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Synthesis and Fluorescent Behaviour of 2-Aryl-4,5-Dihydro-1*H*-1,2,4-triazoles

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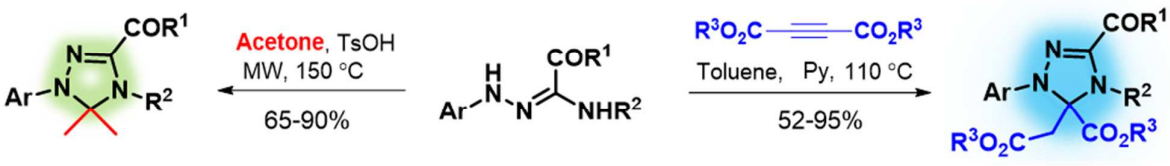


ABSTRACT

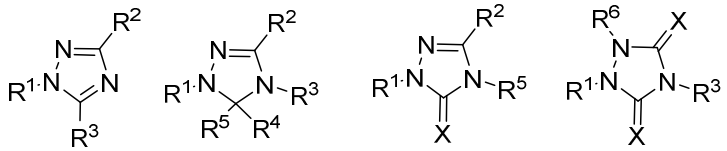
A series of new 4,5-dihydro-1*H*-1,2,4-triazoles was synthesized from amidrazones and acetylenedicarboxylic acid esters in the presence of pyridine in toluene. The synthesized compounds were characterized by ^{1}H, ^{13}C NMR, FT-IR spectral analyses and XRD data. Optical studies revealed that most of the compounds reported here exhibited emission of blue or green-yellow light upon irradiation in acetone and showed Stokes shifts in the region of 70-96 nm and quantum yields of up to 45%. The interpretation of the experimental findings was supported by state-of-the-art quantum mechanical calculations.

Keywords: 4,5-Dihydro-1*H*-1,2,4-triazole, Amidrazone, Dimethyl acetylenedicarboxylate, Stokes shift, Quantum yield, Fluorescence, Time-Dependent Density Functional Theory, Polarizable Continuum Model

INTRODUCTION

1,2,4-Triazole and its derivatives, an amide *cis*-bond isostere, can be used for both peptide mimicry and drug design, where they can improve the pharmacological properties of the corresponding lead compound.[1] Type **I** 1,2,4-triazoles (Scheme 1) have also been extensively studied as ligands for mononuclear and oligonuclear metal coordination, exhibiting interesting physical and chemical properties.[2] Non-aromatic 1,2,4-triazoline (**II**, **III**) and –triazolidine (**IV**) are lesser known and are relatively unstable.[3] The most widely spread dihydro- and tetrahydrotriazoles usually include C=X exocyclic double bonds in their structures.[3] Triazolines and triazolidines, like their aromatic analogues, are readily hydrolysed in acidic media. 4,5-Dihydro-1*H*-1,2,4-triazoles **II**, **III** are famous for their ability to form stable carbenes, which are applied as ligands and in organic catalysis.[4]

Scheme 1. Known types of 1,2,4-triazoles, -triazolines and -triazolidines



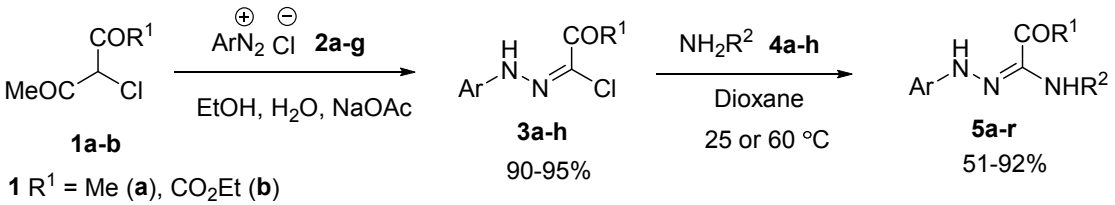
The main method for the synthesis of 4,5-dihydrotriazoles **II** is the 1,3-dipolar cycloaddition of nitrilimines to dipolarophiles bearing C=N bonds.[5] However, this approach is unable to provide a variety of substituents in the resulting triazoles because it is limited by the availability of nitrilimines and appropriate reactive dipolarophiles. P. Frohberg and coauthors in their search for new inhibitors of lypoxygenases, enzymes that are potent mediators of inflammatory and allergic reactions in human, described the synthesis of 5,5-dialkyl-4,5-dihydrotriazoles **II** (R^1 = Ar, R^2 = COMe, R^3 = Alkyl, R^4, R^5 = Me) by cyclization of amidrazones with ketones.[6] The main disadvantage of these reactions was their limitation of the number of carbonyl compounds (only acetone and methylethylketone) that can be used for this reaction. It worth noting that this reaction proceeded only by refluxing amidrazone at a large excess of liquid ketone.

