The reaction of acyl cyanides with "Huisgen zwitterion": an interesting rearrangement involving ester group migration between oxygen and nitrogen atoms†

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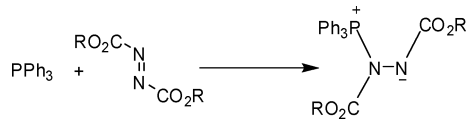
A novel rearrangement involving ester group migration was found in the reaction of acyl cyanides and Huisgen zwitterions, affording hydrazone derivatives at higher temperature (90 °C) and azine derivatives at lower temperature (20 °C), respectively. Interestingly, the reaction temperature is identified as a critical factor to control the final products. Presumably, the rearrangement involving ester group migration between oxygen and nitrogen atoms leads to the formation of different products.

Introduction

Nucleophilic phosphine organocatalysis has drawn remarkable attention and become a highly dynamic chemical research area due to its wide applicability in organic synthesis.[1] Phosphines have proven to be particular versatile as catalysts or reagents in many types of reactions.[2] One of these reactions is the Mitsunobu reaction,[3] in which the "Huisgen zwitterion"[4] formed by phosphines and azodicarboxylates plays a crucial role (Scheme 1). Although the Huisgen zwitterions can be applied in preparation of synthetically useful compounds such as vinyl hydra-α-ketoesters,[5] and protected hydrazones from salicylaldehydes,[6] the chemistry of Huisgen zwitterions has received limited attention until recent years. Recently, a number of interesting reactions including the reaction of this zwitterion with various carbonyl compounds have been explored. In 2005, Lee and co-workers have reported the reaction of the zwitterions with aliphatic aldehydes and α-ketoesters for the synthesis of bisadducts and oxadiazolines.[7] The Huisgen zwitterions have also been systemically studied by Nair's group, which led to fruitful results for the synthesis of *N*,*N*-dicarboethoxy monohydrazones, dihydro-1,2,3-benzoxadiazoles, functional pyrazoles and pyrazolines, as well as pyrazolopyridazine derivatives through the reactions involving the Huisgen zwitterions.[8] Very recently, Wang and co-workers reported the reaction of 2-acylaziridines with the Huisgen zwitterions to furnish the 2-pyrazoline ring with excellent yields.[9]

Acyl cyanides have proven to be extremely useful reagents in organic synthesis due to the electrophilicity of both functions in acyl cyanides being enhanced by the proximity of the CO and CN groups.[10] Inspired by previous work on the chemistry of Huisgen zwitterions and as a part of our continuing interest on nucleophilic phosphine and amine mediated or catalyzed reactions,[11] we systematically investigated the reactions of Huisgen zwitterions with acyl cyanides. Herein, we are delighted to report our novel findings in these reactions. The results of our studies provide an alternative way to synthesize medically and synthetically interesting azine and hydrazone derivatives.[12]



Scheme 1 Huisgen zwitterions.

Results and discussion

On the basis of the previous investigation, it was known that both steric and electronic properties of phosphines may affect dramatically the outcome of the reaction.[13] Therefore, we initiated our investigation by seeking an optimal phosphine promoter for the reaction between acyl cyanides **1a** and diisopropyl azodicarboxylate (DIAD) **2a** (Table 1, entries 1–5). The results revealed that triphenylphosphine was the best promoter in this reaction, yielding the product in 98% yield (Table 1, entry 1). However, other phosphines gave poor results, with yields of less than 80%, presumably due to the different nucleophilicity of the employed phosphines (Table 1, entries 2-4). The structure of product **3a** was assigned based on spectroscopic data. Unambiguous evidence for structure of **3c** (Table 2, entry 3) was obtained from single-crystal X-ray analysis (Fig. 1),[14] which showed both of the carboisopropoxy groups on the same nitrogen atom (Fig. 1). Triphenylphosphine oxide was also isolated from the reaction mixture, which indicated that triphenylphosphine participated in the reaction and was oxidized into triphenylphosphine oxide.

During the optimization of reaction conditions, we were surprised to find that reducing the reaction temperature to room temperature (20 °C) led to totally different products. The ^{1}H NMR data implied that the two isopropyl groups were separated far away from each other, which were different from the previously observed chemical shifts of product **3**. It was initially difficult to

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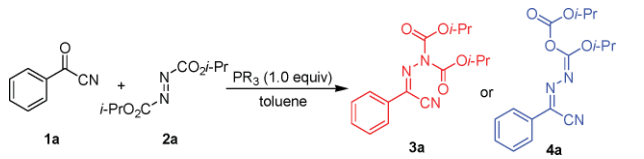
† Electronic supplementary information (ESI) available: ^{13}C and ^{1}H NMR spectroscopic and analytic data for all new compounds shown in Tables 1–3 and X-ray crystal data of **3c** and **4g**. CCDC reference numbers 713523 & 724590. For ESI and crystallographic data in CIF or other electronic format see DOI: 10.1039/b913196e

Table 1 Phosphine-mediated reaction of dialkyl azodicarboxylate with acyl cyanides[a]



Entry	PR_3	Temperature/°C	Time/h	Yield (**3a**)[b]	Yield (**4a**)[b]
1	PPh_3	90	1	98	—[c]
2	PPh_2Me	90	3	81	—
3	$PPhMe_2$	90	3	46	—
4	PBu_3	90	3	53	—
5	$P(OEt)_3$	90	3	68	—
6	PPh_3	20	1	—	71
7	$P(4\text{-}OMeC_6H_4)_3$	20	1	—	62
8	$P(4\text{-}FC_6H_4)_3$	20	1	—	73
9	PBu_3	20	1	—	46
10	$P(OEt)_3$	20	1	—	50
11	PPh_2Me	20	1	—	72
12	$PPhMe_2$	20	1	—	62

[a] Reactions were carried out with **1a** (0.3 mmol), **2a** (0.3 mmol), phosphine (0.3 mmol) in **2** mL of toluene. [b] Yield of isolated product. [c] Not detected.

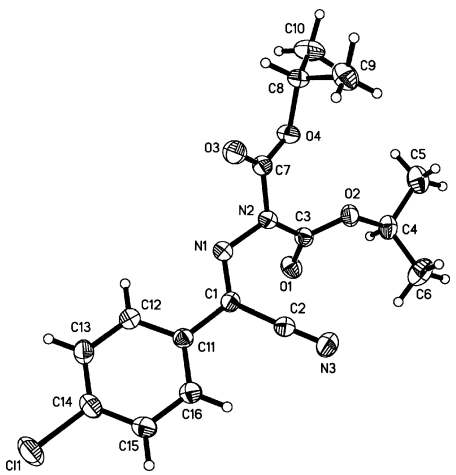
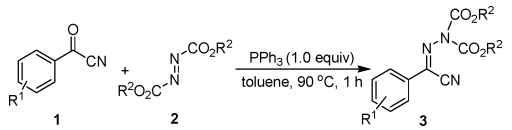


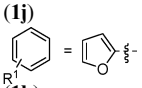
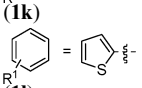
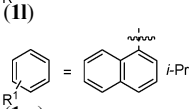
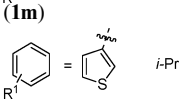
Fig. 1 Single-crystal X-ray structure of **3c**.

assign the structures of the new products until the single-crystal X-ray analysis of the product **4g** (Table 3, entry 7) was obtained from the product of the reaction between the 3,4,5-trimethoxybenzoyl cyanide and **2a** (Fig. 2).[15] From the X-ray analysis, we can see that one of the isopropyl carboxy groups was isomerized, and another isopropyl carboxy group was connected to the oxygen atom of the isomerized isopropyl carboxy group (Fig. 2).

