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Novel Building Blocks: 1-Aryl-2-chloro-1-ethoxyethenes – Preparations and Transformations

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Dedicated to Professor Tadashi Kataoka on the occasion of his retirement

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We described here a simple method for the preparation of 1-aryl-2-chloro-1-ethoxyethenes **2a**–**u**, which are prodrugs for Alzheimer's disease, by the reaction of dichloroacetaldehyde diethyl acetal with various aryl and alkenyllithium compounds in high yields.

Introduction

Some thienyl and phenyl α-halomethyl ketones play a crucial role as effective nonATP competitive inhibitors of glycogen synthase kinase (GSK-3β), which is the most important enzyme for the formation of both amyloid plaques and neurofibrillary tangles.[1] There are several biochemical processes; however, the acetylcholine esterase inhibitors are the only available drugs in the market. The search for new types of inhibitors of GSK-3β is most important for the mechanistic and therapeutic usefulness in the treatment of Alzheimer's disease (AD).[2]

Previously, we investigated the syntheses and reactions of alkoxyalkenes bearing some useful substituents such as organosulfanyl, organoselanyl,[3] and perfluoroalkyl groups.[4–5] The alkoxy alkenes that have an enol structure, which can easily undergo hydrolysis to give the alkyl ketone derivatives, and the halogen-substituted alkoxy alkenes prepared by our original methods would both be expected to be novel precursors for aryl chloromethyl ketones and a prodrug in the treatment of Alzheimer's disease (Figure 1). We fortunately discovered and obtained a small amount of 2-chloro-1-ethoxystyrene accompanied by diphenylacetylene in a preliminary investigation of dichloroacetaldehyde diethyl acetal with phenyllithium. We further optimized the reaction conditions and improved the reaction as a general synthetic procedure of 1-aryl-2-chloro-1-ethoxyethenes. Because our method provides various kinds of 1-aryl-2-chloro-1-ethoxyethenes,[6] easy supply of test compounds helps to solve the mechanism of AD and to clarify the structure–activity relationship. Here we report the synthesis and hydrolysis reactions of new 1-aryl-2-chloro-1-ethoxyethenes and also their transformation into 1,3-diaryl-2-chloroenones which can be expected to serve as cyclooxygenase inhibitors.[7]

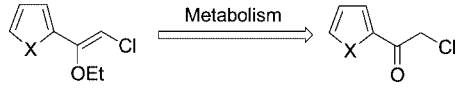

Figure 1. 2-(2-Chloro-1-ethoxyethenyl)thiophenes as prodrugs for Alzheimer's disease.

Results and Discussion

First, we examined the optimization of the reaction conditions of dichloroacetaldehyde diethyl acetal and phenyllithium in [Equation (1)]. A large excess of phenyllithium caused the formation of diphenylacetylene. The best yield of **2a** with no detection of diphenylacetylene was obtained when using DME as the reaction medium cooled to –60 °C. The selection of the reaction medium is important for the successful formation of the chloroethoxyethenes. Additives, such as TMEDA and HMPA, were not effective. The product was proven to be 2-chloro-1-ethoxystyrene (**2a**), not 1-chloro-2-ethoxystyrene, by the fact that the hydrolysis of **2a** gave the chloromethyl phenyl ketone or its acetal, and the lithiation and alkylation of **2a** provided the allylic alcohol described below. Furthermore, the reactions of dibromoacetaldehyde diethyl acetal with bases have been reported to provide the bromoketene diethyl acetal.[8] The stereochemistry of **2a** was confirmed to be (*E*) by NOE experiments.

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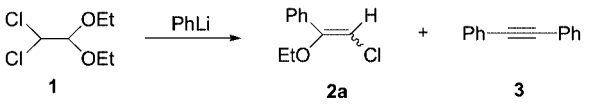
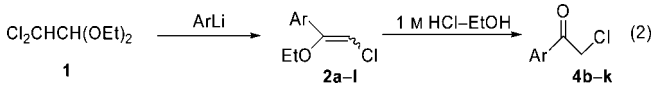


1 **2a** **3** (1)

Next, we examined the reactions of dichloroacetaldehyde diethyl acetal with various aryllithiums [Equation (2)] under almost the same conditions. These results are shown in Table 1. The *p*- and *o*-methoxyphenyllithiums yielded corresponding 2-chloro-1-ethoxyethenes **2b** and **2c** in moderate yields (Table 1, Entries 2 and 3), accompanied by a small amount of 2-chloro-2-(*p*-methoxyphenyl)acetaldehyde diethyl acetal. We also examined the reactions with heteroaromatic compounds, such as thiophenes and furans. 2-Thienyllithiums in the presence of 2,2′-bipyridyl according to a previous report[9] gave 2-thienylethenes **2d**–**f** in high yields (Entries 4–6); however, these compounds are labile at room temperature. Representative 2-chloro-1-ethoxy-1-thienylethene (**2d**) is stable for 1 d at 5 °C. 5-Methylthiophene **2e** and 5-trimethylsilyl derivative **2f** were exclusively provided and found usable as a pure reagent for 7 d when stored at 5 °C. Otherwise, the 5-methoxy-2-thienyllithium directly provided chloromethyl thienyl ketone **3g** in 88% yield, not by way of 2-chloro-1-ethoxyethene **2g** (Entry 7). We also performed the reactions with 2-furyllithiums; however, these enol ethers are more labile than the thienyl derivatives. Therefore, as soon as they were prepared, they were used in the next step. The 1-aryl-2-chloro-1-ethoxyethenes underwent hydrolysis in the presence of one drop of 1 M HCl to successfully provide corresponding aryl chloromethyl ketones **3a**–**i** (Entries 1–9). 2-Lithiated *N*-methylpyrrole under various conditions did not produce satisfactory results; therefore, we modified the method by adding the LDA treated dichloroacetaldehyde diethyl acetal to the corresponding aryllithium, which resulted in the successful production of ketone **3j** in 67% yield (Entry 11). 2-(2-Chloro-1-ethoxyethenyl)pyridine (**2k**) was easily obtained as a compound stable in acids (Entry 12). The usual hydrolysis with some acids did not give the corresponding chloromethyl pyridyl ketone, but pyridylethene **2k** was recovered; therefore, we examined other methods leading to the corresponding aryl chloromethyl ketones and succeeded in producing diethyl acetal **3k** by the usual conditions shown in Entry 12. Furthermore, we also attempted the preparation of enol ethers bearing a heteroaromatic ring. 2-Lithio-1-methylimidazole provided enol ether **2l** in good yield; however, its hydrolysis did not give **3l** and most of **2l** was recovered (Entry 13). The reaction of 2-lithio-1,3-thiazole gave a complex mixture because the product is highly labile at room temperature (Entry 14). Interestingly, indolyllithium formed ketene diethyl acetal **4o**, not the corresponding enol ether (Entry 15). We next performed the reactions of the alkenyllithiums with dichloroacetaldehyde diethyl acetal. First, we selected the norbornenyllithium derived from D-camphor 2,4,6-triisopropylbenzenesulfonylhydrazone/sec-BuLi (Shapiro olefin process). The reaction with dichloroacetaldehyde diethyl acetal provided (*E*)-2-(2-chloro-1-ethoxyethenyl)bornene (**2p**) (Entry 16); however, the yield was not satisfactory. We next examined the other alkenyllithium bearing the β-alkoxy group as shown in Entries 17–20. The α-phenylsulfanyl and selanyl alkenyllithiums gave corresponding butadienes **2q** and **2r** with high stereoselectivity. Trifluoromethyl-substituted alkenyllithiums provided butadienes **2s** and **2t** in high yields. These dialkoxybutadienes are very labile in acid and purification by silica gel resulted in the decomposition of the products. Therefore, the dienes were purified by the alumina. Lithium phenylacetylide also gave enyne **2u** (Entry 21). The stereochemistries of these enol ethers were determined by NOE experiments as shown in Table 2.



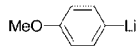
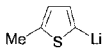
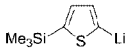
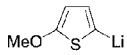
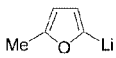
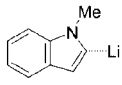
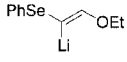
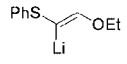
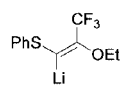
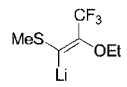
1 **2a–l** **4b–k** (2)

(2)

The olefinic proton of the (*Z*) isomers appears in lower field than that of the (*E*) isomer in the ^{1}H NMR spectrum; therefore, the stereoisomers of the products, to which the stereochemistries could not be assigned, is speculated to be (*E*). The plausible mechanism for the formation of the enol ethers is shown in Scheme 1. First, dichloroacetaldehyde diethyl acetal **5** reacts with the aryllithium to form β-chloroketene diethyl acetal **6** by elimination of hydrogen chloride (the first step),[8] followed by the successive addition–elimination of the aryllithiums to produce (*E*)- and (*Z*)-1-aryl-2-chloro-1-ethoxyethenes (**8**) (the second step). The bulky aryllithiums could attack the chlorine atom at the α-position of β-chloroketene acetal **6**, but not the α-carbon of the ethoxy group, to provide α-arylketene diethyl acetals (Entry 15). The high (*E*)-selectivity of the products is explained as follows. The products could form via the two conformations of intermediate **7**. *Syn* confomer **7** should be unfavorable because of the dipole interaction between the ethoxy and chlorine groups. Therefore, elimination of the ethoxy group would occur from favorable *anti*-**7** to give the (*E*) isomer. The attractive features of this method include its versatility (the accessible aryllithiums were effectively employed in each reaction). In particular, some 2-thienyl derivatives having a strong inhibiting activity of GSK-3β in Alzheimer's disease were exclusively yielded by comparing the other usual methods.[10]

To prepare the 1-aryl-2-chloro-1-ethoxyethenyl analogs, we performed lithiations with strong bases, and their reactions with electrophiles are shown in Scheme 2. The lithiation of 2-(2-chloro-1-ethoxyethenyl)thiophene (**2d**) with *n*-butyllithium at –78 °C proceeded at the α-position of the chloride atom and the reaction with benzaldehyde gave the corresponding allylic alcohol bearing the thienyl group (**9d**). The reaction intermediate is a β-ethoxyethenyllithium and is generated with high stereoselectivity.[11] The treatment of allylic alcohol **9d** with acid exclusively gave 2-chloro-3-phenyl-1-(2-thienyl)prop-2-enone (**10d**) in high yield. 1-Fu-

Table 1. Syntheses of 1-aryl-2-chloro-1-ethoxyethenes and their hydrolyses.

