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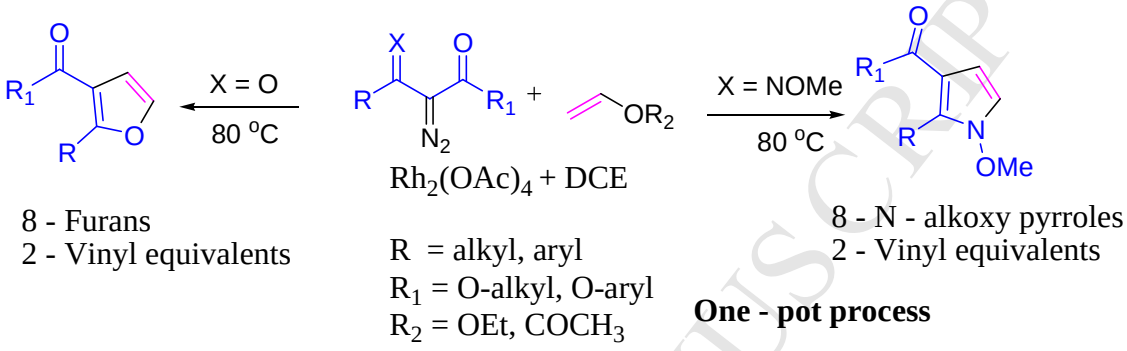

For the first time, we report the synthesis of 2-substituted N-alkoxy pyrrole 3-carboxylate and furan 3-carboxylate *via* Rh-catalyzed [3+2] cycloaddition between α-diazo oxime ether or *α*-diazo carbonyl compounds with vinyl equivalents in a one-pot process. We have demonstrated ethyl vinyl ether as well as vinyl acetate as vinyl equivalents and both were found to give excellent yields. We have also demonstrated the synthesis of N-alkoxy dihydropyrrole derivatives by carrying out the reaction at low temperature.

Keywords: N-alkoxy pyrrole, [3+2] cycloaddition, imino carbenoids, 2,3-disubstituted furan, diazo carbonyl compounds.

Rhodium-catalyzed synthesis of 2,3 – disubstituted N-methoxy pyrroles and furans *via* [3+2] cycloaddition between metal carbenoids and activated olefins

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Pyrroles are the basic nitrogen containing heterocycles,[1] which have attracted the synthetic chemists throughout the world. Pyrrole derivatives find application[2] in several fields such as medicinal, agrochemical, dyes, flavouring agents, pesticides, solar cells, organic functional molecules etc. They exhibit several biological activities[3] such as antifungal, antibacterial, antitumor, antimalarial, antibiotic, antipsychotic and used for the treatment of diseases such as Alzheimer, neoplastic etc. Owing to the potential applications of pyrrole derivatives, several methods have been reported to obtain them. In addition to the classical methods such as Paal-Knorr,[4] Huisgen[5] and Hantzsch,[6] several other methods[7] had been developed in recent years. Generally, the synthesis involves intramolecular cyclization or cycloaddition in the presence of metal catalysts.

In recent years, imino carbenoids have gained much attention in synthetic organic chemistry as they react with a variety of functional groups including highly unreactive aromatic hydrocarbon. 1 – Sulfonyl – 1, 2, 3 triazole derivatives have been demonstrated as the stable precursor for imino carbenoids[8] and successfully subjected to transannulation with alkyne, alkene, vinyl ether to get pyrroles. Since, 1 – sulfonyl – 1, 2, 3-triazole is generally prepared from terminal alkyne and tosyl azide in the presence of Cu catalyst to avoid regioisomers whereas, 2 – substituted heterocycles cannot be synthesized by this approach. Further, the sulfonyl group is deprotected under harsh reaction conditions to obtain N- heterocycles. **Recently, Xu et. al. have reported[9] $Cu(hfacac)_2$ catalyzed synthesis of highly substituted/fused pyrroles *via* carbene cascade reaction of *α*-imino diazo compounds.** We have reported[10] that *α*-diazo oxime ether could also serve as a precursor for imino carbenoids. Unlike 1,2,3-triazole derivatives as precursors for imino carbenoids, highly

substituted derivatives could be prepared regioselectively with α-diazo oxime ether. In this communication, we report for the first time, synthesis of 2, 3-disubstituted N-alkoxy pyrrole *via* 3+2 cycloaddition between α-diazo oxime ether and ethyl vinyl ether (**Fig. 1**).