Similarly, several commonly used phosphines were investigated to this reaction at room temperature, and the results were also summarized in Table 1 (entries 6–12). Triphenylphosphine was still better than other phosphines, such as PBu_3, $P(OEt)_3$, to give the product **4a** in 71% yield (Table 1, entries 9–12). Further examination revealed that the triphenylphosphines with different substituents influenced the yield slightly (Table 1, entries 6–8). The electron-withdrawing substituent on the benzene ring of triphenylphosphine led to increasing the yield of **4a** slightly (Table 1, entry 8). Compromise the yield on the experimental cost,

Table 2 Triphenylphosphine-mediated reaction of dialkyl azodicarboxylate with acyl cyanides at 90 °C[a]



entry	R^1	R^2	Product	yield/**3**[b]
1	(**1a**) H	*i*-Pr	**3a**	98
2	(**1b**) 4-Br	*i*-Pr	**3b**	95
3	(**1c**) 4-Cl	*i*-Pr	**3c**	73
4	(**1d**) 3-CF_3	*i*-Pr	**3d**	68
5	(**1e**) 2-Cl	*i*-Pr	**3e**	81
6	(**1f**) 4-CH_3	*i*-Pr	**3f**	92
7	(**1g**) 4-OCH_3	*i*-Pr	**3g**	88
8	(**1h**) 3,5-2CH_3	*i*-Pr	**3h**	80
9	(**1i**) 3,4,5-3OCH_3	*i*-Pr	**3i**	90
10	(**1a**) H	Et	**3j**	74
11	(**1b**) 4-Br	Et	**3k**	73
12	(**1g**) 4-OCH_3	Et	**3l**	84
13	(**1j**) 	*i*-Pr	**3m**	87
14	(**1k**) 	*i*-Pr	**3n**	68
15	(**1l**) 	*i*-Pr	**3o**	82
16	(**1m**) 	*i*-Pr	**3p**	88

[a] Reactions were carried out with **1** (0.3 mmol); **2** (0.3 mmol), PPh_3 (0.3 mmol) in toluene (2 mL) at 90 °C. [b] Isolated yield.

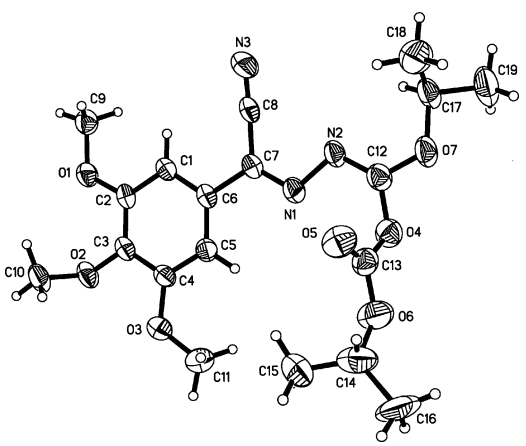
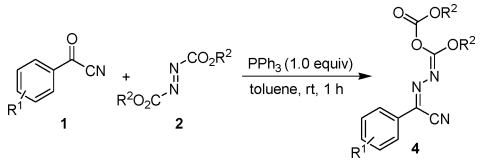


Fig. 2 Single-crystal X-ray structure of **4g**.

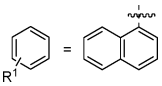
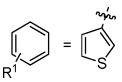
the cheaper triphenylphosphine was chosen as the best promoter at room temperature (20 °C) for this reaction.

Having identified the optimal phosphine promoter for the efficient syntheses of the products at two different temperatures prompted us to probe the scope of the reaction using various acyl cyanides (Table 2 and 3). First, the generality of the reaction was investigated at 90 °C (Table 2, entries 1–16). In the presence of triphenylphosphine, the diazoester **2a** reacted with both

Table 3 Phosphine-mediated reaction of dialkyl azodicarboxylate with acyl cyanides at room temperature (20 °C)[a]



1 2 4

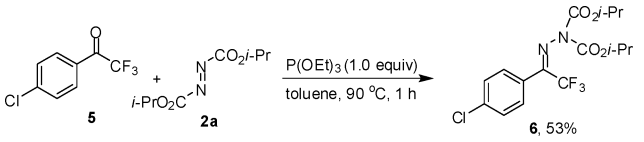
Entry	R^1	R^2	Product	Yield (**4**)[b]
1	H	*i*-Pr	**4a**	71
2	4-Br	*i*-Pr	**4b**	68
3	4-Cl	*i*-Pr	**4c**	69
4	4-CH_3	*i*-Pr	**4d**	87
5	4-OCH_3	*i*-Pr	**4e**	99
6	3,5-2CH_3	*i*-Pr	**4f**	86
7	3,4,5-3OCH_3	*i*-Pr	**4g**	87
8	3,4,5-3OCH_3	Et	**4h**	79
9	4-OCH_3	Et	**4i**	70
10		*i*-Pr	**4j**	73
11		*i*-Pr	**4k**	60

[a] Reactions were carried out with **1** (0.3 mmol), **2** (0.3 mmol), PPh_3 (0.3 mmol) in toluene (2 mL) at room temperature (20 °C). [b] Isolated yield.

electron-deficient and electron-rich acyl cyanides to provide the dialkyl monohydrazones in good to excellent isolated yields (Table 2, entries 1–9). Similar results were obtained with respect to DEAD (Table 2, entries 10–12). Notably, the heteroaryl cyanides and 1-naphthoyl cyanide also proceeded smoothly to give high yields under the optimal reaction conditions (Table 2, entries 13–16).

Furthermore, the scope of the reaction was examined again at room temperature (20 °C) using various acyl cyanides (Table 3, entries 1–11). In general, the electron-rich acyl cyanides gave the products in high yields, while the electron-deficient acyl cyanides produced the products in slightly lower yields (Table 3, entries 1–7). Instead of DIAD, diethyl azocarboxylate (DEAD) also displayed good reactivity with acyl cyanides in this reaction (Table 3, entries 8 and 9). It should be noted that 1-naphthoyl cyanide and thiophene-3-carbonyl cyanide also worked very well under the optimized reaction conditions (Table 3, entries 10 and 11).