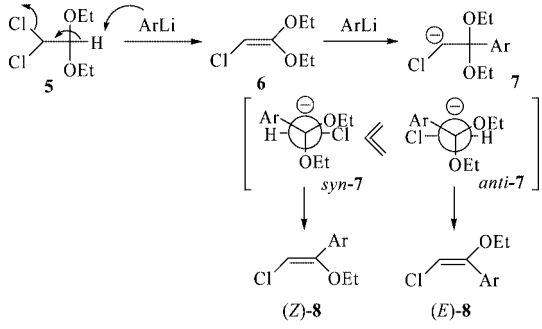
Entry	ArLi	Conditions	Yield of enol ether [%] (*E*:*Z*)	Yield of ketone [%]
1	PhLi	DME, –60 °C, 15 min	**2a** 60 (94:6)	**3a** quant.
2		Ether/DME, –60 °C,15 min	**2b** 51 (100:0)	**3b** 62
3		Ether/DME, –60 °C, 15 min	**2c** 48 (100:0)	**3c** 76
4		THF, –20 °C, 15 min	**2d** 82 (100:0)	**3d** 76
5		THF, –20 °C, 15 min	**2e** 71 (100:0)	**3e** 60
6		THF, –20 °C, 15 min	**2f** 83 (100:0)	**3f** 85
7		THF, –20 °C, 15 min	—	**3g** 88
8		THF, –20 °C, 15 min	**2h** 77 (100:0)	**3h** 73
9		THF,– 20 °C, 15 min	**2i** 50 (100:0)	**3i** 95
10		Ether/THF,-60 °C,15 min	...	**3j** 18
11		LDA, ether/THF, –78 °C, 15min[a]	–	**3j** 67
12		ether, –20 °C, 15 min	**2k** 75 (100:0)	**3k** 60[b]
13		LDA, ether/THF, –78 to –20 °C,15 min	**2l** 75 (100:0)	–
14		ether, –75 °C, 15 min	a complex mixture	–
15		ether, –78 °C, 15 min	...	**4o** 30[c]
16		THF, –20 °C, 15 min	**2p** 38 (100:0)	
17		THF, –20 °C, 15 min	**2q** 46[d] (74:26)	
18		THF, –20 °C, 15 min	**2r** 33 (100:0)	
19		THF, –20 °C, 15 min	**2s** 78 (100:0)	
20		THF, –20 °C, 15 min	**2t** 66 (100:0)	
21		THF, –20 °C, 15 min	**2u** 48[e] (83:17)	

[a] A THF solution of dichloroacetaldehyde diethyl acetal treated with LDA was added to the aryllithiums in THF. [b] Chloromethyl pyridyl ketone was obtained as diethyl acetal by the usual acetalization conditions of $CH(OEt)_3$/TsOH in EtOH. [c] 2-(*N*-Methyl-2-indolyl)ketene diethyl acetal was obtained. [d] 3*E*:3*Z* = 74:26. [e] *E*:*Z* = 83:17.

Table 2. ^{1}H NMR spectroscopic chemical shifts of the olefinic proton of enol ethers **2**.

Enols	Chemical shift of (*E*)-enol ether [ppm]	Chemical shift of (*Z*)-enol ether [ppm]	Enols	Chemical shift of (*E*)-enol ether [ppm]	Chemical shift of (*Z*)-enol ether [ppm]
2a	5.59[a]	6.83	**2k**	5.70[a]	–
2b	5.54[a]	6.70	**2l**	5.80	–
2c	5.62[b]	–	**2p**	5.35[a]	–
2d	5.61	–	**2q**	5.47[a]	6.85
2e	5.55[a]	–	**2r**	5.51[a]	–
2f	5.60[c]	–	**2s**	5.00[a]	–
2h	5.60	–	**2t**	5.54[d]	–
2i	5.54	–	**2u**	5.98[a]	6.53
2j	5.54	–			

[a] 2% NOE enhancement between the methylene protons of the ethoxy group and the olefinic proton was observed. [b] 2% NOE enhancement was observed between the methyl proton of the ethoxy group and the olefinic proton. [c] 9% NOE enhancement was observed between the methylene proton of the ethoxy group and the olefinic proton. [d] 8% NOE enhancement was observed between the methylene proton of the ethoxy group and the olefinic proton.



Scheme 1. Plausible mechanism for the formation of 1-aryl-2-chloro-1-ethoxyethenes.

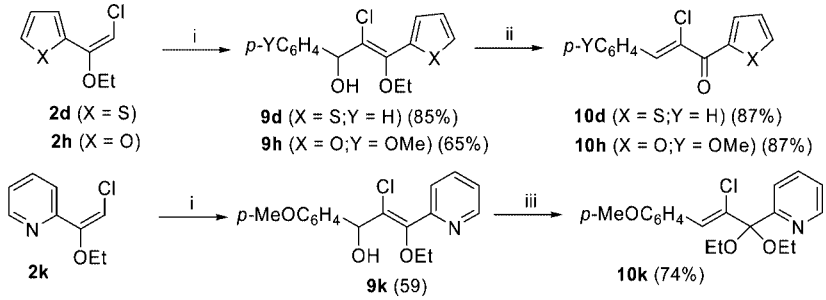
ryl derivative **10h** was also obtained from corresponding allylic alcohol **9h** by using the same procedure. Pyridyl enol ether **2k** afforded corresponding acetal **10k**. These preliminary investigations show the new transformation into the 3-aryl-2-chloro-3-ethoxypropen-1-ols and α,β-unsaturated aryl ketones by our original methodology using β-alkoxy-β-aryl-α-chloroethenyllithiums.[12] The 1,3-biaryl and 1,3-bis(hetaryl)-2-chloro-α,β-unsaturated ketones have been utilized as cyclooxygenase inhibitors (nonsteroidal antiinflammatory drugs) or semiconducting materials.[13]

Conclusions

In summary, we have described a simple and convenient method for the preparation of new 1-aryl-2-chloro-1-ethoxyethenes that can be transformed into aryl chloromethyl ketones, which have a strong inhibiting activity on GSK-3β in Alzheimer's disease.[1] Transformations into other useful derivatives have also been shown in this report. These results show that 1-aryl-2-chloro-1-ethoxyethenes could be a novel building block for various types of biologically active compounds. Now, we are fully investigating the synthesis of 1,3-biaryl-2-chloro-α,β-unsaturated ketones and these results will be reported elsewhere.

Experimental Section

Elemental analyses were measured with a J Science Labo CHN corder (MT-6) at the Center of Instrumentation of Gifu University. Mass and high resolution mass spectra were obtained with a JEOL MS700 spectrometer with a direct insertion probe at an ionization voltage of 70 eV. IR spectra were measured with a JASCO FT-IR 460 PLUS instrument. ^{1}H- and ^{13}C NMR spectra were measured with a JEOL ECA500 spectrometer. Chemical shifts are expressed in parts per million (ppm) with respect to tetramethylsilane as an internal standard. Splitting patterns are designated as follows: s, singlet; d, doublet; t, triplet; q, quartet.



Scheme 2. Alkenylation with 1-aryl-2-chloro-1-ethoxyethenes of aromatic aldehydes.

Typical Experimental Procedure for (*E*)-2-Chloro-1-ethoxystyrene (2a): Phenyllithium in diethyl ether (9.63 mL, 9.63 mmol) was added to a DME (5.0 mL) solution of dichloroacetaldehyde diethyl acetal (0.60 g, 3.2 mmol) at –60 °C under an Ar atmosphere. The mixture was stirred for 15 min and poured into water (50 mL). The organic layer was separated, and the aqueous layer was extracted with diethyl ether (2 × 20 mL). The combined organic layers were dried with $MgSO_4$. The solvent was removed under reduced pressure. The residue was purified by preparative TLC on silica gel with ether/*n*-hexane (1:100) as the eluent to give title compound **2a** (0.35 g, 60%) as a pale yellow oil. IR (KBr): $\tilde{\nu}$ = 2925, 2357, 2341, 1052 (C–O), 512 (C–Cl), 471, 444, 417 cm^{-1}. ^1H NMR (500 MHz, $CDCl_3$): δ = 1.37 (t, J = 7 Hz, 3 H, CH_3), 3.85 (q, J = 7 Hz, 2 H, OCH_2), 5.59 (s, 1 H, olefinic H), 7.34–7.40 (m, 3 H, ArH), 7.59–7.61 (m, 2 H, ArH) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ = 14.66 (q), 64.39 (t), 94.43 (d), 127.91 (d × 2), 128.70 (d × 2), 128.91 (d), 133.91 (s), 156.02 (s) ppm. HRMS: calcd. for $C_{10}H_{11}OCl$ 182.0498; found 182.0408. Product **2a** was too volatile to measure the elemental analysis. (*Z*)-**2a** was observed in the ^1H NMR spectrum in another experiment. ^1H NMR (500 MHz, $CDCl_3$): δ = 1.39 (t, J = 7 Hz, 3 H, CH_3), 4.07 (q, J = 7 Hz, 2 H, OCH_2), 6.83 (s, 1 H, olefinic H), 7.23–7.26 (m, 1 H, ArH), 7.30–7.46 (m, 2 H, ArH), 7.46–7.48 (m, 2 H, ArH). The NOE enhancement between the olefinic proton and the methylene protons of the ethoxy group of (*E*)-**2a** was observed to be 2%.