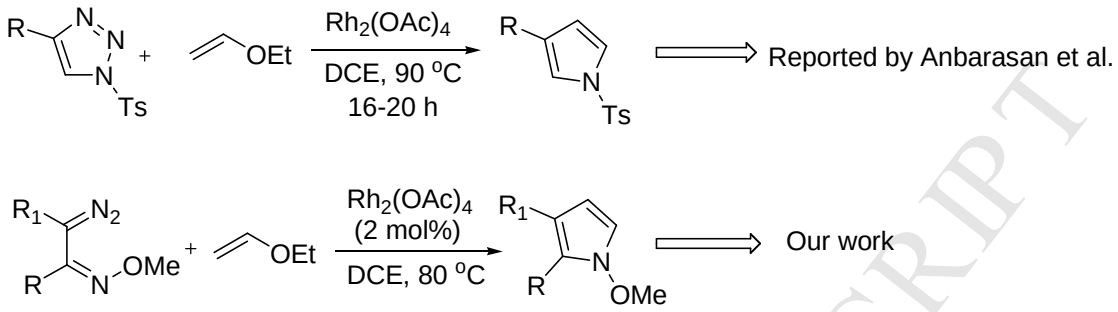
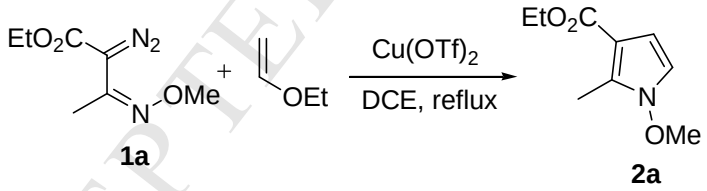


Fig. 1

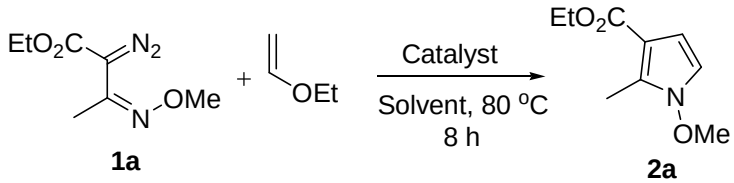
Recently, we reported[11] a two-step one-pot process for the synthesis of α-diazo oxime ether directly from the β-keto ester. During the investigation of its ability to serve as potential building block in the synthesis of N-heterocycles, we found that, the α-diazo oxime ether **1a** undergoes [3+2] cycloaddition with ethyl vinyl ether in the presence of $Cu(OTf)_2$ (5 mol%), in dichloroethane (DCE) at 80 °C to give N-methoxy pyrrole **2a** in poor yield of 21% (**Scheme 1**).



Scheme 1: Synthesis of 2,3-disubstituted N-alkoxy pyrrole

In order to improve the yield of N-methoxy pyrrole **2a**, we screened several transition metal catalysts that are known to form metal carbenoids in different solvents and the results are tabulated (**Table 1**).

Table 1: Optimization of reaction conditions[a]

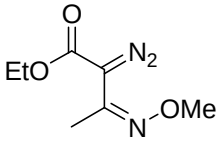
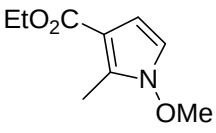


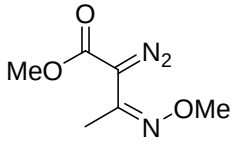
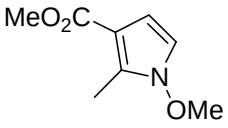
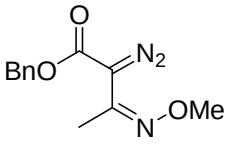
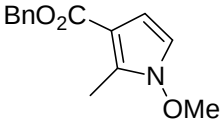
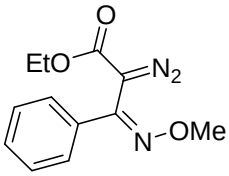
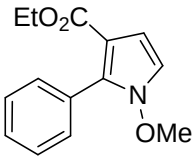
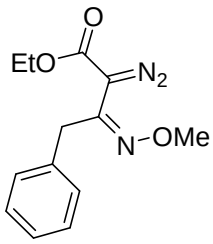
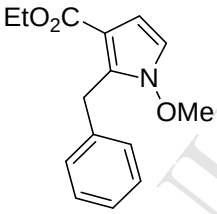
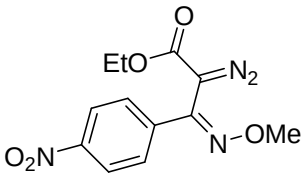
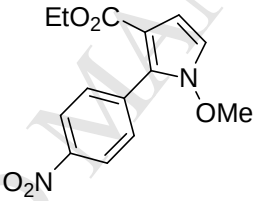
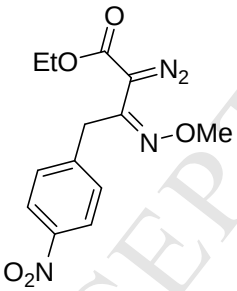
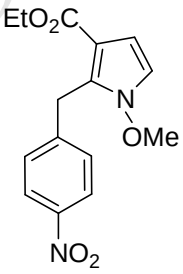
Entry	Catalyst (mol %)	Solvent	Yield[b] (%)
1	$Cu(OTf)_2$ (2.0)	DCE	21
2	$Cu(OTf)_2$ (5.0)	DCE	38
3	$Cu(hfacac)_2$ (2.0)	DCE	Trace[c]
4	$Cu(hfacac)_2$ (5.0)	DCE	25
5	$Rh_2(OAc)_4$ (1.0)	DCE	73
6	**$Rh_2(OAc)_4$ (2.0)**	**DCE**	**87 (90)[e]**
7	$Rh_2(OAc)_4$ (2.0)	$CHCl_3$	68[d]
8	$Rh_2(OAc)_4$ (2.0)	THF	65[d]
9	$Rh_2(OAc)_4$ (2.0)	Toluene	69

