoxymethyl)benzofuro[3,2-c]pyridine (**8l**).* The product was obtained as yellow needles (88.0 mg, 64%): mp 134−138 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.12 (s, 1H), 7.94 (d, J = 7.6 Hz, 1H), 7.67 (s, 1H), 7.54−7.51 (m, 1H), 7.44 (t, J = 6.8 Hz, 1H), 7.34 (t, J = 7.6 Hz, 1H), 7.23 (t, J = 7.6 Hz, 2H), 6.97−6.95 (m, 2H), 6.91 (t, J = 6.0 Hz, 1H), 5.29 (s, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 162.0, 158.2, 156.2, 155.9, 142.6, 129.6, 128.2, 123.8, 121.5, 121.2, 121.0, 120.7, 114.8, 112.0, 105.0, 70.4; FTIR (Zn−Se ATR, cm^{-1}) 2923, 2857, 1605, 1054; HRMS (ESI) calcd for [$C_{18}H_{13}NO_2$] requires [M + H]$^+$ 276.1025, found 276.1051.

*3-Butylbenzofuro[3,2-c]pyridine (**8m**).* The product was obtained as a yellow oil (100.5 mg, 62%); ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.07 (s, 1H), 7.90 (d, J = 7.6 Hz, 1H), 7.51−7.49 (m, 1H), 7.43−7.39 (m, 1H), 7.33−7.29 (m, 1H), 7.27 (s, 1H), 2.88 (t, J = 8.0 Hz, 2H), 1.74−1.67 (m, 2H), 1.39−1.30 (m, 2H), 0.88 (t, J = 7.6 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 162.0, 161.0, 155.9, 142.3, 127.8, 123.7, 121.7, 120.9, 119.4, 111.8, 105.9, 38.3, 32.3, 22.4, 13.9; FTIR (Zn−Se ATR, cm^{-1}) 2925, 2858, 1599; HRMS (ESI) calcd for [$C_{15}H_{15}NO$] requires [M + H]$^+$ 226.1232, found 226.1251.

*3-Cyclohexylbenzofuro[3,2-c]pyridine (**8n**).* The product was obtained as a yellow oil (82.9 mg, 66%); ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.07 (s, 1H), 7.91 (d, J = 7.6 Hz, 1H), 7.52−7.50 (m, 1H), 7.45−7.39 (m, 1H), 7.33−7.29 (m, 2H), 2.84−2.78 (m, 1H), 1.99−1.95 (m, 2H), 1.84−1.80 (m, 2H), 1.72−1.69 (m, 1H), 1.56−1.43 (m, 2H), 1.41−1.34 (m, 2H), 1.29−1.17 (m, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 165.4, 162.1, 156.0, 142.3, 127.7, 124.3, 123.6, 121.8, 121.5, 120.8, 119.4, 111.8, 104.1, 46.8, 33.2, 26.6, 26.0; FTIR (Zn−Se ATR, cm^{-1}) 2926, 2854, 1599; HRMS (ESI) calcd for [$C_{17}H_{17}NO$] requires [M + H]$^+$ 252.1388, found 252.1408.

*4-(Benzofuro[3,2-c]pyridin-3-yl)butan-1-ol (**8p**).* The product was obtained as brown needles (82.2 mg, 55%): mp 104−108 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.04 (s, 1H), 7.91 (d, J = 7.6 Hz, 1H), 7.52−7.50 (m, 1H), 7.42 (t, J = 6.8 Hz, 1H), 7.34−7.29 (m, 2H), 3.64 (t, J = 6.1 Hz, 2H), 2.93 (t, J = 7.6 Hz, 2H), 2.24 (br s, 1H), 1.87−1.80 (m, 2H), 1.64−1.58 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 162.0, 160.5, 156.0, 142.4, 127.9, 123.7, 121.7, 120.9, 119.5, 111.8, 106.1, 62.3, 37.9, 32.0, 26.2; FTIR (Zn−Se ATR, cm^{-1}) 3245, 2965, 2923, 1592; HRMS (ESI) calcd for [$C_{15}H_{15}NO_2$] requires [M + H]$^+$ 242.1181, found 242.1184.

*4D-3-Phenylbenzo[4,5]thieno[2,3-c]pyridine (**7u**).* The product was obtained as yellow needles (78.7 mg, 60%): mp 114−118 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.13 (s, 1H), 8.24 (s, 0.1H), 8.34 (d, J = 7.6 Hz, 1H), 8.04 (d, J = 7.6 Hz, 2H), 7.86 (d, J = 8.4 Hz, 1H), 7.55−7.44 (m, 4H), 7.38−7.35 (m, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 152.7, 144.4, 142.7, 141.4, 139.5, 134.6, 133.9, 129.1, 128.8, 128.6, 127.0, 124.9, 123.4, 122.9, 112.5, 112.2 (t, J = 118.2 Hz, 1C); FTIR (Zn−Se ATR, cm^{-1}) 3057, 2923, 1592; HRMS (ESI) calcd for [$C_{17}H_{10}DNS$] requires [M + H]$^+$ 263.0753, found 263.0747.