Typical Experimental Procedure for the Hydrolysis of 2a: One drop of an EtOH solution of 1 M HCl was added to a solution of **2a** (0.10 g, 0.55 mmol) in $ClCH_2CH_2Cl$ (1.0 mL) at room temperature. The mixture was stirred for 10 min and poured into water (30 mL). The organic layer was separated, and the aqueous layer was extracted with diethyl ether. The combined organic layers were dried with $MgSO_4$. The solvent was removed under reduced pressure. The residue was purified by preparative TLC on silica gel with ether/*n*-hexane (1:100) as the eluent to give phenacyl chloride (58.0 mg, 69%).

Acetalization of 2a: An EtOH (0.50 mL) solution of 1 M HCl was added to a EtOH (0.50 mL) solution of **2a** (0.10 g, 0.55 mmol) at room temperature. The mixture was stirred for 10 min and poured into a saturated $NaHCO_3$ (50.0 mL) solution. The usual work up afforded phenacyl chloride diethyl acetal (96.0 mg, 77%) as a yellow oil. IR (KBr): $\tilde{\nu}$ = 2976, 2931, 2889, 1448, 1390, 1283 (CH_2Cl), 1188, 1054 (C–O), 763–702 (phenyl) cm^{-1}. ^1H NMR (500 MHz, $CDCl_3$): δ = 1.23 (t, J = 7 Hz, 6 H, CH_3 × 2), 3.40–3.46 (m, 2 H, OCH_2), 3.48–3.54 (m, 2 H, OCH_2), 3.75 (s, 2 H, OCH_2), 7.30–7.39 (m, 3 H, ArH), 7.53–7.55 (m, 2 H, ArH) ppm. ^{13}C NMR (500 MHz, $CDCl_3$): δ = 15.08 (q × 2), 47.30 (t), 57.02 (t × 2), 101.35 (s), 127.15 (d × 2), 127.89 (d × 2), 128.17 (d), 139.27 (s) ppm. HRMS: calcd. for $C_{12}H_{17}O_2Cl$ 228.0917; found 228.0944.

(*E*)-2-Chloro-1-ethoxy-*p*-methoxystyrene (2b): To an ether/DME (1:1, 2.0 mL) solution of dichloroacetaldehyde diethyl acetal (0.22 g, 1.16 mmol) was added a *p*-methoxyphenyllithium (prepared from 4-bromoanisole and *t*BuLi according to the literature) [14] at –60 °C under an Ar atmosphere. The work up procedure afforded (*E*)-2-chloro-1-ethoxy-*p*-methoxystyrene (**2b**) (0.13 g, 51%) as a yellow oil. IR (KBr): $\tilde{\nu}$ = 2927, 2934, 1607, 1510, 1252, 1210, 1176–1124 (C–O), 1034, 909–834 (phenyl), 734 (C–Cl) cm^{-1}. ^1H NMR (500 MHz, $CDCl_3$): δ = 1.36 (t, J = 7 Hz, 3 H, CH_3), 3.83 (s, 3 H, OCH_2), 3.78–3.89 (m, 2 H, OCH_2), 5.54 (s, 1 H, olefinic H), 6.92 (dd, J = 2 and 7 Hz, 2 H, ArH), 7.57 (dd, J = 2 and 7 Hz, 2 H, ArH) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ = 14.71 (q), 55.24 (q), 64.32 (t), 93.83 (d), 113.30 (d × 2), 126.28 (s), 130.11 (d × 2), 155.72 (s), 159.91 (s) ppm. HRMS: calcd. for $C_{11}H_{13}O_2Cl$ 212.0604; found 212.0552. Product **2b** was too volatile to measure the elemental analysis. (*Z*)-**2b** was obtained under other reaction conditions. (*Z*)-**2b**: IR (KBr): $\tilde{\nu}$ = 2977, 2932, 2367, 2345, 1610, 1511, 1459, 1441, 1287, 1251, 1211, 1175–1114–1094–1055 (C–O), 1037, 909–834 (phenyl), 764–737–650 (C–Cl), 483 cm^{-1}. ^1H NMR (500 MHz, $CDCl_3$): δ = 1.37 (t, J = 7 Hz, 3 H, CH_3), 3.81 (s, 3 H, OCH_3), 4.05 (q, J = 7 Hz, 2 H, OCH_2), 6.70 (s, 1 H, olefinic H), 6.86 (d, J = 9 Hz, 2 H, ArH), 7.38 (d, J = 9 Hz, 2 H, ArH) ppm. HRMS: calcd. for $C_{11}H_{13}O_2Cl$ 212.0604; found 212.0552. The NOE enhancement between the olefinic proton and the methylene protons of the ethoxy group of (*E*)-**2b** was observed to be 3%.

***p*-Methoxyphenacyl Chloride (3b):** M.p. 96–97 °C (dec.). IR (KBr): $\tilde{\nu}$ = 1693 (C=O), 1599, 1513, 1266–1224 (CH_2Cl), 1173, 1021 (C–O), 845–820–781 (phenyl), 590 cm^{-1}. ^1H NMR (500 MHz, $CDCl_3$): δ = 3.89 (s, 3 H, OCH_3), 4.66 (s, 2 H, CH_2), 6.97 (dd, J = 2 and 7 Hz, 2 H, ArH), 7.96 (dd, J = 2 and 7 Hz, 2 H, ArH). MS: m/z = 184 $[M]^+$, 149 $[M - Cl]^+$, 135 $[M - CH_2Cl]^+$. $C_9H_9O_2Cl$ (184.62): calcd. C 58.55, H 4.91; found C 58.34, H 4.84.

(*E*)-2-Chloro-1-ethoxy-*o*-methoxystyrene (2c): To an ether/DME (1:1, 2.0 mL) solution of dichloroacetaldehyde diethyl acetal (0.50 g, 2.67 mmol) was added a *o*-methoxyphenyllithium (prepared from anisole and *n*BuLi according to the literature)[14] at –60 °C under an Ar atmosphere. The work up procedure afforded (*E*)-2-chloro-1-ethoxy-*o*-methoxystyrene (**2c**) (0.27 g, 48%) as a yellow oil. **2c**: IR (KBr): $\tilde{\nu}$ = 2980, 1632, 1597, 1494, 1463, 1280–1248–1207–1133–1101 (C–O), 1048, 1027, 908 (phenyl), 754 (C–Cl) cm^{-1}. ^1H NMR (500 MHz, $CDCl_3$): δ = 1.31 (t, J = 7 Hz, 3 H, CH_3), 3.83 (q, J = 7 Hz, 2 H, OCH_2), 3.84 (s, 3 H, OCH_3), 5.62 (s, 1 H, olefinic H), 6.93–7.00 (m, 2 H, ArH), 7.23–7.29 (m, 1 H, ArH), 7.33–7.37 (m, 1 H, ArH) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ = 15.12 (q), 55.46 (q), 64.38 (t), 96.00 (d), 111.27 (d), 120.49 (d), 123.35 (s), 130.28 (d), 130.39 (d), 154.66 (s), 156.95 (s) ppm. HRMS: calcd. for $C_{11}H_{13}O_2Cl$ 212.0604; found 212.0582. Product **2c** was too volatile to measure the elemental analysis. The stereochemistry of (*E*)-**2c** was determined by NOE experiments from which irradiation of the methyl protons of the ethoxy group increased the intensity of the olefinic proton (2%).

***o*-Methoxyphenacyl Chloride (3c):** M.p. 65–67 °C (dec.). IR (KBr): $\tilde{\nu}$ = 1682 (C=O), 1483 (CH_2Cl), 1017 (C–O), 760 (phenyl) cm^{-1}. ^1H NMR (500 MHz, $CDCl_3$): δ = 3.94 (s, 3 H, OCH_3), 4.78 (s, 2 H, CH_2), 6.99 (J = 8 Hz, 1 H, 3-H), 7.03–7.06 (m, 1 H, ArH), 7.51–7.54 (m, 1 H, ArH), 7.86–7.88 (m, 1 H, ArH) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ = 51.05 (t), 55.62 (q), 111.56 (d), 121.02 (d), 124.83 (s), 131.23 (d), 134.78 (d), 158.88 (d), 192.14 (s) ppm. MS: m/z = 184 $[M]^+$, 149 $[M - Cl]^+$, 135 $[M - CH_2Cl]^+$. $C_9H_9ClO_2$ (184.62): calcd. C 58.55, H 4.91; found C 58.26, H 4.89.