[a]Reaction conditions: *α*-diazo Oxime ether 1a (2 mmol), ethyl vinyl ether (3 mmol), Solvent (3 mL/mmol), 80 °C, 8 h. [b]Yield corresponds to the isolated product by column chromatography, [c]Observed by HPLC. [d]Reaction was carried out in sealed tube. [e]Yield with 3 mol% $Rh_2(OAc)_4$.

In contrast to our earlier reports,[12] in which copper salts were found to be a better catalyt than Rhodium complexes to promote [3+2] cycloaddition between imino carbenoids and enamino esters or nitriles, $Rh_2(OAc)_4$ was found to give better yield of [3+2] cycloaddition product than copper catalysts. The optimal catalyst loading was found to be 2 mol%. Increasing the catalyst loading (3 mol%) did not improve the yield considerably while decreasing the catalyst loading to 1 mol% diminished the yield (**Entry 5**, **Table 1**). Among the solvents, dichloroethane gave the maximum yield, while the reaction in THF or $CHCl_3$ resulted in poor yields of pyrrole **2a.** It is noteworthy to observe that we obtained pyrrole directly without any acid treatment.[10a]

Table 2: Synthesis of N-alkoxy pyrroles *via* [3+2] cycloaddition[a]

Entry	Diazo carbonyl compound **1**	Product **2**	Yield[b]	
			With Ethyl vinyl ether	With Vinyl acetate
a			87	85

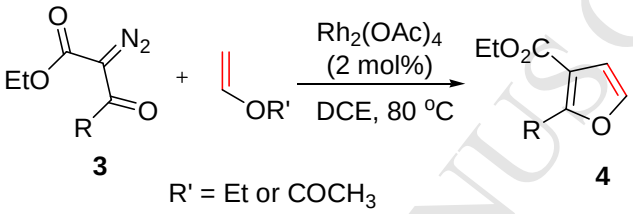
b			86	86
c			81	82
d			79	81
e			80	80
f			83	82
g			81	80

[a]Reaction conditions: *α*-diazo oxime ether (2 mmol), vinyl equivalents (3 mmol), DCE (3 mL/mmol), 80 [o]C, 8 h. [b]Yield corresponds to the isolated product by column chromatography.

After optimizing the reaction conditions, we treated several *α*-diazo oxime ethers with vinyl ether (1.5 equivalent) in the presence of $Rh_2(OAc)_4$ and the results are tabulated (**Table 2**). 2-aryl or 2-alkyl substituted N-methoxy pyrrole 3-carboxylates were conveniently synthesized following this route in good yields. The bulkiness in the diazo compound had negligible effect on the yield of the corresponding cyclized product.

Pirrung et.al[13] have successfully employed vinyl acetate to couple with diazo carbonyl compounds to get the corresponding 3+2 cycloaddition product which was further converted into furans. Considering the availability of vinyl acetate we believed that vinyl acetate could serve as a better alternate for ethyl vinyl ether. As expected, under the same reaction condition, we got the N-alkoxy pyrrole by replacing ethyl vinyl ether with vinyl acetate.

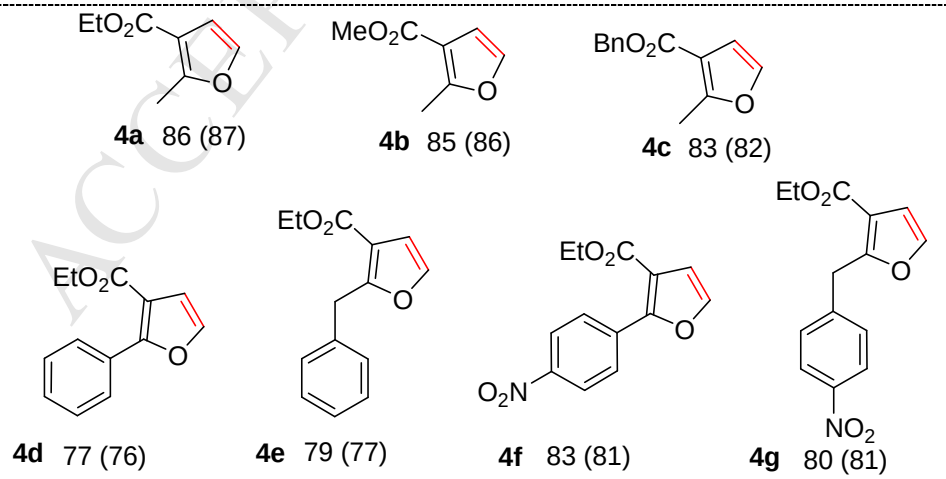
To our surprise, a similar [3+2] cycloaddition with *α*-diazo carbonyl compounds to get furan derivatives in a one-step has not been reported. In all the earlier reports,[13, 14] the dihydrofuran derivatives obtained are treated either with an acid like *p*-TSA or subjected to thermal elimination to get substituted furans.