*4D-3-(4-Methoxyphenyl)benzo[4,5]thieno[2,3-c]pyridine (**7v**).* The product was obtained as yellow needles (93.5 mg, 64%): mp 118−122 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.12 (s, 1H), 8.25 (d, J = 7.63 Hz, 1H), 8.04 (d, J = 9.1 Hz, 2H), 7.88 (d, J = 8.3 Hz, 1H), 7.58−7.54 (m, 1H), 7.51−7.48 (m, 1H), 7.02 (d, J = 9.1 Hz, 2H), 3.86 (s, 3H) ; ^{13}C NMR (100 MHz, $CDCl_3$) δ 160.2, 152.3, 144.2, 142.7, 141.4, 133.9, 133.8, 132.1, 129.0, 128.2, 124.8, 123.3, 122.8, 114.1, 111.3 (t, J = 110.6 Hz, 1C), 55.3; FTIR (Zn−Se ATR, cm^{-1}) 3056, 2931, 2839, 1602, 1248, HRMS (ESI) calcd for [$C_{18}H_{12}DNOS$] requires [M + H]$^+$ 293.0859, found 293.0860.

*4D-3-Phenylbenzofuro[3,2-c]pyridine (**8q**).* The product was obtained as yellow needles (80 mg, 65%): mp 156−160 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.16 (s, 1H), 7.98−7.96(m, 2H), 7.89 (d, J = 7.6 Hz, 1H), 7.49−7.47 (m, 1H), 7.42−7.37 (m, 3H), 7.35−7.27 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 162.1, 156.2, 155.9, 142.9, 139.3, 128.9, 128.8, 128.0, 127.1, 123.8, 121.5, 121.0, 120.2, 111.8, 103.6 (t, J = 99.2 Hz, 1C); FTIR (Zn−Se ATR, cm^{-1}) 3061, 2923, 1592; HRMS (ESI) calcd for [$C_{17}H_{10}DNO$] requires [M + H]$^+$ 247.0982, found 247.0998.

*4D-3-(4-Ethylphenyl)benzofuro[3,2-c]pyridine (**8r**).* The product was obtained as light yellow needles (93.2 mg, 68%): mp 137−141 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.16 (s, 1H), 9.91 (d, J = 8.4 Hz, 3H), 7.51−7.49 (m, 1H), 7.40 (t, J = 7.6 Hz, 1H), 7.31 (t, J = 7.6, Hz, 1H), 7.25 (d, J = 8.4 Hz, 2H), 2.63 (q, J = 7.6 Hz, 2H), 1.20 (t, J = 7.6 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 162.1 156.2, 156.1, 145.3, 142.8, 136.8, 128.3, 127.9, 127.0, 123.7, 121.7, 121.0, 120.0, 111.8, 103.2 (t, J = 99.2 Hz, 1C), 28.6, 15.5; FTIR (Zn−Se ATR, cm^{-1}) 3032, 2957, 2927, 1592, 829; HRMS (ESI) calcd for [$C_{19}H_{14}DNO$] requires [M + H]$^+$ 275.1295, found 275.1296.

*3-Phenylbenzofuro[2,3-c]pyridine (**9a**).* The product was obtained as yellow needles (91 mg, 75%); mp 128−132 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.98 (s, 1H), 8.18 (d, J = 1.5 Hz, 1H), 8.04 (d, J = 7.6 Hz, 2H), 7.98 (d, J = 7.6 Hz, 1H), 7.60−7.54 (m, 2H), 7.51−7.47 (m, 2H), 7.42−7.35 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 157.1, 152.0, 151.5, 139.6, 133.5, 131.9, 129.8, 128.7, 128.3, 126.9, 123.3, 122.3, 121.9, 112.4, 111.8; FTIR (Zn−Se ATR, cm^{-1}) 2923, 1569, 1449, 1189; HRMS (ESI) calcd for [$C_{17}H_{11}NO$] requires [M + H]$^+$ 246.0919 found 246.0931.

*3-(4-Methoxyphenyl)benzofuro[2,3-c]pyridine (**9b**).* The product was obtained as yellow needles (110 mg, 80%): mp 122−126 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.96 (s, 1H), 8.15 (s, 1H), 8.02−7.98 (m, 3H), 7.62−7.58 (m, 2H), 7.41−7.37 (m, 1H), 7.03−7.01 (m, 2H), 3.86 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 160.0, 157.2, 151.7, 151.3, 133.4, 132.3, 132.0, 129.8, 128.2, 123.3, 122.4, 122.0, 114.1, 112.4, 111.0, 55.3; FTIR (Zn−Se ATR, cm^{-1}) 2926, 2839, 1607, 1244, 1108; HRMS (ESI) calcd for [$C_{18}H_{14}NO_2$] requires [M + H]$^+$ 276.1025 found 276.1041.

■ ASSOCIATED CONTENT

Supporting Information

The Supporting Information is available free of charge on the ACS Publications website at DOI: 10.1021/acs.joc.5b01647.

CIF for compounds **7i** (CIF)

DOI: 10.1021/acs.joc.5b01647
J. Org. Chem. 2015, 80, 10548−10560

^{1}H and ^{13}C NMR and HRMS spectral data for all new compounds (PDF)

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Notes

The authors declare no competing financial interest.

ACKNOWLEDGMENTS

This work was supported by the Department of Science and Technology (INT/MEXICO/P-8/2012), UPE-II, Jawaharlal Nehru University, and University of Delhi. S.K., S.P., R.K.S., and M.P. are thankful to the Council of Scientific and Industrial Research, University Grants Commission, for fellowships. We gratefully acknowledge USIC-University of Delhi and AIRF-JNU for providing the instrumentation facilities.

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J. Org. Chem. 2015, 80, 10548−10560