(*E*)-2-(2-Chloro-1-ethoxyethenyl)thiophene (2d): A THF (6.0 mL) solution of thiophene (0.33 g, 3.96 mmol) and 2,2′-bipyridine (10.0 mg, 0.06 mmol) at 0 °C under an Ar atmosphere (modified by the method of 2-furyllithium[9]) was stirred for 30 min. A THF (1.0 mL) solution of dichloroacetaldehyde diethyl acetal (0.20 g, 1.07 mmol) was added dropwise to the reaction mixture at –20 °C. The mixture was stirred for 15 min and poured into water (50.0 mL). The organic layer was separated, and the aqueous layer was extracted with diethyl ether. The combined organic layers were dried with $MgSO_4$. The work up procedure afforded titled compound **2d** (0.16 g, 82%) as a yellow oil. IR (KBr): $\tilde{\nu}$ = 2981, 2926, 2362, 2344, 1195, 706 (thienyl), 460 cm^{-1}. ^1H NMR (500 MHz, $CDCl_3$): δ = 1.39 (t, J = 7 Hz, 3 H, CH_3), 3.89 (q, J = 7 Hz, 2 H, OCH_2), 5.61 (s, 1 H, olefinic H), 7.05–7.07 (m, 1 H, 4-H), 7.35–7.37 (m, 1 H, 5-H), 7.66–7.68 (m, 1 H, 3-H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ = 14.71 (q), 65.14 (t), 94.63 (d), 126.65 (d), 126.78 (d),

127.96 (d), 136.09 (s), 150.22 (s) ppm. HRMS: calcd. for C_8H_9OSCl 188.0062; found 188.0026. Product **2d** was too volatile to measure the elemental analysis.

Chloromethyl 2-Thienyl Ketone (3d): M.p. 42–43 °C (dec.). IR (KBr): $\tilde{\nu}$ = 1675 (C=O), 1414, 1217 (CH_2Cl), 726 (thienyl) cm^{-1}. ^1H NMR (500 MHz, $CDCl_3$): δ = 4.61 (s, 2 H, CH_2Cl), 7.18 (dd, J = 4 and 5 Hz, 1 H, 4-H), 7.73 (dd, J = 1 and 5 Hz, 1 H, 5-H), 7.80 (dd, J = 1 and 4 Hz, 1 H, 3-H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ = 45.55 (t), 128.38 (d), 133.06 (d), 135.02 (d), 140.72 (s), 184.15 (s) ppm. MS: m/z = 160 $[M]^+$, 111$[M - CH_2Cl]^+$. C_6H_5ClOS (160.62): calcd. C 44.87, H 3.14; found C 44.59, H 3.11.

(*E*)-2-(2-Chloro-1-ethoxyethenyl)-5-methylthiophene (2e): To a THF (5.0 mL) solution of 5-methyl-2-thienyllithium [prepared from 2-methylthiophene (0.50 g, 5.09 mmol) and 2,2′-bipyridine (10.0 mg, 0.06 mmol) and *n*BuLi (2.6 M solution in *n*-hexane, 1.96 mL)][9] was added a THF (1.0 mL) solution of dichloroacetaldehyde diethyl acetal (0.32 g, 1.70 mmol) at –20 °C. The reaction mixture was stirred for 15 min and poured into water (30 mL). The work up procedure afforded **2e** (0.24 g, 71%). ^1H NMR (500 MHz, $CDCl_3$): δ = 1.37 (t, J = 7 Hz, 3 H, CH_3), 2.48 (s, 3 H, CH_3), 3.88 (q, J = 7 Hz, 2 H, OCH_2), 5.55 (s, 1 H, olefinic H), 6.71 (m, 1 H, 4-H), 7.43 (t, J = 2 Hz, 1 H, 3-H). MS: m/z = 167 $[M - Cl]^+$. Product **2e** was too volatile to measure the elemental analysis. The stereochemistry of **2e** was determined by an NOE experiment. Irradiation of the olefinic proton of (*E*)-**2e** increased the intensity of the methylene protons of the ethoxy group (2%).

Chloromethyl 5-Methyl-2-thienyl Ketone (3e): M.p. 41–42 °C (dec.). IR (KBr): $\tilde{\nu}$ = 2360, 2341, 1676 (C=O), 1457, 1394, 1240–1221 (CH_2Cl), 1067, 815 (thienyl), 786, 713, 669 cm^{-1}. ^1H NMR (500 MHz, $CDCl_3$): δ = 2.54 (d, J = 2 Hz, 3 H, CH_3), 4.56 (s, 2 H, CH_2Cl), 6.83–6.84 (m, 1 H, 4-H), 7.61 (d, J = 4 Hz, 1 H, 3-H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ = 15.75 (q), 45.14 (t), 126.99 (d), 133.65 (d), 138.18 (s), 151.28 (s), 183.46 (s) ppm. MS: m/z = 174 $[M]^+$, 149 $[M - Cl]^+$, 125 $[M - CH_2Cl]^+$. C_7H_7OSCl (174.65): calcd. C 48.14, H 4.04; found C 48.08, H 4.03.

(*E*)-2-(2-Chloro-1-ethoxyethenyl)-5-trimethylsilylthiophene (2f): To a THF (10 mL) solution of 2-lithio-5-trimethylsilylthiophene [prepared from 2-trimethylsilylthiophene (1.00 g, 6.41 mmol), 2,2′-bipyridine (10 mg, 0.06 mmol) and *n*BuLi (2.6 M solution in *n*-hexane, 2.5 mL, 6.41 mmol)][9] was added dichloroacetaldehyde diethyl acetal (0.40 g, 2.14 mmol) at –20 °C under an Ar atmosphere. The reaction mixture was stirred for 15 min. The work up procedure afforded title **2f** (0.46 g, 83%) as a yellow oil. **2f**: IR (KBr): $\tilde{\nu}$ = 2977, 2957, 2931, 2894, 2359, 1251, 1214, 1189, 1120, 1094, 1065, 1056 (C–O), 974, 842 (thienyl), 810 (C–Si), 758 (C–Cl) cm^{-1}. ^1H NMR (500 MHz, $CDCl_3$): δ = 0.32 (s, 9 H, $CH_3 \times 3$), 1.39 (t, J = 7 Hz, 3 H, CH_3), 3.88 (q, J = 7 Hz, 2 H, OCH_2), 5.60 (s, 1 H, olefinic H), 7.18 (d, J = 3 Hz, 1 H, 4-H), 7.71 (d, J = 3 Hz, 1 H, 3-H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ = –0.18 (q × 3), 14.72 (q), 65.10 (t), 94.66 (d), 129.06 (d), 133.51 (d), 141.01 (s), 141.96 (s), 150.38 (s) ppm. HRMS: calcd. for $C_{11}H_{17}ClOSSi$ 260.0458; found 260.0437. Product **2f** was too volatile to measure the elemental analysis. The stereochemistry of (*E*)-**2f** was determined by NOE experiments. Irradiation of the olefinic proton increased the intensity of the methylene protons of the ethoxy group (9%).

Chloromethyl 5-Trimethylsilyl-2-thienyl Ketone (3f): IR (KBr): $\tilde{\nu}$ = 2957, 2360, 1683–1668 (C=O), 1508, 1421, 1252–1216 (CH_2Cl), 1078, 1001, 844, 758–715 (thienyl) cm^{-1}. ^1H NMR (500 MHz, $CDCl_3$): δ = 0.36 (s, 9 H, $CH_3 \times 3$), 4.60 (d, J = 1 Hz, 2 H, CH_2Cl), 7.27 (d, J = 4 Hz, 1 H, 4-H), 7.81 (d, J = 4 Hz, 1 H, 3-H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ = –0.52 (q × 3), 45.84 (t), 133.57 (d), 134.56 (d), 144.62 (s), 152.54 (s), 183.70 (s) ppm. MS: m/z = 232 $[M]^+$, 198 $[M - Cl]^+$, 183 $[M - CH_2Cl]^+$. $C_9H_{13}OSSiCl$ (232.80): calcd. C 46.43, H 5.63; found C 46.16, H 5.49.

Chloromethyl 5-Methoxy-2-thienyl Ketone (3g): To a THF (10.0 mL) solution of 2-lithio-5-methoxythiophene [prepared from 2-methoxythiophene (0.73 g, 6.41 mmol), 2,2′-bipyridine (10 mg, 0.06 mmol) and *n*BuLi (2.6 M solution in *n*-hexane, 2.47 mL, 6.41 mmol)][9] was added dichloroacetaldehyde diethyl acetal (0.40 g, 2.14 mmol) at –20 °C under an Ar atmosphere. The work up procedure provided chloromethyl 5-methoxythienyl ketone (**3g**) (0.36 g, 88%) as an orange powder. **3g**: M.p. 37–38 °C (dec.). IR (KBr): $\tilde{\nu}$ = 1655 (C=O), 1541, 1475, 1418, 1214 (CH_2Cl), 1075 (C–O), 986 (thienyl) cm^{-1}. ^1H NMR (500 MHz, $CDCl_3$): δ = 3.98 (s, 3 H, OCH_3), 4.49 (s, 2 H, CH_2Cl), 6.29 (d, J = 4 Hz, 1 H, 4-H), 7.55 (d, J = 4 Hz, 1 H, 3-H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ = 44.19 (t), 60.57 (q), 106.43 (d), 126.96 (s), 133.97 (d), 175.74 (s), 183.29 (s) ppm. MS: m/z = 190 $[M]^+$. $C_7H_7O_2SCl$ (190.65): calcd. C 44.10, H 3.70; found C 43.99, H 3.63.