Scheme 2: Synthesis of 2,3-disubstituted furan

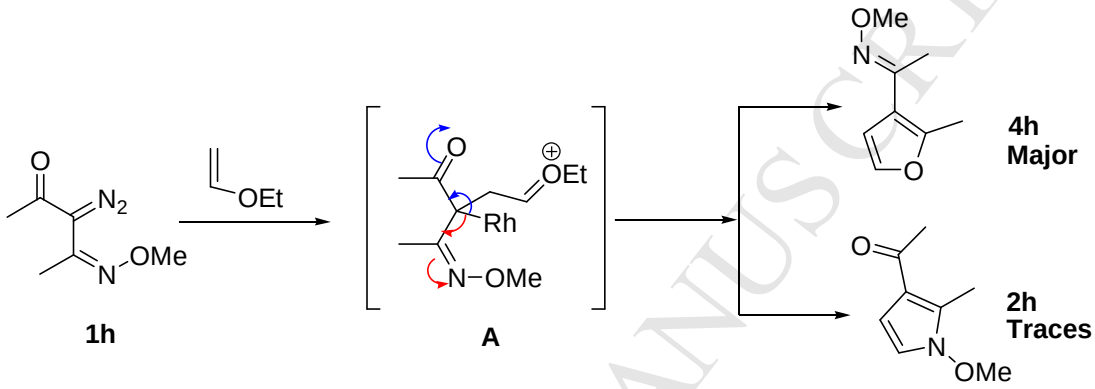
Excited by our observation of direct conversion into heterocycles, presumably due to thermal elimination, we attempted the synthesis of furan 3-carboxylates **4** by taking *α*-diazo carbonyl compounds **3** in place of *α*-diazo oxime ethers. Indeed, we obtained the desired product not only with vinyl ether but also with vinyl acetate under the same reaction conditions (**Scheme 2**). Several diazo carbonyl compounds had been screened and the result is given in **Table 3**.

Table 3: Synthesis of Furan 3- carboxylate derivatives[a,b]



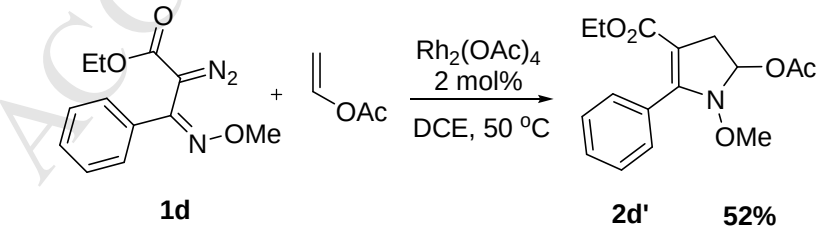
[a]Reaction conditions: *α*-diazo carbonyl ester (2 mmol), vinyl equivalents (3 mmol), DCE (3 mL/1 mmol), refluxed for 8 h, [b]Yield with vinyl acetate has been given in parenthesis.

Since, both α-diazo ketones and imines underwent [3+2] cycloaddition, we were curious to study the relative reactivity of these two groups. We chose α-diazo mono oxime ether of acetylacetone **1h** as the substrate of study and carried out [3+2] cycloaddition with ethyl vinyl ether under the same reaction condition (**Scheme 3**). As expected, we observed the intermediate A to delocalize over the carbonyl due to higher electro negativity of oxygen than imine to give furan 3-carboxylate **4h** in 68% and N-methoxy pyrrole in 21% yields. This may be attributed to the high electronegativity of oxygen atom than amine. A similar behaviour was observed by C. –M. Park et al.[15]



Scheme 3: Relative reactivity study of α-diazo ketones and imines

Further, we were surprised to observe the reaction to eliminate acetic acid or ethanol to give directly pyrrole and furan carboxylates while the earlier reports on this [3+2] cycloaddition resulted in dihydrofuran which upon treatment with acid or heating furnished furan. In order to confirm the formation of dihydropyrrole as the intermediate, we carried out this reaction at 50 ^{o}C and obtained dihydropyrrole **2d'** in 52% isolated yield (**Scheme 4**). This observation strongly supports our prediction that the high temperature (80 ^{o}C) lead to the thermal elimination to give pyrrole.