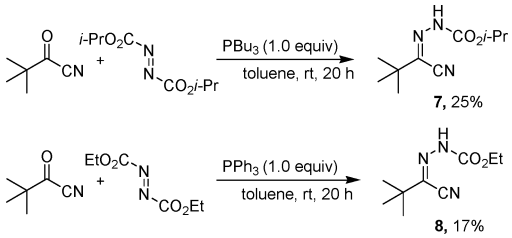
Further, we investigated whether this reaction could proceed using other analogues, for instance, using analogues replaced the CN group of acyl cyanides by another strong electron-withdrawing group CF_3.[16] Thus, we conducted the reaction of 1-(4-chlorophenyl)-2,2,2-trifluoroethanone with the DIAD in the presence of phosphine. Fortunately, the corresponding bis(alkoxycarboxy)hydrazone **6** was obtained in the reaction between the 1-(4-chlorophenyl)-2,2,2-trifluoroethanone (**5**) and the DIAD (**2a**) in the presence of $P(OEt)_3$, although the yield was moderate (Scheme 2). It should be mentioned that trifluoromethylated compounds have received considerable attention, and they have diverse applications in the area of materials science, agrochemistry and biomedical chemistry due to their unique chemical, physical, and biological properties.[17]



5 2a

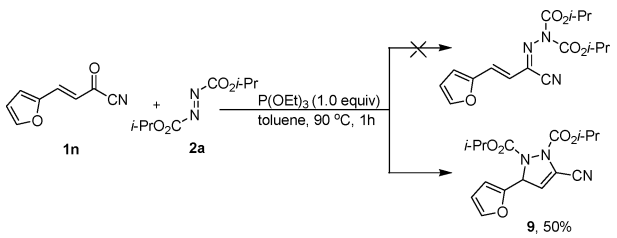
Scheme 2 Reaction of the Huisgen zwittern obtained from DIAD and triethyl phosphite with 1-(4-chlorophenyl)-2,2,2-trifluoroethanone **5**.

We have examined the performance of aliphatic cyanides for this reaction. Unfortunately, the aliphatic cyanides were not suitable for this reaction under the identified optimal reaction conditions. Although we attempted many times to improve the reactions of pivaloyl cyanide with DIAD or DEAD, only small amounts of the mono(alkoxycarbony)hydrazones as those obtained in Nair's system[8e] were isolated (Scheme 3).



Scheme 3 The reaction between pivaloyl cyanide and DEAD/DIAD.

In 2007, Nair's group has reported that the Huisgen zwitterions with simple electron-deficient alkenes could afford pyrazolines in moderate to good yields. Inspired by this work, we investigated further the scope of reaction. The (*E*)-3-(furan-2-yl)acryloyl cyanide **1n** was synthesized and employed as the substrate to examine its reaction with Huisgen zwitterion in the presence of $P(OEt)_3$ (Scheme 4). The reaction afford a product that was subsequently characterized as the pyrazoline derivative **9** (Scheme 4, 50% yield). This demonstrated that the α,β-unsaturated acyl cyanides do not undergo the rearrangement, the reactions proceeding as found by Nair's group.

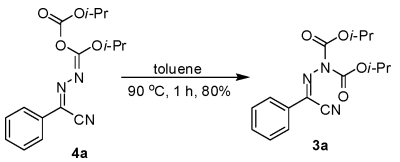


1n 2a

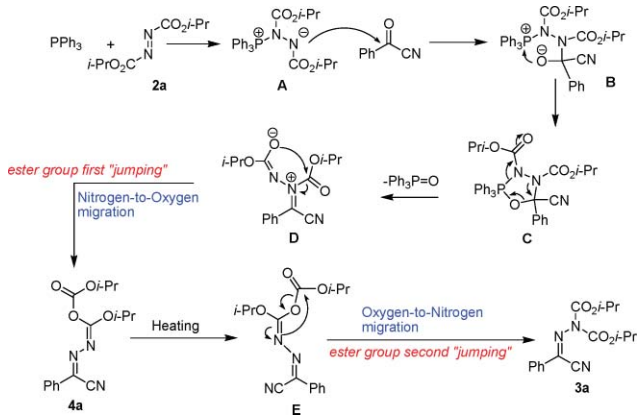
Scheme 4 The reaction between DIAD and α,β-unsaturated acyl cyanides **1n**.

We also found that the products **4** could be transformed to products **3** very slowly if we prolonged the reaction time at room temperature. Based on our observations, we hypothesized that the products **4** might be the intermediate in the formation of the products **3** and could be converted to the products **3** upon heating. Thus, we heated **4a** at 90 °C in toluene without phosphine. As expected, **4a** was easily converted to **3a** in toluene at 90 °C only within 1 h, furnishing the product **3a** in 80% isolated yield (Scheme 5).

A reaction mechanism for the reaction of acyl cyanides with Huisgen zwitterions is proposed in Scheme 6. Presumably, the



Scheme 5 Product **4a** can be converted to **3a** upon heating.



Scheme 6 Plausible reaction mechanism for the reaction.

combination of PPh_3 and diisopropyl azodicarboxylate **2a** generates the Huisgen zwitterion **A**, which undergoes addition to the carbonyl group of the acyl cyanide to form **B**. Subsequently **B** undergoes cyclization to form five-membered intermediate **C** which then decomposes to triphenylphosphine oxide and the intermediate **D**. Then, the intermediate **D** rearranges to the product **4a** by a nitrogen-to-oxygen migration of the alkoxycarbonyl group (the first migration at room temperature. The carbon-oxygen bond of **4a** is cleaved upon heating, which is followed by an oxygen-to-nitrogen migration of the alkoxycarbonyl group affording the bis(alkoxycarbonyl)hydrazone product **3a** *via* intermediate **E** (Scheme 6) (the second migration).

Conclusions

In conclusion, we have discovered a novel reaction between acyl cyanides and Huisgen zwitterions under mild reaction conditions, giving azine and hydrazone derivatives. The reaction temperature is identified as a critical factor to control final products, presumably due to a nitrogen-to-oxygen migration and an oxygen-to-nitrogen remigration of the alkoxycarbonyl group occurring at different temperatures. Efforts are in progress to elucidate further mechanistic details of these reactions and to understand their scope and limitations.

Experimental

General

Toluene was distilled from sodium (Na) under argon (Ar) atmosphere. Melting points were determined on a digital melting point apparatus and temperatures were uncorrected. ^{1}H NMR and ^{13}C NMR spectra were recorded on a Bruker AM-300 or 400 spectrophotometer. Infrared spectra were recorded on a Perkin-Elmer PE-983 spectrometer with absorption in cm^{-1}. Flash column chromatography was performed using 300–400 mesh silica gel. For thin-layer chromatography (TLC), silica gel plates (Huanghai GF_{254}) were used. Elementary analysis was taken on a Carlo-Erba 1106 analyzer. Mass spectra were recorded by EI, ESI, and HRMS were measured on a HP-5989 instrument. All reactions were performed under argon. The starting materials **1a–m** were synthesized according to the previous literature.[18]

Typical reaction procedure for the preparation of 3

Diisopropyl azodicarboxylate/diethyl azodicarboxylate **2** (0.3 mmol) was added to a stirred solution of acyl cyanide **1** (0.3 mmol) and Ph_3P (0.3 mmol) in anhydrous toluene (2.0 mL) under argon at 90 °C, and the mixture was maintained at 90 °C to stir for the required time. The solvent was removed under reduced pressure on a rotary evaporator. The residue was subjected to column chromatography on silica gel (300–400 mesh) to afford the products **3**.