(*E*)-2-(2-Chloro-1-ethoxyethenyl)furan (2h): To a THF (9.0 mL) solution of 2-lithiofuran [prepared from furan (0.95 g, 14.0 mmol), 2,2′-bipyridine (10 mg, 0.06 mmol) and *n*BuLi (2.6 M solution in *n*-hexane, 5.37 mL, 14.0 mmol)][9] was added dichloroacetaldehyde diethyl acetal (0.87 g, 4.65 mmol) at –20 °C under an Ar atmosphere. The reaction mixture was stirred for 15 min and then poured into water (30 mL). The usual work up provided title **2h** (0.61 g, 77%) as a yellow oil. Product **2h** was too sensitive to moisture to isolate in a pure form. Therefore, **2h** was used as soon as possible. **2h**: ^1H NMR (500 MHz, $CDCl_3$): δ = 1.38 (t, J = 7 H_Z, 3 H, CH_3), 3.86 (q, J = 7 H_Z, 2 H, OCH_2), 5.60 (s, 1 H, olefinic H), 6.46 (dd, J = 2 and 4 Hz, 1 H, 4-H), 6.92 (d, J = 4 Hz, 1 H, 3-H), 7.47 (d, J = 2 Hz, 1 H, 5-H) ppm. MS: m/z = 171 $[M - 1]^+$. Product **2h** was too volatile to measure the elemental analysis.

Chloromethyl Furyl Ketone 3h: IR (KBr): $\tilde{\nu}$ = 1682 (C=O), 1466 (CH_2Cl), 766 (furyl) cm^{-1}. ^1H NMR (500 MHz, $CDCl_3$): δ = 4.58 (d, J = 1 Hz, 2 H, CH_2Cl), 6.60 (dd, J = 1 and 3 Hz, 1 H, 4-H), 7.14 (d, J = 3 Hz, 1 H, 3-H), 7.64 (s, 1 H, 5-H) ppm. MS: m/z = 144 $[M]^+$. The structure of **3h** was determined by comparison to the authentic data.[10a]

(*E*)-2-(2-Chloro-1-ethoxyethenyl)-5-methylfuran (2i): To a THF (9.0 mL) solution of 2-lithio-5-methylfuran [prepared from 2-methylfuran (0.95 g, 11.6 mmol), 2,2′-bipyridine (10 mg, 0.06 mmol) and *n*BuLi (2.6 M solution in *n*-hexane, 4.45 mL, 11.6 mmol)][9] was added dichloroacetaldehyde diethyl acetal (0.72 g, 3.86 mmol) at –20 °C under an Ar atmosphere. The reaction mixture was stirred for 15 min. The work up procedure provided **2i** (0.36 g, 50%) as a yellow oil. ^1H NMR(500 MHz, $CDCl_3$): δ = 1.37 (t, J = 7 Hz, 3 H, Me), 2.33 (s, 3 H, Me), 3.85 (q, J = 7 Hz, 2 H, OCH_2), 5.54 (s, 1 H, olefinic H), 6.05 (dd, J = 1 and 3 Hz, 1 H, 3-H), 6.79 (d, J = 3 Hz, 1 H, 4-H) ppm. MS: m/z = 186 $[M]^+$. Product **2i** was too volatile to measure the elemental analysis.

Chloromethyl 5-Methyl-2-furyl Ketone (3i): M.p. 64–65 °C (dec.). IR (KBr): $\tilde{\nu}$ = 6444, 1678 (C=O), 1512, 1399, 1375, 1260–1207 (CH_2Cl), 1062, 1031, 961–802–782–737 (furyl) cm^{-1}. ^1H NMR (500 MHz, $CDCl_3$): δ = 2.42 (s, 3 H, CH_3), 4.53 (s, 2 H, CH_2Cl), 6.23–6.25 (m, 1 H, 4-H), 7.25–7.34 (m, 1 H, 3-H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ = 13.85 (q), 44.62 (t), 109.41 (d), 120.76 (d), 148.87 (s), 158.82 (s), 179.17 (s) ppm. MS: m/z = 157 $[M - 1]^+$, 123 $[M - Cl]^+$, 109 $[M - CH_2Cl]^+$. $C_7H_7ClO_2$ (158.59): calcd. C 53.02, H 4.45; found C 52.93, H 4.38.

Chloromethyl *N*-Methyl-2-pyrroyl Ketone (3j): To an ether/THF (1:1, 20.0 mL) solution of 2-lithio-1-methylpyrole [prepared from *N*-methylpyrole (0.81 g, 10.2 mmol), TMEDA (0.78 g, 6.70 mmol)

and *n*BuLi (2.6 M solution in *n*-hexane, 2.34 mL) according to the literature][15] was added dichloroacetaldehyde diethyl acetal (0.38 g, 2.03 mmol) at –60 °C under an Ar atmosphere. The reaction mixture was stirred for 15 min. The work up procedure provided the residue. The residue was used for the next hydrolysis step without further purification. Title compound **3j** (57 mg, 18%) was obtained. M.p. 36–37 °C (dec.). IR (KBr): $\tilde{\nu}$ = 1671 (C=O), 1405, 1385, 1276 (CH_2Cl), 1090, 973, 755 cm^{-1}. ^1H NMR (500 MHz, $CDCl_3$): δ = 3.95 (s, 3 H, CH_3), 4.50 (s, 2 H, CH_2Cl), 6.17 (dd, J = 3 and 4 Hz, 1 H, 4-H), 6.90 (t, J = 2 Hz, 1 H, 3-H), 6.99 (dd, J = 2 and 4 Hz, 1 H, 5-H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ = 37.56 (q), 45.65 (t), 108.60 (d), 119.83 (d), 127.85 (s), 132.25 (d), 181.30 (s) ppm. MS: m/z = 157 $[M]^+$, 108 $[M - CH_2Cl]^+$. C_7H_8NOCl (157.60): calcd. C 53.35, H 5.12, N 8.89; found C 53.24, H 5.10, N 8.78.

Modified Method for 3j. Typical Procedure with LDA: A THF (8.0 mL) solution of dichloroacetaldehyde diethyl acetal (0.38 g, 2.03 mmol) treated with LDA [prepared from diisopropylamine (0.31 g, 3.05 mmol) and *n*BuLi (2.6 M solution in *n*-hexane, 1.20 mL, 3.05 mmol)] was added to an ether/THF (1:1, 20.0 mL) solution of 2-lithio-1-methylpyrole (prepared by the above method) at –78 °C. The work up procedure provided chloromethyl *N*-methylpyrroyl ketone (**3j**) (0.21 g, 67%).

(*E*)-2-(2-Chloro-1-ethoxyethenyl)pyridine (2k): To an ether (9.0 mL) solution of 2-lithiopyridine [prepared from 2-bromopyridine (1.01 g, 6.41 mmol) and *n*BuLi (2.6 M solution in *n*-hexane, 2.47 mL, 6.41 mmol) according to the literature][16] was added dichloroacetaldehyde diethyl acetal (0.40 g, 2.14 mmol) at –20 °C under an Ar atmosphere. The usual work up provided title compound **2k** (0.30 g, 75%) as a yellow oil. IR (KBr): $\tilde{\nu}$ = 2981, 2360, 1584, 1567, 1471, 1434, 1342, 1219, 1143 (C–O), 1029, 992, 915, 792 (C–Cl), 747 (pyridyl) cm^{-1}. ^1H NMR (500 MHz, $CDCl_3$): δ = 1.40 (t, J = 7 H_Z, 3 H, CH_3), 3.92 (q, J = 7 Hz, 2 H, OCH_2), 5.70 (s, 1 H, olefinic H), 7.26–7.29 (m, 1 H, ArH), 7.59 (d, J = 9 Hz, 1 H, ArH), 7.73 (t, J = 8 Hz, 1 H, ArH), 8.71 (d, J = 4 Hz, 1 H, ArH) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ = 14.43 (q), 64.59 (t), 95.92 (d), 123.36 (d), 124.35 (d), 135.94 (d), 149.25 (d), 152.42 (s), 154.91 (s) ppm. MS: m/z = 185 $[M + 2]^+$. $C_9H_{10}NOCl$ (183.64): C 58.87, H 5.49, N 7.63; found C 58.76, H 5.37, N 7.40. The stereochemistry of (*E*)-**2k** was determined by NOE experiments. Irradiation of the olefinic proton of **2k** increased the intensity of the methylene protons of the ethoxy group (2%).

Chloromethyl 2-Pyridyl Ketone Diethyl Acetal (3k): IR (KBr): $\tilde{\nu}$ = 2978, 1721 (CO), 1589, 1468, 1436, 1391, 1301–1240 (CH_2Cl), 1197, 1148, 1116, 1102–1061 (C–O), 1020, 903, 791, 767, 750, 644, 620 cm^{-1}. ^1H NMR (500 MHz, $CDCl_3$): δ = 1.24 (t, J = 7 Hz, 6 H, $CH_3 \times 2$), 3.34–3.40 (m, 2 H, OCH_2), 3.53–3.59 (m, 2 H, OCH_2), 4.05 (s, 2 H, CH_2Cl), 7.23–7.26 (m, 1 H, ArH), 7.70–7.74 (m, 1 H, ArH), 7.79–7.81 (m, 1 H, ArH), 8.66–8.67 (m, 1 H, ArH) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ = 14.13 (q × 2), 45.18 (t), 57.18 (t × 2), 103.88 (s), 123.07 (d), 123.24 (d), 135.95 (d), 149.13 (d), 157.38 (s) ppm. MS: m/z = 228 $[M - 1]^+$. $C_{11}H_{16}NO_2Cl$ (229.71): calcd. C 57.52, H 7.02, N 6.10; found C 57.43, H 6.94, N 5.93.