Scheme 4: N-methoxy dihydropyrrole formation at low temperature

Based on the above observation, we strongly believe that the metal carbenoids formed from α-diazo carbonyl compound undergo [3+2] cycloaddition with vinyl ether or vinyl acetate to give dihydropyrrole derivative **C**, which upon extended heating eliminates ethanol or acetic

acid to give N-alkoxy pyrrole **D** **(Fig. 2).**

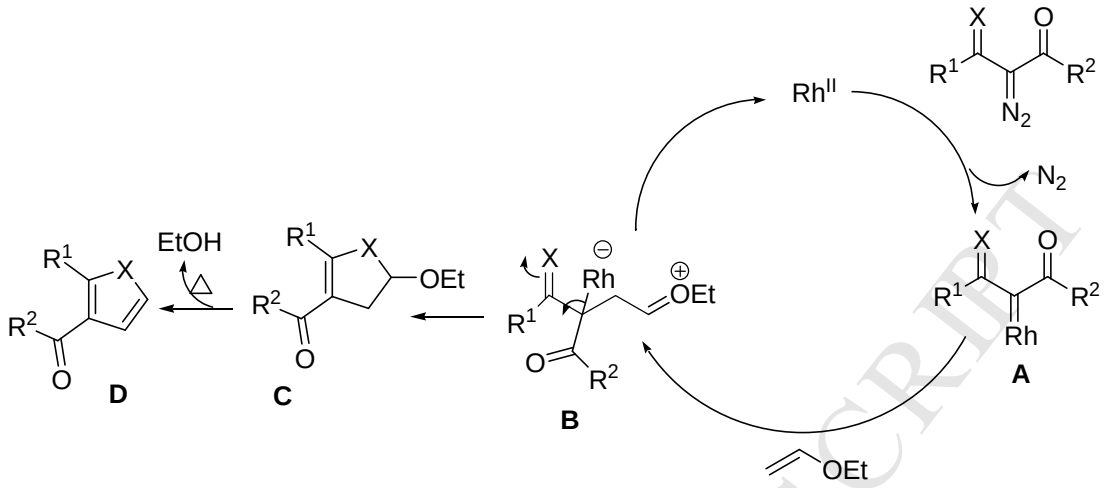


Fig. 2: Proposed catalytic cycle for the (3+2) cycloaddition

Conclusion

In conclusion, we have described a direct synthesis of N-alkoxy pyrroles and furan 3-carboxylates from *α*-diazo oxime ethers and *α*-diazo carbonyl compounds, respectively *via* [3+2] cycloaddition with vinyl ether or vinyl acetate. Thermal elimination of ethanol or acetic acid to give N-alkoxy pyrrole or furan 3-carboxylates, directly, was confirmed by carrying out the reaction at low temperature. Thus, the method can also be employed to obtain N-methoxy dihydropyrrole derivative by simply carrying out the reaction at low temperature. 2, 3-disubstituted N-alkoxy pyrrole derivatives are expected to have interesting biological activities, which needs further investigation.

Experimental section:

All reagents and solvents were obtained from Merck and Aldrich is used without any purification. ^{1}H- and ^{13}C- NMR spectra were recorded on Bruker FT- 500 or 400 using tetramethylsilane (TMS) as an internal standard. The IR spectra were recorded on Shimadzu FT-IR spectrophotometer (in KBr).The compounds were purified by column chromatography using silica gel (100-200 mesh) and pet ether: ethyl acetate. TLC was performed using silica gel 60 F_{254} pre-coated on aluminium sheets, obtained from Merck. Visualization of spots on TLC plate was done with UV light (254 nm).

General procedure

To a solution α-diazo oxime ether (2 mmol) and $Rh_2(OAc)_4$ (2 mol %) in DCE (4 mL) under nitrogen atmosphere and at room temperature was added a solution of ethyl vinyl ether (216 mg, 0.288 mL, 3 mmol) in DCE (2 mL) was added through a syringe. The reaction mixture was heated at 80 ^oC for 8 h. After the completion of the reaction as indicated by the TLC, the reaction mixture was cooled to room temperature and purified by column chromatography using a pet ether/ethyl acetate 19:1 mixture as eluent to afford the pyrrole **2a.**

Synthesis of Ethyl 1-methoxy-2-methyl-1*H*-pyrrole-3-carboxylate (2a): The title compound was prepared according to the general procedure and the product was obtained as colorless viscous oil; Yield: 87% (318.4 mg); **R_f (5 % Pet ether/ethyl acetate) 0.33**; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.21 (d, 1H, *J* = 7.2 Hz), 6.80 (d, 1H, *J* = 7.2 Hz), 4.31 (q, 2H, *J* = 3.2 & 6 Hz), 3.98 (s, 3H), 2.41 (s, 3H), 1.32 (t, 3H, *J* = 3.6 Hz); ^{13}C NMR (125 MHz, $CDCl_3$): δ 164.81, 138.06, 130.13, 129.87, 107.96, 60.69, 57.21, 15.62, 14.68; MS-EI (m/z) Calcd. for $C_9H_{13}NO_3$: 183.0895; found: 183.0899.