(*Z*)-Diisopropyl-2-(cyano(phenyl)methylene)hydrazine-1,1-dicarboxylate (3a). Oil. IR (CH_2Cl_2) ν 2985, 2940, 2228, 1791, 1763, 1358, 1304, 1231, 1094, 910 cm^{-1}; ^{1}H NMR ($CDCl_3$, 300 MHz, TMS): δ 1.38 (12H, d, J = 6.3 Hz, CH_3), 5.12–5.21 (2H, m, CH), 7.51 (2H, t, J = 6.9 Hz, Ar), 7.61 (1H, t, J = 7.8 Hz, Ar), 8.04 (2H, d, J = 7.5 Hz, Ar). ^{13}C NMR ($CDCl_3$, 75 MHz): δ 21.6, 73.0, 109.8, 127.9, 129.1, 130.4, 133.2, 146.0, 150.4. MS (ESI) m/z 318.2 (M^++1). HRMS (ESI) calcd for $C_{16}H_{19}N_3O_4$ requires (M^++1) 318.1376, found 318.14538.

(*Z*)-Diisopropyl-2-((4-bromophenyl)(cyano)methylene)hydrazine-1,1-dicarboxylate (3b). mp. 94–96 °C; IR (CH_2Cl_2) ν 2985, 2938, 2228, 1798, 1764, 1376, 1300, 1094, 910 cm^{-1}; ^{1}H NMR ($CDCl_3$, 300 MHz, TMS): δ 1.38 (12H, d, J = 6.3 Hz, CH_3), 5.13–5.22 (2H, m, CH), 7.65 (2H, d, J = 8.7 Hz, Ar), 7.89 (2H, d, J = 8.7 Hz, Ar). ^{13}C NMR ($CDCl_3$, 75 MHz): δ 21.6, 73.3, 109.5, 128.2, 129.1, 129.4, 132.3, 143.6, 150.4. MS (EI) m/z 309 (M^+-86, 2.43), 269 (6.13), 267 (7.11), 223 (5.91), 195 (7.81), 114 (10.90), 44 (5.86), 43 (100.00), 41 (17.73). Anal. calcd for $C_{16}H_{18}BrN_3O_4$ (%) (395.05): C, 48.50; H, 4.58; Br, 20.17; N, 10.60; O, 16.15 found: C, 48.39; H, 4.57; N, 10.58.

(*Z*)-Diisopropyl-2-((4-chlorophenyl)(cyano)methylene)hydrazine-1,1-dicarboxylate (3c). mp. 81–83 °C; IR (CH_2Cl_2) ν 2985, 2939, 2228, 1798, 1764, 1300, 1094, 837 cm^{-1}; ^{1}H NMR ($CDCl_3$, 300 MHz, TMS): δ 1.38 (12H, d, J = 6.3 Hz, CH_3), 5.12–5.22 (2H, m, CH), 7.49 (2H, d, J = 8.4 Hz, Ar), 7.97 (2H, d, J = 8.4 Hz, Ar). ^{13}C NMR ($CDCl_3$, 75 MHz): δ 21.6, 73.3, 109.6, 129.0, 129.4, 139.6, 143.7, 150.4. MS (EI) m/z 265 (M+-86, 3.49), 223 (9.16), 179 (7.16), 151 (8.82), 43 (100.00), 42 (4.60). Anal. calcd for $C_{16}H_{18}ClN_3O_4$ (%) (351.09): C, 54.63; H, 5.16; Cl, 10.08; N, 11.94; O, 18.19 found: C, 54.73; H, 5.28; N, 12.01.

(*Z*)-Diisopropyl-2-(cyano(3-(trifluoromethyl)phenyl)methylene)-hydrazine-1,1-dicarboxylate (3d). Oil. IR (CH_2Cl_2) ν 2987, 2941, 2228, 1799, 1767, 1377, 1232, 1097 cm^{-1}; ^{1}H NMR ($CDCl_3$, 300 MHz, TMS): δ 1.41 (12H, d, J = 6.6 Hz, CH_3), 5.15–5.24 (2H, m, CH), 7.68 (1H, dd, J_1 = 7.8 Hz, J_2 = 8.1 Hz, Ar), 7.85 (1H, d, J = 7.8 Hz, Ar), 8.20 (1H, d, J = 8.1 Hz, Ar), 8.29 (1H, s, Ar). ^{19}F NMR ($CDCl_3$, 282 MHz): δ –68.6. ^{13}C NMR ($CDCl_3$, 75 MHz): δ 21.6, 73.6, 109.4, 123.3 (q, J = 271.4 Hz), 124.2 (q, J = 3.7 Hz), 129.6 (q, J = 3.2 Hz), 129.8, 130.9, 131.4, 131.7 (q, J = 33.2 Hz), 141.8, 150.4. MS (ESI) m/z 386.2 (M^++1). HRMS

(ESI) calcd for $C_{17}H_{18}F_3N_3O_4$ requires (M^++1) 386.1249 found 386.13197.

(*Z*)-Diisopropyl-2-((2-chlorophenyl)(cyano)methylene)hydrazine-1,1-dicarboxylate (3e). Oil. IR (CH_2Cl_2) ν 2986, 2939, 2225, 1799, 1766, 1590, 1377, 1311, 1093 cm^{-1}; ^1H NMR ($CDCl_3$, 400 MHz, TMS): δ 1.40 (12H, d, J = 6.4 Hz, CH_3), 5.15–5.22 (2H, m, CH), 7.39–7.43 (1H, m, Ar), 7.50–7.52 (2H, m, Ar), 7.70 (1H, d, J = 7.6 Hz, Ar). ^{13}C NMR ($CDCl_3$, 100 MHz): δ 21.6, 73.2, 109.6, 127.4, 129.9, 130.7, 131.4, 133.1, 133.4, 144.0, 149.9. MS (ESI) m/z 352.2 (M^++1). HRMS (ESI) calcd for $C_{16}H_{18}ClN_3O_4$ requires (M^++1) 352.0986 found 352.10558.

(*Z*)-Diisopropyl-2-(cyano(p-tolyl)methylene)hydrazine-1,1-dicarboxylate (3f). Oil. IR (CH_2Cl_2) ν 2985, 2939, 2229, 1797, 1762, 1305, 1094, 910 cm^{-1}; ^1H NMR ($CDCl_3$, 400 MHz, TMS): δ 1.37 (12H, d, J = 6.0 Hz, CH_3), 2.44 (3H, s, CH_3), 5.12–5.19 (2H, m, CH), 7.31 (2H, d, J = 8.0 Hz, Ar), 7.93 (2H, d, J = 8.0 Hz, Ar). ^{13}C NMR ($CDCl_3$, 100 MHz): δ 21.6, 72.8, 109.9, 127.8, 127.9, 144.4, 147.0, 150.4. MS (ESI) m/z 332.0 (M^++1), 354.0 (M^++Na). HRMS (ESI) calcd for $C_{17}H_{21}N_3O_4$ requires (M^++Na) 354.1430, found 354.14226.