(*E*)-2-(2-Chloro-1-ethoxyethenyl)-3-methylimidazole (2l): To an ether (13.0 mL) solution of 2-lithio-1-methylimidazole [prepared from *N*-imidazole (0.53 g, 6.41 mmol), *n*BuLi (2.47 mL, 6.41 mmol) according to the literature][17] was added dichloroacetaldehyde diethyl acetal (0.40 g, 2.14 mmol) at –75 °C under an Ar atmosphere. The reaction mixture was warmed to –20 °C and stirred for 15 min. The work up procedure provided title compound **2l** (0.31 g, 75%) as a yellow oil. IR (KBr): $\tilde{\nu}$ = 2981, 2937, 1475, 1444, 1408, 1392, 1281, 1211, 1136–1068 (C–O), 927, 901, 751–733 (C–Cl) cm^{-1}. ^1H NMR (500 MHz, $CDCl_3$): δ = 1.36 (t, J = 7 Hz, 3 H, CH_3), 3.67 (s, 3 H, N–CH_3), 3.88 (q, J = 7 Hz, 2 H, OCH_2), 5.80 (s, 1 H, olefinic H), 6.93 (d, J = 1 Hz, 1 H, 4-H), 7.13 (d, J = 1 Hz, 1 H, 5-H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ = 14.48 (q), 15.27 (s), 33.38 (q), 64.89 (t), 99.82 (d), 121.43 (d), 128.81 (d), 147.72 (s) ppm. MS: m/z = 186 $[M]^+$. $C_8H_{11}ClN_2O$ (186.64): calcd. C 51.48, H 5.94, N 15.00; found C 51.18, H 5.89, N 14.78.

2-(2′,2′-Diethoxyethenyl)-*N*-methylindole (4o): To an ether (5.0 mL) solution of 2-lithio-1-methylindole [prepared from *N*-methylindole (0.31 g, 2.35 mmol) and *n*BuLi (2.6 M solution in *n*-hexane, 0.90 mL) according to the literature][18] was added dichloroacetaldehyde diethyl acetal (0.22 g, 1.18 mmol) at –78 °C under an Ar atmosphere. The reaction mixture was warmed to –20 °C and then stirred for 15 min. The usual work up produced title compound **4o** (87 mg, 30%) as a yellow oil. IR (KBr): $\tilde{\nu}$ = 2980, 2937, 2894, 2361, 2343, 1655, 1608, 1388, 1342, 1315, 1243, 1197–1093–1059 (C–O), 1028, 935, 883–750–739 (phenyl) cm^{-1}. ^1H NMR (500 MHz, $CDCl_3$): δ = 1.18 (t, J = 7 Hz, 3 H, CH_3), 1.38 (t, J = 7 Hz, 3 H, CH_3), 3.65 (q, J = 7 Hz, 2 H, OCH_2), 3.80 (s, 3 H, N–CH_3), 3.89 (q, J = 7 Hz, 2 H, OCH_2), 5.65 (s, 1 H, olefinic H), 6.75 (s, 1 H, 3-H), 7.13–7.16 (m, 1 H, ArH), 7.27–7.30 (m, 1 H, ArH), 7.37 (d, J = 8 Hz, 1 H, ArH), 7.66 (d, J = 8 Hz, 1 H, ArH) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ = 14.60 (q), 15.14 (q), 30.71 (q), 64.88 (t), 66.14 (t), 98.87 (d), 105.26 (d), 109.67 (d), 119.95 (d), 121.27 (d), 122.69 (d), 127.17 (s), 130.56 (s), 137.58 (s), 151.68(s) ppm. MS: m/z = 177. $C_{15}H_{19}NO_2$ (245.32): calcd. C 73.44, H 7.81, N 5.71; found C 73.18, H 7.68, N 5.53.

(*E*)-2-(2-Chloro-1-ethoxyethenyl)bornene (2p). Typical Procedure: To an *n*-hexane/tetramethylenediamine (1:1, 8.0 mL) solution of 2-lithiobornene [prepared from D-camphor 2,4,6-triisopropylbenzenesulfonyl hydrazide (0.85 g, 2.10 mmol) and *s*-BuLi (1.0 M solution in cyclohexane/*n*-hexane, 4.62 mL, 4.62 mmol) according to the literature][19] was added a THF (3.0 mL) solution of 2-chloroketene diethyl acetal [generated in situ from dichloroacetaldehyde diethyl acetal (0.20 g, 1.07 mmol) and LDA (diisopropylamine (0.16 g, 1.60 mmol) and *n*BuLi (0.62 mL, 1.60 mmol)] at –50 °C under an Ar atmosphere. The mixture was warmed to –20 °C and stirred for 15 min. The usual work up and the purification with preparative TLC on alumina (ether/*n*-hexane, 1:100) produced title compound **2p** (87 mg, 38%) as a yellow oil. IR (KBr): $\tilde{\nu}$ = 2955, 2873, 1687, 1669, 1591, 1474, 1459, 1442, 1387, 1366, 1334, 1292, 1204, 1181–1153, 1115–1107, 1081 (C–O), 1028, 917, 886, 835, 725 (C–Cl), 420 cm^{-1}. ^1H NMR (500 MHz, $CDCl_3$): δ = 0.78 (s, 2 H, CH_2), 0.91 (s, 2 H, CH_2), 1.03 (s, 2 H, CH_2), 1.29 (t, J = 7 Hz, 3 H, CH_3), 1.54 (s, 2 H, CH_2), 1.83–1.89 (m, 1 H, CH), 2.38–2.39 (m, 1 H, CH), 3.71 (q, J = 7 Hz, 2 H, OCH_2), 5.35 (s, 1 H, olefinic H), 6.22 (d, J = 3 Hz, 1 H, olefinic H). ^{13}C NMR (500 MHz, $CDCl_3$): δ = 11.43 (q), 19.76 (q), 24.93 (t), 31.47 (t), 52.14 (t), 55.43 (s), 56.82 (s), 63.37 (d), 77.19 (t), 93.48 (d), 137.50 (d), 155.24 (s). MS: m/z = 213 $[M + 1]^+$.

(1*E*,3*E*)- and (1*E*,3*Z*)-4-Chloro-1,3-diethoxy-2-(phenylselanyl)buta-1,3-diene (2q): To a THF (7.0 mL) solution of 1-lithio-2-ethoxy-1-(phenylselanyl)ethene [generated in situ from 2-ethoxy-1-(phenylselanyl)ethene (0.68 g, 3.00 mmol) and *n*BuLi (2.6 M solution in *n*-hexane,1.15 mL, 3.00 mmol) according to the literature][3] was added 2-chloro-1,1-diethoxyethene [prepared from dichloroacetaldehyde diethyl acetal (0.19 g, 1.00 mmol), diisopropylamine (0.15 g, 1.5 mmol) and *n*BuLi (2.6 M solution in *n*-hexane, 0.58 mL) in THF (3.0 mL)] at –78 °C under an Ar atmosphere. The reaction mixture was warmed to 0 °C and stirred for 1 h. The usual work up and the purification with preparative TLC on alumina (ether/*n*-hexane, 1:100) provided title compound **2q** (0.15 g, 46%) as a yellow oil.

IR (KBr): $\tilde{\nu}$ = 2362, 2344, 1648, 1637, 1628, 1059 (C–O), 737 (C–Cl), 669 (phenyl), 491, 421 cm^{-1}. ^1H NMR (500 MHz, $CDCl_3$): δ = 1.19 [t, J = 7 Hz, (3*E*)-CH_3], 1.34 [t, J = 7 Hz, (3*Z*)-CH_3], 3.69 [q, J = 7 Hz, (3*E*)-OCH_3], 3.75 [q, J = 7 Hz, (3*Z*)-OCH_2], 4.03–4.09 [m, (3*E*)- and (3*Z*)-OCH_2], 5.47 [s, (3*E*)-olefinic H], 6.85 [s, (3*E*)-olefinic H], 6.95 [s, (3*Z*)-olefinic H], 7.18–7.26 [m, (3*E*)- and (3*Z*)-ArH], 7.34–7.38 [m, (3*Z*)-ArH], 7.50–7.52 [m, (*E*)- and (*Z*)-ArH × 2], 7.55–7.59 [m, (3*E*)-ArH] ppm. ^{13}C NMR of (*3E*)-**2q**: (100 MHz, $CDCl_3$): δ = 14.50 (q), 15.48 (q), 64.47 (t), 69.54 (t), 97.53 (d), 97.75 (s), 128.66 (d × 2), 128.80 (d), 130.69 (d × 2), 152.82 (s), 156.22 (d) ppm. HRMS: calcd. for $C_{14}H_{17}O_2ClSe$ 332.0080; found 332.0042. The NOE enhancement between the olefinic proton and the methylene protons of the ethoxy group of (*E*)-**2q** was observed to be 2%.

(1*E*,3*E*)-4-Chloro-1,3-diethoxy-2-(phenylsulfanyl)buta-1,3-diene (2r): To a THF (5.0 mL) solution of 1-lithio-2-ethoxy-1-(phenylsulfanyl)ethene [generated in situ from 2-ethoxy-1-(phenylsulfanyl)-ethene (0.36 g, 2.0 mmol) and *n*BuLi (2.6 M solution of *n*-hexane, 0.77 mL, 2.00 mmol)][3] was added 1-chloro-2,2-diethoxyethene [prepared from dichloroacetaldehyde diethyl acetal (0.19 g, 1.00 mmol), diisopropylamine (0.15 g, 1.50 mmol) and *n*BuLi (2.6 M solution in *n*-hexane, 0.58 mL) in THF (3.0 mL)] at –70 °C under an Ar atmosphere. The mixture was warmed at –20 °C and stirred for 15 min. The usual work up and the purification with preparative TLC on alumina (ether/*n*-hexane, 1:100) provided title compound **2r** (94 mg, 33%) as a yellow oil. IR (KBr): $\tilde{\nu}$ = 2980, 2931, 2886, 1625, 1605, 1583, 1478, 1440, 1391, 1355, 1307, 1206–1181–1132–1114–1061–1026 (C–O), 1000, 924, 885–860 (phenyl), 741–691 (C–Cl) cm^{-1}. ^1H NMR (500 MHz, $CDCl_3$): δ = 1.19 (t, J = 7 Hz, 3 H, CH_3), 1.36 (t, J = 7 Hz, 3 H, CH_3), 3.68 (q, J = 7 Hz, 2 H, OCH_2), 4.07 (q, J = 7 Hz, 2 H, OCH_2), 5.51 (s, 1 H, olefinic H), 6.83 (s, 1 H, olefinic H), 7.12–7.15 (m, 1 H, ArH), 7.22–7.25 (m, 2 H, ArH × 2), 7.36–7.38 (m, 2 H, ArH × 2) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ = 14.49 (q), 15.43 (q), 40.87 (s), 64.54 (t), 69.82 (t), 98.88 (d), 125.61 (d), 127.86 (d × 2), 128.42 (d × 2), 137.09 (s), 151.64 (s), 155.86 (d) ppm HRMS: calcd. for $C_{14}H_{17}ClO_2S$ 284.0634; found 284.0625.