Methyl 1-methoxy-2-methyl-1*H*-pyrrole-3-carboxylate (2b): Yield: 86% (290.68 mg); obtained as a colorless gum; **R_f (5 % Pet ether/ethyl acetate) 0.35**; ^{1}H NMR (400 MHz, $CDCl_3$): δ 6.91 (d, 1H, *J* = 7.6 Hz), 6.75 (d, 1H, *J* = 7.6 Hz), 3.91 (**s**, 3H), 3.87 (s, 3H), 2.31 (**s**, 3H); ^{13}C NMR (125 MHz, $CDCl_3$): δ 164.85, 139.69, 128.56, 127.96, 107.09, 58.13, 51.74, 15.66; MS-EI (m/z) Calcd. for $C_8H_{11}NO_3$: 169.0739; found: 169.0732.

Benzyl 1-methoxy-2-methyl-1*H*-pyrrole-3-carboxylate (2c): Yield: 81% (477.9 mg); obtained as a reddish brown gum; **R_f (5 % Pet ether/ethyl acetate) 0.31**; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.44 – 7.33(m, 5H), 6.89 (d, 1H, *J* = 7.2 Hz), 6.69 (d, 1H, J = 6.8 Hz), 5.13 (s, 2H), 3.87 (s, 3H), 2.32 (s, 3H); ^{13}C NMR (125 MHz, $CDCl_3$): δ 165.08, 137.51, 135.11, 129.43, 129.38, 128.90, 128.55, 128.50, 127.81, 127.77, 109.42, 65.97, 57.21, 15.51; MS-EI (m/z) Calcd. for $C_{14}H_{15}NO_3$: 245.1052; found: 245.1055.

Ethyl 1-methoxy-2-phenyl-1*H*-pyrrole-3-carboxylate (2d): Yield: 79% (387.52 mg); obtained as dark yellow oil; **R_f (5 % Pet ether/ethyl acetate) 0.32**; **IR (cm^{-1}) 2978, 1705, 1238, 1062, 975, 752, 696**; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.67 (d, 1H, *J* = 7.7 Hz), 7.48 – 7.25 (m, 4H), 6.884 (d, 1H, *J* = 4.4 Hz), 6.694 (d, 1H, *J* = 4.0 Hz), 4.210 (q, 2H, *J* = 7.2 Hz & 14.4 Hz), 3.961 (s, 3H), 1.320 (t, 3H, *J* = 7.2 Hz); ^{13}C NMR (125 MHz, $CDCl_3$): δ 163.39, 138,66 131.46, 129.52, 129.17, 127.12, 126.46, 126.18, 125.89, 125.86, 108.34, 60.11, 57.86, 14.34; MS-EI (m/z) Calcd. for $C_{14}H_{15}NO_3$: 245.1052; found: 245.1052.

Ethyl 5-acetoxy-1-methoxy-2-phenyl-4,5-dihydro-1*H*-pyrrole-3-carboxylate (2d'): Yield 52% (317.5 mg); Obtained as dark yellow oil; **R_f (5 % Pet ether/ethyl acetate) 0.35**; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.65-7.27 (m, 5H), 6.31 (t, 1H, *J* = 7.6 Hz), 4.19 (q, 2H, *J* = 7.6 Hz), 3.84 (s, 3H), 2.75 (d, 2H, *J* = 8 Hz), 2.15 (s, 3H), 1.22 (t, 3H, *J* = 7.2 Hz); ^{13}C NMR (125 MHz, $CDCl_3$): δ 180.16, 168.66, 151.14, 135.16, 129.14, 129.14, 128.343, 126.01, 106.21, 80.09, 62.04, 60.89, 33.04, 20.13, 13.87; MS-EI (m/z) Calcd. for $C_{15}H_{16}N_2O_5$: 305.1263; found: 305.1266.

Ethyl 2-benzyl-1-methoxy-1*H*-pyrrole-3-carboxylate (2e): Yield: 80% (414.88 mg); obtained as yellow oil; **R_f (5 % Pet ether/ethyl acetate) 0.32**; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.50 – 7.38 (m, 5H), 7.25 (d, 1H, *J* = 7.2 Hz), 6.73 (d, 1H, *J* = 7.2 Hz), 4.52 (q, 2H, *J* = 7.2 Hz), 4.05 (s, 3H), 1.52 (t, 3H, *J* = 7.6 Hz); ^{13}C NMR (125 MHz, $CDCl_3$): δ 164.95, 138.98, 137.76, 129.52, 129.17, 128.98, 128.70, 128.69, 128.11, 128.10, 108.78, 60.75, 57.26, 30.23, 14.13; MS-EI (m/z) Calcd. for $C_{15}H_{17}NO_3$: 259.1208; found: 259.1208.