(*Z*)-Diisopropyl-2-(cyano(4-methoxyphenyl)methylene)hydrazine-1,1-dicarboxylate (3g). Oil. IR (CH_2Cl_2) ν 2985, 2939, 2228, 1795, 1764, 1606, 1308, 1095 cm^{-1}; ^1H NMR ($CDCl_3$, 300 MHz, TMS): δ 1.36 (12H, d, J = 6.3 Hz, CH_3), 3.89 (3H, s, OCH_3), 5.10–5.19 (2H, m, CH), 7.01 (2H, d, J = 9.0 Hz, Ar), 8.00 (2H, d, J = 9.0 Hz, Ar). ^{13}C NMR ($CDCl_3$, 75 MHz): δ 21.6, 55.5, 72.7, 109.9, 114.5, 122.8, 130.0, 147.5, 150.4, 163.9. MS (ESI) m/z 348.2 (M^++1). HRMS (ESI) calcd for $C_{17}H_{21}N_3O_5$ requires (M^++1) 348.1481, found 348.15603.

(*Z*)Diisopropyl-2-(cyano(3,5-dimethylphenyl)methylene)hydrazine-1,1-dicarboxylate (3h). Oil. IR (CH_2Cl_2) ν 2985, 2939, 2229, 1789, 1763, 1609, 1233, 1095 cm^{-1}; ^1H NMR ($CDCl_3$, 400 MHz, TMS): δ 1.37 (12H, d, J = 6.4 Hz, CH_3), 2.39 (6H, s, CH_3), 5.12–5.19 (2H, m, CH), 7.23 (1H, s, Ar), 7.65 (2H, s, Ar). ^{13}C NMR ($CDCl_3$, 100 MHz): δ 21.1, 21.7, 72.9, 110.0, 125.7, 130.2, 135.2, 138.9, 147.5, 150.4. MS (ESI) m/z 346.2 (M^++1). HRMS (MALDI) calcd for $C_{18}H_{23}N_3O_4$ requires (M^++Na) 368.1588, found 368.15808.

(*Z*)-Diisopropyl

2-(Cyano(3,4,5-trimethoxyphenyl)methylene)hydrazine-1,1-dicarboxylate (3i). Oil. IR (CH_2Cl_2) ν 2985, 2941, 1842, 2229, 1798, 1762, 1504, 1351, 1130 cm^{-1}; ^1H NMR ($CDCl_3$, 400 MHz, TMS): δ 1.38 (12H, d, J = 6.0 Hz, CH_3), 3.93 (6H, s, OCH_3), 3.94 (3H, s, OCH_3), 5.13–5.20 (2H, m, CH), 7.28 (2H, s, Ar). ^{13}C NMR ($CDCl_3$, 100 MHz): δ 21.7, 56.3, 61.0, 73.0, 105.3, 110.0, 125.5, 142.8, 146.7, 150.4, 153.5. MS (ESI) m/z 408.0 (M^++1). HRMS (ESI) calcd for $C_{19}H_{25}N_3O_7$ requires (M^++Na) 430.1585 found 430.15769.

(*Z*)-Diethyl-2-(cyano(phenyl)methylene)hydrazine-1,1-dicarboxylate (3j). Oil. IR (CH_2Cl_2) ν 2985, 2938, 2228, 1802, 1768, 1102 cm^{-1}; ^1H NMR ($CDCl_3$, 400 MHz, TMS): δ 1.37 (6H, t, J = 7.6 Hz, CH_3), 4.40 (4H, q, J = 7.6 Hz, CH_2), 7.52 (2H, t, J = 8.0 Hz, Ar), 7.62 (1H, t, J = 7.6 Hz, Ar), 8.05 (2H, d, J = 7.2 Hz, Ar). ^{13}C NMR ($CDCl_3$, 100 MHz): δ 14.0, 64.4, 109.6, 128.0, 129.1, 130.2, 133.5, 147.4, 150.5. MS (ESI) m/z 290.2 (M^++1), 312.2 (M^++Na). HRMS (ESI) calcd for $C_{14}H_{15}N_3O_4$ requires (M^++1) 290.1063 found 290.11353.

(*Z*)-Diethyl-2-((4-bromophenyl)(cyano)methylene)hydrazine-1,1-dicarboxylate (3k). mp. 82–84 °C; IR (CH_2Cl_2) ν 2984, 1937, 2228, 1802, 1767, 1588, 1310,1006 cm^{-1}; ^1H NMR ($CDCl_3$, 400 MHz, TMS): δ 1.38 (6H, t, J = 7.2 Hz, CH_3), 4.41 (4H, q, J = 7.2 Hz, CH_2), 7.66 (2H, d, J = 8.8 Hz, Ar), 7.90 (2H, d, J = 8.8 Hz, Ar). ^{13}C NMR ($CDCl_3$, 100 MHz): δ 14.0, 64.6, 109.3, 128.5, 129.2, 132.4, 145.2, 150.5. MS (ESI) m/z 368.0 (M^++1). HRMS (ESI) calcd for $C_{14}H_{14}BrN_3O_4$ requires (M^++1) 368.0168 found 368.02421.

(*Z*)-Diethyl-2-(cyano(4-methoxyphenyl)methylene)hydrazine-1,1-dicarboxylate (3l). Oil. IR (CH_2Cl_2) ν 2984, 2939, 2229, 1799, 1761, 1605, 1176, 1103 cm^{-1}; ^1H NMR ($CDCl_3$, 400 MHz, TMS): δ 1.36 (6H, t, J = 7.2 Hz, CH_3), 3.89 (3H, s, OCH_3), 4.38 (4H, q, J = 7.2 Hz, CH_2), 7.01 (2H, d, J = 9.2 Hz, Ar), 8.01 (2H, d, J = 9.2 Hz, Ar). ^{13}C NMR ($CDCl_3$, 75 MHz): δ 14.1, 55.6, 64.3, 109.8, 114.7, 122.9, 130.3, 148.7, 150.7, 164.2. MS (ESI) m/z 320.2 (M^++1). HRMS (ESI) calcd for $C_{15}H_{17}N_3O_5$ requires (M^++1) 320.1168 found 320.12407.