(2*E*,4*E*)-5-Chloro-2,4-diethoxy-3-(phenylsulfanyl)-1,1,1-trifluoropenta-2,4-diene (2s): To a THF (3.0 mL) solution of 1-lithio-2-ethoxy-3,3,3-trifluoro-1-(phenylsulfanyl)prop-1-ene [generated in situ from 2-ethoxy-3,3,3-trifluoro-1-(phenylsulfanyl)prop-1-ene (0.37 g, 1.06 mmol) and *n*BuLi (2.6 M solution in *n*-hexane, 0.31 mL, 1.06 mmol) according to the literature][4] was added 2-chloro-1,1-diethoxyethene [prepared from dichloroacetaldehyde diethyl acetal (99 mg, 0.53 mmol), diisopropylamine (81 mg, 0.80 mmol) and *n*BuLi (2.6 M solution in *n*-hexane, 0.31 mL, 0.80 mmol) in THF (2.0 mL)] at –78 °C under an Ar atmosphere. The reaction mixture was warmed to room temp. and stirred for 12 h. The usual work up and the purification with preparative TLC on alumina (ether/*n*-hexane, 1:100) provided title compound **2s** (0.145 g, 78%) as a yellow oil. IR (KBr): $\tilde{\nu}$ = 3104, 3062, 2984, 2940, 2900, 1653, 1602, 1475, 1442, 1395–1368–1310–1254 (C–F), 1185, 1124–1068 (C–O), 1024, 1010, 893, 858, 839 (phenyl), 750, 709–690 (C–Cl), 496, 426 cm^{-1}. ^1H NMR (500 MHz, $CDCl_3$): δ = 1.11 (t, J = 7 Hz, 3 H, CH_3), 1.44 (t, J = 7 Hz, 3 H, CH_3), 2.84–3.47 (m, 2 H, OCH_2), 4.16 (q, J = 7 Hz, 2 H, OCH_2), 5.00 (s, 1 H, olefinic H), 7.29–7.39 (m, 3 H, ArH × 3), 7.55–7.57 (m, 2 H, ArH × 2) ppm. ^{19}F NMR (376.4 MHz, $CDCl_3$): δ = –12.19 (d, J = 11 Hz, 3F, CF_3) ppm. MS: m/z = 352 $[M]^+$. $C_{15}H_{16}O_2F_3SCl$ (352.80): calcd. C 51.07, H 4.57; found C 51.02, H 4.48. The NOE enhancement between the olefinic proton and the methylene protons of the 4-ethoxy group of (2*E*,4*E*)-**2s** was observed to be 2%.

(2*E*,4*E*)-5-Chloro-2,4-diethoxy-3-(methylsulfanyl)-1,1,1-trifluoropenta-2,4-diene (2t): To a THF (5.0 mL) solution of 1-lithio-2-ethoxy-3,3,3-trifluoro-1-(methylsulfanyl)prop-1-ene [generated in situ from 2-ethoxy-3,3,3-trifluoro-1-(methylsulfanyl)prop-1-ene (0.37 g, 2.0 mmol) and *n*BuLi (2.6 M solution in *n*-hexane, 0.77 mL, 2.0 mmol) according to the literature][4] was added 2-chloro-1,1-diethoxyethene [prepared from dichloroacetaldehyde diethyl acetal (0.19 g, 1.0 mmol), diisopropylamine (0.15 g, 1.5 mmol) and *n*BuLi (2.6 M solution of *n*-hexane, 0.58 mL, 1.50 mmol)] at –78 °C under an Ar atmosphere. The reaction mixture was warmed to room temp. and stirred for 7 h. The usual work up and the purification with preparative TLC on alumina (ether/*n*-hexane, 1:100) provided title compound **2t** (0.19 g, 66%) as a yellow oil. IR (KBr): $\tilde{\nu}$ = 3105, 2985, 2931, 2900, 2367, 2345, 1648, 1602, 1478, 1439, 1395–1368–1325–1308 (C–F), 1183, 1123–1073 (C–O), 1011, 972, 893, 863, 841, 751, 731, 696 (C–Cl) cm^{-1}. ^1H NMR (500 MHz, $CDCl_3$): δ = 1.34 (t, J = 7 Hz, 3 H, CH_3), 1.38 (t, J = 7 Hz, 3 H, CH_3), 2.17 (s, 3 H, SCH_3), 3.80 (s, 2 H, OCH_2), 4.06 (q, J = 7 Hz, 2 H, OCH_2), 5.54 (s, 1 H, olefinic H) ppm. ^{19}F NMR (376.4 MHz, $CDCl_3$): δ = –3.43 (s, 3F, CF_3) ppm. HRMS: calcd. for $C_{10}H_{14}O_2F_3SCl$ 290.0355; found 290.0366. Product **2t** was too volatile to measure the elemental analysis. The NOE enhancement between the olefinic proton and the methylene protons of the ethoxy group of (2*E*,4*E*)-**2t** was observed to be 8%.

(*E*)- and (*Z*)-3-Ethoxy-4-chloro-1-phenylbut-3-en-1-yne (2u): To a THF (10.0 mL) solution of phenylethynyllithium [prepared from phenylacetylene (0.62 g, 6.07 mmol) and *n*BuLi (2.6 M solution in *n*-hexane, 2.33 mL, 6.07 mmol)] was added 2-chloro-1,1-diethoxyethene [prepared from dichloroacetaldehyde diethyl acetal (0.38 g, 2.02 mmol), diisopropylamine (0.31 g, 3.03 mmol) and *n*BuLi (2.6 M solution in *n*-hexane, 1.17 mL, 3.03 mmol)] at –20 °C under an Ar atmosphere. The reaction mixture was stirred for 15 min. The work up procedure provided title compound **2u** (*E*:*Z* = 83:17) (0.17 g, 42%) as a yellow oil. IR (KBr): $\tilde{\nu}$ = 3084, 2982, 2929, 2345, 2223, 1602, 1490, 1442, 1369, 1338, 1181, 1172, 1114 (C–O), 1039, 961, 885–832 (phenyl), 756–689 (C–Cl) cm^{-1}. ^1H NMR (500 MHz, $CDCl_3$): δ = 1.34 (t, J = 7 Hz, 3 H, CH_3), 3.96 (q, J = 7 Hz, 2 H, OCH_2), 5.98 (s, 1 H, *E*-olefinic H), 7.33–7.37 (m, 3 H, ArH), 7.52–7.54 (m, 2 H, ArH) {a small amount of the (*Z*) isomer was observed at δ = 6.53 [s, (*Z*)-olefinic H] in the ^1H NMR spectrum}. ^{13}C NMR of (3*E*) isomer (500 MHz, $CDCl_3$): δ = 14.71 (q), 65.49 (t), 80.56 (s), 96.73 (s), 128.34 (d × 2), 129.15 (d), 131.77 (d × 2), 141.13 (s). HRMS: calcd. for $C_{12}H_{11}OCl$ 206.0498; found 206.0474. The NOE enhancement between the olefinic proton and the methylene protons of the ethoxy group of (3*E*)-**2u** was observed to be 2%.

(*Z*)-2-(2-Chloro-1-ethoxy-3-phenyl-3-hydroxyprop-2-enyl)thiophene (9d). Typical Procedure: To a THF (6.0 mL) solution of (*E*)-2-(2-chloro-1-ethoxyethenyl)thiophene (**2d**)(0.50 g, 2.65 mmol) was added *n*BuLi (1.02 mL, 2.65 mmol) at –78 °C under an Ar atmosphere. After 10 min stirring, a THF (1.0 mL) solution of benzaldehyde (0.19 g, 1.77 mmol) was added dropwise to the mixture. The mixture was stirred for 10 min and poured into water (50 mL). The usual work up afforded title compound **9d** (0.39 g, 85%) as a yellow oil. IR (KBr): $\tilde{\nu}$ = 3733 (OH), 1612, 1052 (C–O), 701 (C–Cl) cm^{-1}. ^1H NMR (500 MHz, $CDCl_3$): δ = 1.31 (t, J = 7 Hz, 3 H, Me), 2.97 (br. s, 1 H, OH), 3.75–3.90 (m, 2 H, OCH_2), 6.20 (s, 1 H, CHO), 7.04 (dd, J = 4 and 5 Hz, 1 H, 4-H), 7.19–7.37 (m, 4 H, ArH), 7.45–7.48 (m, 3 H, ArH) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ = 15.23 (q), 68.71 (t), 70.23 (d), 124.18 (s), 125.90 (d × 2), 126.83 (d), 127.54 (d), 127.57 (d), 128.25 (d × 2), 129.50 (d), 135.37 (s), 140.83 (s), 146.44 (s) ppm. MS: m/z = 294 $[M]^+$, 259 $[M - Cl]^+$.