Ethyl 1-methoxy-2-(4-nitrophenyl)-1*H*-pyrrole-3-carboxylate (2f): Yield: 83% (481.8 mg); obtained as yellow oil; **R_f (5 % Pet ether/ethyl acetate) 0.31**; ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.232 – 8.198 (m, 2H), 7.459 – 7.243 (m, 2H), 7.254 (d, 1H, *J* = 3.6 Hz), 6.728 (d, 1H, *J* = 4.4 Hz), 4.210 (q, 2H, *J* = 4.8 Hz & 14.4 Hz), 4.004 (s, 3H), 1.320 (t, 3H, *J* = 7.2 Hz); ^{13}C NMR (125 MHz, $CDCl_3$): δ 165.00, 147.84, 138.98, 129.52, 129.17, 128.14, 128.04, 125.95, 125.82, 108.37, 60.76, 57.91, 14.77; MS-EI (m/z) Calcd. for $C_{14}H_{14}N_2O_5$: 290.0903; found: 290.0905.

Ethyl 2-(4-nitrobenzyl)-1-methoxy-1*H*-pyrrole-3-carboxylate (2g): Yield: 81% (492.9 mg); obtained as brown gum; **R_f (5 % Pet ether/ethyl acetate) 0.36**; ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.22 (d, 1H, *J* = 8 Hz), 8.19 (d, 1H, *J* = 8 Hz), 7.53 (d, 1H, *J* = 7.6 Hz), 7.50 (d, 1H, *J* = 7.6 Hz), 7.18 (d, 1H, *J* = 8.4 Hz), 7.09 (d, 1H, *J* = 8.8 Hz), 4.52 (q, 2H, *J* = 7.2 Hz), 4.31 (s, 2H), 4.04 (s, 3H), 1.51 (t, 2H, *J* = 7.6 Hz); ^{13}C NMR (125 MHz, $CDCl_3$): δ 164.95, 147.98, 138.98, 137.26, 129.52, 129.17, 128.14, 128.04, 122.11, 122.09, 108.28, 60.85, 57.26, 32.54, 14.23; MS-EI (m/z) Calcd. for $C_{15}H_{16}N_2O_5$: 304.1059; found: 304.1056.

General procedure for the synthesis of furan 3-carboxylate derivatives: To a solution *α*-diazo ester **3a** (318 mg, 2 mmol) and $Rh_2(OAc)_4$ (2 mol %) in DCE (4 mL) under nitrogen atmosphere and at room temperature was added a solution of ethyl vinyl ether (216 mg, 0.288 mL, 3 mmol) in DCE (2 mL) was added through a syringe. The reaction mixture was heated at 80 ^{o}C for 8 h. After the completion of the reaction as indicated by the TLC, the reaction

mixture was cooled to room temperature and purified by column chromatography using a pet ether/ethyl acetate 19:1 mixture as eluent to afford the pyrrole **4a.**

Synthesis of ethyl 2-methylfuran-3-carboxylate (4a): The title compound was prepared following the general procedure and obtained as pale yellow oil; Yield: 86% (265 mg); **R_f (5 % Pet ether/ethyl acetate) 0.42**; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.126 (d, 1H, *J* = 4.8 Hz), 6.741 (d, 1H, *J* = 5.2 Hz), 4.998 (q, 2H, *J* = 7.6 Hz & 13.6 Hz), 2.037 (s, 3H), 1.325 (t, 3H, *J* = 4.4 Hz; ^{13}C NMR (125 MHz, $CDCl_3$): δ 165.19, 154.15, 138.63, 115.54, 109.89, 60.91, 14.95, 13.11; MS-EI (m/z) Calcd. for $C_8H_{10}O_3$: 154.0630; Found: 154.0633.

Methyl 2-methylfuran-3-carboxylate (4b): Yield: 85% (238.07 mg); obtained as pale yellow oil; **R_f (5 % Pet ether/ethyl acetate) 0.40**; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.525 (d, 1H, *J* = 2 Hz), 6.723 (d, 1H, *J* = 2 Hz), 3.766 (s, 3H), 2.586 (s, 3H); ^{13}C NMR (125 MHz, $CDCl_3$): δ 165.09, 154.37, 139.54, 114.42, 109.79, 51.12, 13.23; MS-EI (m/z) Calcd. for $C_7H_8O_3$: 140.0473; Found: 140.0477.

Benzyl 2-methylfuran-3-carboxylate (4c): Yield: 83% (358.9 mg); obtained as yellow oil; **R_f (5 % Pet ether/ethyl acetate) 0.39**; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.526 (d, 1H, *J* = 2 Hz), 7.375 – 7.190 (m, 5H), 6.730 (d, 1H, *J* = 2 Hz), 5.136 (s, 2H), 2.593 (s, 3H); ^{13}C NMR (125 MHz, $CDCl_3$): δ 165.00, 154.54, 140.10, 135.15, 129.52, 128.75, 128.63, 127.95, 127.73, 112.48, 64.97, 13.15; MS-EI (m/z) Calcd. for $C_{13}H_{12}O_3$: 216.0786; Found: 216.0782.