(*E*)-Diisopropyl-2-(cyano(furan-2-yl)methylene)hydrazine-1,1-dicarboxylate (3m). Oil. IR (CH_2Cl_2) ν 3131, 2986, 2940, 2234, 1791, 1794, 1095 cm^{-1}; ^1H NMR ($CDCl_3$, 400 MHz, TMS): δ 1.37 (12H, d, J = 6.0 Hz, CH_3), 5.12–5.19 (2H, m, CH), 6.65 (1H, dd, J_1 = 1.6 Hz, J_2 = 3.6 Hz, Ar), 7.25 (1H, dd, J_1 = 0.8 Hz, J_2 = 3.6 Hz, Ar), 7.72 (1H, dd, J_1 = 0.8 Hz, J_2 = 1.6 Hz, Ar). ^{13}C NMR ($CDCl_3$, 100 MHz): δ 21.6, 73.1, 108.8, 113.0, 119.1, 135.6, 145.9, 147.9, 150.3. MS (ESI) m/z 308.2 (M^++1). HRMS (ESI) calcd for $C_{14}H_{17}N_3O_5$ requires (M^++1) 308.1168 found 308.12402.

(*E*)-Diisopropyl-2-(cyano(thiophen-2-yl)methylene)hydrazine-1,1-dicarboxylate (3n). Oil. IR (CH_2Cl_2) ν 3107, 2984, 2938, 2230, 1795, 1763, 1309,1093 cm^{-1}; ^1H NMR ($CDCl_3$, 400 MHz, TMS): δ 1.37 (12H, d, J = 6.0 Hz, CH_3), 5.11–5.18 (2H, m, CH), 7.20 (1H, dd, J_1 = 4.4 Hz, J_2 = 5.2 Hz, Ar), 7.64 (1H, dd, J_1 = 1.2 Hz, J_2 = 5.2 Hz, Ar), 7.75 (1H, dd, J_1 = 1.2 Hz, J_2 = 4.4 Hz, Ar). ^{13}C NMR ($CDCl_3$, 100 MHz): δ 21.6, 72.9, 109.2, 128.2, 133.3, 134.3, 135.2, 141.6, 150.3. MS (ESI) m/z 324.2 (M^++1). HRMS (ESI) calcd for $C_{14}H_{17}N_3O_4S$ requires (M^++1) 324.0940 found 324.10089.

(*Z*)-Diisopropyl-2-(cyano(naphthalen-1-yl)methylene)hydrazine-1,1-dicarboxylate (3o). Oil. IR (CH_2Cl_2) ν 2985, 2939, 2226, 1798, 1761, 1511, 1093 cm^{-1}; ^1H NMR ($CDCl_3$, 400 MHz, TMS): δ 1.42 (12H, d, J = 6.0 Hz, CH_3), 5.18–5.25 (2H, m, CH), 7.55–7.67 (3H, m, Ar), 7.91–7.93 (1H, m, Ar), 8.00–8.03 (1H, m, Ar), 8.05 (1H, d, J = 8.0 Hz, Ar), 8.99 (1H, d, J = 8.4 Hz, Ar). ^{13}C NMR ($CDCl_3$, 100 MHz): δ 21.7, 73.0, 110.7, 124.7, 125.5, 127.0, 127.3, 128.5, 128.8, 130.0, 131.1, 133.9, 148.7, 150.1. MS (ESI) m/z 368.0 (M^++1), 389.9 (M^++Na). HRMS (ESI) calcd for $C_{20}H_{21}N_3O_4$ requires (M^++Na) 390.1424 found 390.14222.

(*Z*)-Diisopropyl-2-(cyano(thiophen-3-yl)methylene)hydrazine-1,1-dicarboxylate (3p). Oil. IR (CH_2Cl_2) ν 3107, 2984, 1938, 2230, 1795, 1763, 1561, 1093 cm^{-1}; ^1H NMR ($CDCl_3$, 400 MHz, TMS): δ 1.37 (12H, d, J = 6.4 Hz, CH_3), 5.12–5.19 (2H, m, CH), 7.44 (1H, dd, J_1 = 2.8 Hz, J_2 = 5.2 Hz, Ar), 7.68 (1H, dd, J_1 = 1.2 Hz, J_2 = 5.2 Hz, Ar), 8.08 (1H, dd, J_1 = 1.2 Hz, J_2 = 2.8 Hz, Ar). ^{13}C NMR ($CDCl_3$, 100 MHz): δ 21.7, 73.0, 110.1, 125.3,

128.0, 132.1, 133.9, 141.8, 150.4. MS (ESI) m/z 323.9 (M^++1). HRMS (ESI) calcd for $C_{14}H_{17}N_3O_4S$ requires (M^++Na) 346.0832 found 346.08304.

Typical reaction procedure for the preparation of 4

To a stirred solution of acyl cyanide **1** (0.3 mmol) and Ph_3P (0.3 mmol) in anhydrous toluene (2.0 mL) under argon was added diisopropyl azodicarboxylate/diethyl azodicarboxylate **2** (0.3 mmol) at 20 °C, the mixture was maintained at 20 °C to stir for the time needed. The solvent was removed under reduced pressure on a rotary evaporator. The residue was subjected to column chromatography on silica gel (300–400 mesh) to afford the products **4**.

(**4a**) Oil. IR (CH_2Cl_2) ν 2986, 2940, 1783, 1626, 1214, 1095 cm^{-1}; ^1H NMR ($CDCl_3$, 400 MHz, TMS): δ 1.34 (6H, d, J = 6.0 Hz, CH_3), 1.48 (6H, d, J = 6.0 Hz, CH_3), 4.91–4.99 (1H, m, CH), 5.31–5.38 (1H, m, CH), 7.42–7.52 (3H, m, Ar), 7.92–7.95 (2H, m, Ar). ^{13}C NMR ($CDCl_3$, 100 MHz): δ 21.2, 21.4, 74.9, 76.6, 110.9, 127.2, 128.8, 131.4, 131.8, 138.4, 148.6, 155.7. MS (ESI) m/z 318.0 (M^++1), 340.1 (M^++Na). HRMS (ESI) calcd for $C_{16}H_{19}N_3O_4$ requires (M^++Na) 340.1268 found 340.12676.

(**4b**) Oil. IR (CH_2Cl_2) ν 2986, 1939, 2225, 1783, 1622, 1213, 1095 cm^{-1}; ^1H NMR ($CDCl_3$, 300 MHz, TMS): δ 1.35 (6H, d, J = 6.3 Hz, CH_3), 1.48 (6H, d, J = 6.3 Hz, CH_3), 4.90–4.99 (1H, m, CH), 5.30–5.39 (1H, m, CH), 7.58 (2H, d, J = 8.7 Hz, Ar), 7.80 (2H, d, J = 8.7 Hz, Ar). ^{13}C NMR ($CDCl_3$, 75 MHz): δ 21.2, 21.4, 75.0, 76.8, 110.6, 126.5, 128.5, 130.3, 132.1, 137.3, 148.5, 155.9. MS (ESI) m/z 395.9 (M^++1), 418.9 (M^++Na). HRMS (ESI) calcd for $C_{16}H_{18}BrN_3O_4$ requires (M^++Na) 418.0373 found 418.03621.