$C_{15}H_{15}O_2SCl$ (294.80): calcd. C 61.11, H 5.13; found C 60.89, H 5.10.

(*E*)-2-[2-Chloro-1-ethoxy-3-(*p*-methoxyphenyl)-3-hydroxyprop-1-enyl]furan (9h): To a THF (2.0 mL) solution of (*E*)-2-(2-chloro-1-ethoxyethenyl)furan (**2h**)(95 mg, 0.55 mmol) was added *n*BuLi (2.6 M solution in *n*-hexane, 0.21 mL, 0.55 mmol) at –78 °C under an Ar atmosphere. After stirring for 10 min, a THF (1.0 mL) solution of *p*-methoxybenzaldehyde (50 mg, 0.37 mmol) was added dropwise to the mixture. The mixture was stirred for 10 min and then poured into water (50 mL). The usual work up produced title compound **9h** (0.11 g, 65%) as a yellow oil. IR (KBr): $\tilde{\nu}$ = 3443 (OH), 2932, 1612, 1511 (furyl), 1248, 1172, 1068, 1032 (C–O), 830, 748 (C–Cl) cm^{-1}. ^1H NMR (500 MHz, $CDCl_3$): δ = 1.31 (t, J = 7 Hz, 3 H, Me), 2.84 (d, J = 7 Hz, 1 H, OH), 3.77 (s, 3 H, OMe), 3.79–3.89 (m, 2 H, OCH_2), 6.15 (d, J = 7 Hz, 2 H, ArH), 6.46 (dd, J = 2 and 3 Hz, 1 H, ArH), 6.86–6.88 (m, 3 H, ArH), 7.38 (d, J = 8 Hz, 2 H, ArH), 7.47 (d, J = 2 Hz, 1 H, ArH) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ = 15.17 (q × 2), 55.14 (q), 68.54 (t), 69.53 (d), 111.11 (d), 113.59 (d × 2), 113.85 (d), 124.04 (s), 127.10 (d × 2), 132.94 (s), 142.62 (d), 142.92 (s), 146.51 (s) 158.96 (s) ppm. MS: m/z = 303 $[M - 5]^+$.

(*E*)-2-[2-Chloro-1-ethoxy-3-hydroxy-3-(*p*-methoxyphenyl)prop-1-enyl]pyridine (9k): To a THF (4.0 mL) solution of (*E*)-2-(2-chloro-1-ethoxyethenyl)pyridine (**2k**) (0.20 g, 1.09 mmol) was added *n*BuLi (2.6 M solution in *n*-hexane, 0.42 mL, 1.09 mmol) at –78 °C under an Ar atmosphere. After stirring for 10 min, a THF (1.0 mL) solution of *p*-methoxybenzaldehyde (0.10 g, 0.73 mmol) was added dropwise to the mixture. The mixture was stirred for 10 min and then poured into water (50 mL). The usual work up produced title compound **9k** (0.14 g, 59%) as a yellow oil. IR (KBr): $\tilde{\nu}$ = 3422 (OH), 3205, 1614, 1589, 1509, 1468, 1434, 1299, 1242, 1084, 750 cm^{-1}. ^1H NMR (500 MHz, $CDCl_3$): δ = 1.24 (t, J = 7 Hz, 3 H, Me), 3.59 (d, J = 4 Hz, 1 H, OH), 3.61–3.71 (m, 2 H, OCH_2), 3.78 (s, 3 H, OMe), 6.29 (d, J = 4 Hz, 1 H, CHO), 6.89 (d, J = 9 Hz, 2 H, ArH), 7.24–7.27 (m, 1 H, ArH), 7.48 (d, J = 9 Hz, 2 H, ArH), 7.57 (d, J = 8 Hz, 1 H, ArH), 7.70–7.74 (m, 1 H, ArH), 8.68–8.69 (m, 1 H, ArH) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ = 15.01 (q), 55.08 (q), 66.44 (t), 69.14 (d), 113.48 (d × 2), 123.38 (d), 124.55 (s), 125.58 (d), 127.13 (d × 2), 133.18 (s), 136.09 (d), 149.36 (d), 149.75 (s), 151.78 (s), 158.81 (s) ppm. MS: m/z = 319 (small $[M]^+$). $C_{17}H_{18}ClNO_3$ (319.79): calcd. C 63.85, H 5.67, N 4.38; found C 63.68, H 5.63, N 4.35.

(*Z*)-1-Chloro-2-phenylethenyl 2-Thienyl Ketone (10d). Typical Procedure: TMSOTf (72 mg, 0.32 mmol) was added dropwise to a CH_2Cl_2 (2.0 mL) solution of **9d** (84 mg, 0.032 mmol) at –78 °C under an Ar atmosphere. The usual work up provided title compound **10d** (70 mg, 87%) as a yellow oil. IR (KBr): $\tilde{\nu}$ = 1641, 1411 (thienyl), 1605, 1262, 1510, 1491, 1447, 1201, 763 (C–Cl), 730, 691 cm^{-1}. ^1H NMR (500 MHz, $CDCl_3$): δ = 7.17 (dd, J = 4 and 5 Hz, 1 H, 4-H), 7.42–7.47 (m, 3 H, ArH), 7.66 (s, 1 H, olefinic H), 7.74 (dd, J = 1 and 5 Hz, 1 H, 5-H), 7.85–7.87 (m, ArH, 3 H, 3-H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ = 127.95 (d), 128.56 (d × 2), 129.01 (s), 130.20 (d), 130.50 (d × 2), 132.85 (s), 134.54 (d), 134.74 (d), 137.07 (d), 141.49 (s), 182.25 (s) ppm. MS: m/z = 248 $[M]^+$, 213 $[M - Cl]^+$. $C_{13}H_9SCl$ (232.73): calcd. C 62.78, H 3.65; found C 62.64, H 3.56.

(*Z*)-1-Chloro-2-(*p*-methoxyphenyl)ethenyl 2-Furyl Ketone (10h): TMSOTf (69.0 mg, 0.31 mmol) was added dropwise to a CH_2Cl_2 (2.0 mL) solution of **9h** (95 mg, 0.31 mmol) at –78 °C under an Ar atmosphere. The usual work up produced title compound **10h** (70 mg, 87%) as a yellow oil. IR (KBr): $\tilde{\nu}$ = 3435, 3133, 2934, 2839, 1644, 1597 (furyl), 1509, 1462, 1258, 1180, 1094, 1027 (C–O), 793 (C–Cl), 535 cm^{-1}. ^1H NMR (500 MHz, $CDCl_3$): δ = 3.86 (s, 3 H, OMe), 6.58–6.60 (m, 1 H, 4-H), 6.94–6.98 (m, 2 H, 3-H and ArH), 7.37 (d, J = 3 Hz, 1 H, olefinic H), 7.69 (t, J = 1 Hz, 1 H, 5-H), 7.84–7.92 (m, 3 H, ArH) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ = 55.41 (q), 112.25 (d), 114.12 (d × 2), 120.57 (d), 125.70 (s), 126.65 (s), 132.95 (d × 2), 137.98 (d), 147.14 (d), 150.91 (s), 161.35 (s), 176.86 (s) ppm. MS: m/z = 262 $[M]^+$, 227 $[M - Cl]^+$. $C_{14}H_{11}O_3Cl$ (262.69): calcd. C 64.01, H 4.22; found C 63.72, H 4.26.

(*Z*)-2-[2-Chloro-1,1-diethoxy-3-(*p*-methoxyphenyl)prop-2-enyl]pyridine (10k). Typical Procedure: To an EtOH (2.0 mL) solution of **9k** (57 mg, 0.18 mmol) was added ethyl orthoformate (0.13 g, 0.89 mmol) and *p*-toluenesulfonic acid (3.00 mg, 0.02 mmol) at room temperature. The mixture was stirred for 30 min and poured into a saturated $NaHCO_3$ (30.0 mL). The work up procedure afforded title compound **10k** (46 mg, 74%) as a yellow oil. IR (KBr): $\tilde{\nu}$ = 2982, 2937, 2896, 2363, 1603, 1510, 1285, 1250, 1184, 1069, 833 cm^{-1}. ^1H NMR (500 MHz, $CDCl_3$): δ = 1.28 (t, J = 7 Hz, 6 H, Me), 3.36–3.42 (m, 2 H, OCH_2), 3.53–3.60 (m, 2 H, OCH_2), 3.80 (s, 3 H, OMe), 6.87 (d, J = 8 Hz, 2 H, ArH), 7.20 (dd, J = 5 and 8 Hz, 1 H, ArH), 7.55 (s, 1 H, olefinic H), 7.70–7.72 (m, 1 H, ArH), 7.71 (d, J = 8 Hz, 2 H, ArH), 7.86 (br. d, J = 8 Hz, 1 H, ArH), 8.63 (br. d, J = 6 Hz, 1 H, ArH) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ = 15.08 (q × 2), 55.15 (q), 57.87 (t × 2), 102.04 (s), 113.40 (d × 2), 122.85 (d), 123.20 (d), 126.78 (d), 126.93 (s), 129.51 (s), 131.04 (d × 2), 135.94 (d), 149.09 (d), 158.29 (s), 159.23 (s) ppm. MS: m/z = 347 $[M]^+$. $C_{19}H_{22}ClNO_3$ (347.84): calcd. C 65.61, H 6.38, N 4.03; found C 65.37, H 6.33, N 4.02.

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