Ethyl 2-phenylfuran-3-carboxylate (4d): Yield: 77% (358.9 mg); obtained as dark yellow oil; **R_f (5 % Pet ether/ethyl acetate) 0.42**; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.903 (d, 1H, *J* = 2 Hz), 7.545 (m, 5H), 6.989 (d, 1H, *J* = 2 Hz), 4.193 (q, 2H, *J* = 7.2 Hz & 14.4 Hz), 1.343 (t, 3H, *J* = 7.2 Hz); ^{13}C NMR (125 MHz, $CDCl_3$): δ 164.93, 151.11, 138.77, 131.01, 127.96, 127.66, 127.04, 125.19, 124.95, 114.75, 109.60, 51.01, 14.24; MS-EI (m/z) Calcd. for $C_{13}H_{12}O_3$: 216.0786; Found: 216.0785.

Ethyl 2-benzylfuran-3-carboxylate (4e): Yield: 79% (363.8 mg); obtained as dark yellow oil; **R_f (5 % Pet ether/ethyl acetate) 0.44**; **IR (cm^{-1}) 2956, 1714, 1234, 1209, 1081, 774, 697, 665**; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.545 (s, 1H, *J* = 2 Hz), 7.367 (m, 5H), 6.747 (d, 1H, *J* = 2.4 Hz), 4.184 (q, 2H, *J* = 6.8 Hz & 14 Hz), 3.766 (s, 2H), 1.300 (t, 3H, *J* = 6.8 Hz); ^{13}C NMR (125 MHz, $CDCl_3$): δ 165.04, 156.16, 139.54, 133.64, 131.60, 128.92, 128.78, 128.47, 128.27, 114.42, 108.40, 60.75, 32.78, 14.24; MS-EI (m/z) Calcd. for $C_{14}H_{14}O_3$: 230.0943; Found: 230.0941.

Ethyl 2-(4-nitrophenyl) furan-3-carboxylate (4f): Yield: 83% (433.6 mg); obtained as

reddish brown oil; **R_f (5 % Pet ether/ethyl acetate) 0.46**; ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.285 – 8.256 (m, 2H), 8.081 (d, 1H, *J* = 2 Hz), 7.673 – 7.264 (m, 2H), 6.816 (d, 1H, *J* = 2 Hz), 4.183 (q, 2H, *J* = 7.2 Hz & 14 Hz), 1.344 (t, 3H , *J* = 7.2 Hz); ^{13}C NMR (125 MHz, $CDCl_3$): δ 165.04, 150.66, 140.60, 130.25, 125.16, 125.15, 124.54, 124.51, 113.52, 109.42, 60.78, 14.94; MS-EI (m/z) Calcd. for $C_{13}H_{11}NO_5$: 261.0637; Found: 261.0633.

Ethyl 2-(4-nitrobenzyl) furan-3-carboxylate (4g): Yield: 80% (440.0 mg); obtained as reddish brown oil; **R_f (5 % Pet ether/ethyl acetate) 0.45**; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.508 (d, 2H, *J* = 8.4 Hz), 6.927 (d, 2H, *J* = 8 Hz), 6.460 (d, 1H, *J* = 7.2 Hz), 5.288 (d, 1H, *J* = 7.2 Hz), 4.352 (q, 2H, *J* = 7.2 Hz & 14.4 Hz), 4.148 (s, 2H), 1.705 (t, 3H, J = 6.8 Hz); ^{13}C NMR (125 MHz, $CDCl_3$): δ 163.74, 156.00, 147.97, 140.89, 134.26, 129.59, 129.57, 123.22, 123.19, 114.23, 109.86, 60.57, 32.55, 14.13; MS-EI (m/z) Calcd. for $C_{14}H_{13}NO_5$: 275.0794; Found: 275.0799.

(*E*)-1-(2-methylfuran-3-yl) ethanone O-methyl oxime (4h): Yield 68% (208.1 mg); Obtained as pale yellow gum; **R_f (5 % Pet ether/ethyl acetate) 0.43**; 1H NMR (400 MHz, $CDCl_3$): δ 7.213 (d, 1H, *J* = 1.6 Hz), 6.623 (d, 1H, *J* = 1.6 Hz), 3.781 (s, 3H), 2.355 (s, 3H), 2.056 (s, 3H); 13C NMR (125 MHz, $CDCl_3$): δ 156.54, 154.35, 138.63, 128.86, 109.90, 61.18, 17.95, 13.13; MS-EI (m/z) Calcd. for $C_8H_{11}NO_2$: 153.0790; Found: 153.0794.

Associated content

Supporting Information:

Supporting Information containing ^{1}H and ^{13}C NMR spectra of all the compounds.

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