(**4c**) Oil. IR (CH_2Cl_2) ν 2987, 2940, 2225, 1783, 1622, 1214, 1094 cm^{-1}; ^1H NMR ($CDCl_3$, 400 MHz, TMS): δ 1.35 (6H, d, J = 6.0 Hz, CH_3), 1.48 (6H, d, J = 6.0 Hz, CH_3), 4.91–4.98 (1H, m, CH), 5.31–5.38 (1H, m, CH), 7.42 (2H, d, J = 8.4 Hz, Ar), 7.87 (2H, d, J = 8.4 Hz, Ar). ^{13}C NMR ($CDCl_3$, 100 MHz): δ 21.2, 21.5, 75.1, 76.8, 110.7, 128.4, 129.2, 129.9, 137.2, 138.0, 148.5, 155.9. MS (ESI) m/z 352.0 (M^++1), 373.9 (M^++Na). HRMS (ESI) calcd for $C_{16}H_{18}ClN_3O_4$ requires (M^++Na) 374.0878 found 374.08694.

(**4d**) Oil. IR (CH_2Cl_2) ν 2987, 2940, 2225, 1783, 1622, 1214, 1094 cm^{-1}; ^1H NMR ($CDCl_3$, 400 MHz, TMS): δ 1.35 (6H, d, J = 6.0 Hz, CH_3), 1.48 (6H, d, J = 6.0 Hz, CH_3), 4.91–4.98 (1H, m, CH), 5.31–5.38 (1H, m, CH), 7.42 (2H, d, J = 8.4 Hz, Ar), 7.87 (2H, d, J = 8.4 Hz, Ar). ^{13}C NMR ($CDCl_3$, 100 MHz): δ 21.2, 21.5, 75.1, 76.8, 110.7, 128.4, 129.2, 129.9, 137.2, 138.0, 148.5, 155.9. MS (ESI) m/z 352.0 (M^++1), 373.9 (M^++Na). HRMS (ESI) calcd for $C_{16}H_{18}ClN_3O_4$ requires (M^++Na) 374.0878 found 374.08694.

(**4e**) mp. 75–77 °C; IR (CH_2Cl_2) ν 2986, 1939, 2225, 1783, 1627, 1214, 1095 cm^{-1}; ^1H NMR (benzene-d_6, 400 MHz, TMS): δ 0.96 (6H, d, J = 6.0 Hz, CH_3), 1.14 (6H, d, J = 6.0 Hz, CH_3), 3.23 (3H, s, OCH_3), 4.67–4.74 (1H, m, CH), 5.16–5.23 (1H, m, CH), 6.61 (2H, d, J = 8.8 Hz, Ar), 7.94 (2H, d, J = 8.8 Hz, Ar). ^{13}C NMR (benzene-d_6, 100 MHz): δ 21.0, 21.2, 54.9, 74.6, 76.4, 111.6, 114.6, 124.7, 129.3, 138.7, 149.2, 155.8, 162.9. MS (ESI) m/z 348.1 (M^++1). HRMS (ESI) calcd for $C_{17}H_21N_3O_5$ requires (M^++Na) 370.1373 found 370.13749.

(**4f**) Oil. IR (CH_2Cl_2) ν 2986, 2939, 2225, 1782, 1627, 1207, 1086 cm^{-1}; ^1H NMR ($CDCl_3$, 300 MHz, TMS): δ 1.36 (6H, d, J = 6.0 Hz, CH_3), 1.48 (6H, d, J = 6.0 Hz, CH_3), 2.35 (6H, s, CH_3), 4.92–5.01 (1H, m, CH), 5.29–5.39 (1H, m, CH), 7.12 (1H, s, Ar), 7.55 (2H, s, Ar). ^{13}C NMR ($CDCl_3$, 75 MHz): δ 21.1, 21.2, 21.4, 74.8, 76.4, 111.1, 125.0, 131.2, 133.6, 138.5, 138.7, 148.6, 155.3. MS (ESI) m/z 346.0 (M^++1), 368.0 (M^++Na). HRMS (ESI) calcd for $C_{18}H_{23}N_3O_4$ requires (M^++Na) 368.1581 found 368.15692.

(**4g**) Oil. IR (CH_2Cl_2) ν 2986, 2942, 2842, 2226, 1784, 1628, 1590, 1212, 1096 cm^{-1}; ^1H NMR ($CDCl_3$, 400 MHz, TMS): δ 1.31 (6H, d, J = 6.4 Hz, CH_3), 1.48 (6H, d, J = 6.0 Hz, CH_3), 3.92 (9H, s, OCH_3), 4.90–4.97 (1H, m, CH), 5.30–5.37 (1H, m, CH), 7.19 (2H, s, Ar). ^{13}C NMR ($CDCl_3$, 100 MHz): δ 21.2, 21.4, 56.2, 61.0, 74.9, 76.5, 104.4, 110.9, 126.6, 138.0, 141.4, 148.4, 153.4, 155.2. MS (ESI) m/z 407.9 (M^++1), 429.9 (M^++Na). HRMS (ESI) calcd for $C_{19}H_{25}N_3O_7$ requires (M^++Na) 430.1585 found 430.15792.

(**4h**) Oil. IR (CH_2Cl_2) ν 2985, 2942, 2842, 2227, 1789, 1633, 1590, 1206 cm^{-1}; ^1H NMR ($CDCl_3$, 400 MHz, TMS): δ 1.33 (3H, t, J = 7.2 Hz, CH_3), 1.48 (3H, t, J = 7.2 Hz, CH_3), 3.91 (3H, s, OCH_3), 3.92 (6H, s, OCH_3), 4.31 (2H, q, J = 7.2 Hz, CH_2), 4.57 (2H, q, J = 7.2 Hz, CH), 7.19 (2H, s, Ar). ^{13}C NMR ($CDCl_3$, 100 MHz, TMS): δ 13.8, 14.0, 56.2, 61.0, 66.2, 68.0, 104.4, 110.8, 126.5, 138.4, 141.5, 148.9, 153.4, 155.9. MS (ESI) m/z 380.0 (M^++1). HRMS (ESI) calcd for $C_{17}H_{21}N_3O_7$ requires (M^++Na) 402.1272 found 402.12674.

(**4i**) Oil. IR (CH_2Cl_2) ν 2985, 2940, 2842, 2225, 1785, 1630, 1604, 1261, 1205 cm^{-1}; ^1H NMR ($CDCl_3$, 400 MHz, TMS): δ 1.35 (3H, t, J = 7.2 Hz, CH_3), 1.46 (3H, t, J = 7.2 Hz, CH_3), 3.86 (3H, s, OCH_3), 4.32 (2H, q, J = 7.2 Hz, CH_2), 4.55 (2H, q, J = 7.2 Hz, CH), 6.95 (2H, d, J = 9.2 Hz, Ar), 7.87 (2H, d, J = 9.2 Hz, Ar). ^{13}C NMR ($CDCl_3$, 100 MHz, TMS): δ 13.7, 14.0, 55.5, 66.2, 67.7, 111.0, 114.3, 124.0, 129.0, 138.5, 149.1, 155.4, 162.7. MS (ESI) m/z 320.0 (M^++1), 341.9 (M^++Na). HRMS (ESI) calcd for $C_{15}H_{17}N_3O_5$ requires (M^++Na) 342.1060 found 342.10585.

(**4j**) Oil. IR (CH_2Cl_2) ν 3051, 2985, 2939, 2223, 1778, 1628, 1217, 1093 cm^{-1}; ^1H NMR (benzene-d_6, 300 MHz, TMS): δ 0.79 (6H, d, J = 6.3 Hz, CH_3), 1.17 (6H, d, J = 6.3 Hz, CH_3), 4.56–4.65 (1H, m, CH), 5.24–5.33 (1H, m, CH), 7.00 (1H, t, J = 7.8 Hz, Ar), 7.24 (1H, t, J = 7.8 Hz, Ar), 7.42 (1H, t, J = 8.4 Hz, Ar), 7.49 (1H, d, J = 8.1 Hz, Ar), 7.54 (1H, d, J = 8.1 Hz, Ar), 7.95 (1H, d, J = 8.1 Hz, Ar), 9.20 (1H, d, J = 8.4 Hz, Ar). ^{13}C NMR (benzene-d_6, 75 MHz, TMS): δ 21.0, 21.2, 74.8, 76.8, 112.4, 125.1, 126.4, 126.7, 128.2, 128.5, 129.0, 130.7, 131.1, 132.5, 134.4, 140.4, 149.2, 156.4. MS (ESI) m/z 368.0 (M^++1). HRMS (ESI) calcd for $C_{20}H_{21}N_3O_4$ requires (M^++Na) 390.1424 found 390.14189.

(**4k**) Oil. IR (CH_2Cl_2) ν 3105, 2986, 2940, 2227, 1783, 1626, 1218, 1095 cm^{-1}; ^1H NMR ($CDCl_3$, 400 MHz, TMS): δ 1.34 (6H, d, J = 6.4 Hz, CH_3), 1.46 (6H, d, J = 6.0 Hz, CH_3), 4.91–4.98 (1H, m, CH), 5.28–5.35 (1H, m, CH), 7.36 (1H, dd, J_1 = 2.8 Hz, J_2 = 4.8 Hz, Ar), 7.52 (1H, dd, J_1 = 1.2 Hz, J_2 = 4.8 Hz, Ar), 7.90 (1H, dd, J_1 = 1.2 Hz, J_2 = 2.8 Hz, Ar). ^{13}C NMR ($CDCl_3$, 100 MHz, TMS): δ 21.2, 21.4, 74.9, 76.4, 111.2, 124.9, 127.4, 129.2, 133.8, 134.9, 148.5, 155.2. MS (ESI) m/z 323.9 (M^++1), 345.9 (M^++Na). HRMS (ESI) calcd for $C_{14}H_{17}N_3O_4S$ requires (M^++Na) 346.0832 found 346.08309.

The products 6–9 were prepared using a procedure similar to that for the preparation of 3

(*Z*)-Diisopropyl-2-(1-(4-chlorophenyl)-2,2,2-trifluoroethylidene)hydrazine-1,1-dicarboxylate (6). Oil. IR (CH_2Cl_2) ν 2986, 2941, 1752, 1594, 1281, 1147 cm^{-1}; ^1H NMR ($CDCl_3$, 300 MHz, TMS): δ 1.21 (12H, d, J = 6.0 Hz, CH_3), 4.84–4.93 (2H, m,

CH), 7.31 (2H, d, J = 8.7 Hz, Ar), 7.44 (2H, d, J = 8.7 Hz, Ar). ^{13}C NMR ($CDCl_3$, 100 MHz): δ 21.4, 72.7, 119.7 (q, J = 275.8 Hz), 126.7, 129.1, 137.4, 150.3, 158.0 (q, J = 33.5 Hz). ^{19}F NMR ($CDCl_3$, 282 MHz): δ −73.94. MS (ESI) m/z 395.2 (M^++1). HRMS (MALDI) calcd for $C_{16}H_{18}ClF_3N_2O_4$ requires (M^++Na) 417.0811 found 417.07994.

(*Z*)-isopropyl-2-(1-cyano-2,2-dimethylpropylidene)hydrazinecarboxylate (7). Oil. IR (CH_2Cl_2) ν 3226, 2979, 2211, 1760, 1513, 1222, 1108 cm^{-1}; ^{1}H NMR ($CDCl_3$, 400 MHz, TMS): δ 1.27 (9H, s, CH_3), 1.32 (6H, d, J = 6.0 Hz, CH_3), 5.04–5.11 (1H, m, CH), 8.52 (1H, s, NH). ^{13}C NMR ($CDCl_3$, 100 MHz): δ 21.9, 27.4, 36.7, 70.8, 109.5, 132.1, 151.7. MS (ESI) m/z 212.1 (M^++1). HRMS (EI) calcd for $C_{10}H_{17}N_3O_2$ requires (M^+) 211.1321, found 211.1321.

(*Z*)-Ethyl-2-(1-cyano-2,2-dimethylpropylidene)hydrazinecarboxylate (8). Oil. IR (CH_2Cl_2) ν 3239, 2971, 2211, 1766, 1514, 1216, 1031 cm^{-1}; ^{1}H NMR ($CDCl_3$, 400 MHz, TMS): δ 1.27 (9H, s, CH_3), 1.34 (3H, t, J = 7.2 Hz, CH_3), 4.31 (2H, q, J = 7.2 Hz, CH), 8.54 (1H, s, NH). ^{13}C NMR ($CDCl_3$, 100 MHz): δ 14.4, 27.4, 36.8, 62.7, 109.4, 132.3, 152.2. MS (ESI) m/z 198.1 (M^++1). HRMS (EI) calcd for $C_9H_{15}N_3O_2$ requires (M^+) 197.1164, found 197.1168.

Diisopropyl-5-cyano-3-(furan-2-yl)-3*H*-pyrazole-1,2-dicarboxylate (9). Oil. IR (CH_2Cl_2) ν 3113, 2985, 2939, 2240, 1736, 1366, 1105 cm^{-1}; ^{1}H NMR ($CDCl_3$, 300 MHz, TMS): δ 1.26–1.38 (12H, m, CH_3), 5.00–5.11 (2H, m, CH), 6.04 (1H, d, J = 3.3 Hz, CH), 6.31 (1H, d, J = 3.3 Hz, CH), 6.34 (2H, m, Ar), 7.37–7.39 (1H, m, Ar). ^{13}C NMR ($CDCl_3$, 75 MHz): δ 21.5, 21.6, 21.7, 21.8, 60.5, 71.7, 72.5, 108.4, 110.5, 110.6, 116.9, 125.2, 143.5, 148.7, 153.8, 156.3. MS (ESI) m/z 334.2 (M^++1), 356.2 (M^++Na). HRMS (MALDI) calcd for $C_{16}H_{19}N_3O_5$ requires (M^++Na) 356.1219 found 356.12169.

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