In this paper, we describe a new method for the synthesis of 4,5-dihydrotriazoles **II** by the cyclization of amidrazones with dimethyl- and diethylacetylene dicarboxylate (DMAD and DEAD) and show the results of their photophysical properties.

RESULTS AND DISCUSSION

Synthesis and Characterization. Arylhydrazones with an amino functional group at the carbon atom of the hydrazone group (usually referred to in the literature as 'amidrazone') were obtained according to the procedure of nucleophilic substitution of the halogen atom of hydrazonoyl chlorides with amines.[7] Access to hydrazonoyl chlorides could be realized via the Japp–Klingemann reaction.[8] Chlorinated dicarbonyl compounds, such as 3-chloropentane-2,4-dione **1a** or ethyl 2-chloro-3-oxobutanoate **1b**, were coupled with diazotized anilines **2a-g** with concomitant release of acetic acid (Scheme 2). Alkyl-, aryl- or hetarylaminocompounds **4a-h**, acting as nitrogen nucleophiles, were added readily to nitrile imines (the reactive species were generated *in situ* from their corresponding hydrazonoyl chloride precursors **3a-h** in the presence of triethylamine) to give the respective amidrazone adducts **5a-r**. This mode of nucleophilic addition to 1,3-dipoles has been well documented[9] for various nucleophiles, and several adducts related to **5** were obtained from the reaction of amines with hydrazonoyl chlorides.

Scheme 2. Synthesis of amidrazones 5



1a-b **3a-h** 90-95% **5a-r** 51-92%

1 R^1 = Me (**a**), CO_2Et (**b**)

2 Ar = 4-MeC_6H_4 (**a**), Ph (**b**), 4-CNC_6H_4 (**c**), (3,5-CF_3)$_2C_6H_3$ (**d**), 2-ClC_6H_4 (**e**), 2-$CF_3C_6H_4$ (**f**), 2-FC_6H_4 (**g**)

3 R^1 = Me, Ar = 4-MeC_6H_4 (**a**); Ph (**b**); 4-CNC_6H_4 (**c**); 3,5-$(CF_3)_2C_6H_3$ (**d**); 2-ClC_6H_4 (**e**); 2-$CF_3C_6H_4$ (**f**); 2-FC_6H_4 (**g**); R^1 = OEt, Ar = 4-CNC_6H_4 (**h**)

4 R^2 = Me (**a**), *n*-Bu(**b**), CH_2CH_2OMe (**c**), *cyclo*-C_6H_{11} (**d**), Bn (**e**), Ph (**f**), 9-ethylcarbazole (**g**), C_6H_4-NH-Ph (**h**)

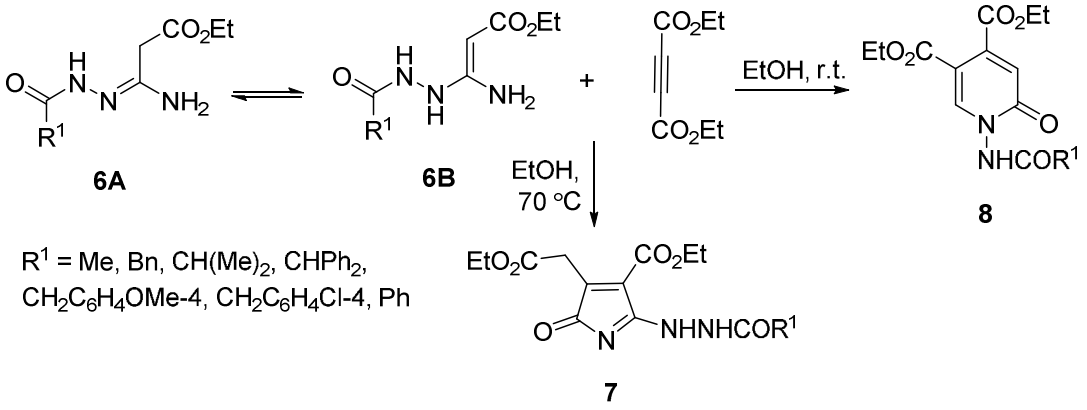
5	R^1	R^2	Ar	**5**	R^1	R^2	Ar
a	Me	Me	4-MeC_6H_4	**j**	Me	Ph	4-MeC_6H_4
b	Me	Me	Ph	**k**	Me	Ph	4-CNC_6H_4
c	Me	Me	4-FC_6H_4	**l**	Me	n-Bu	4-CNC_6H_4
d	Me	Me	4-ClC_6H_4	**m**	Me	CH_2CH_2OMe	4-CNC_6H_4
e	Me	Me	4-CNC_6H_4	**n**	Me	Bn	4-CNC_6H_4
f	Me	Me	3,5-$(CF_3)_2C_6H_3$	**o**	Me	*cyclo*-C_6H_{11}	4-CNC_6H_4
g	Me	Me	2-FC_6H_4	**p**	Me	9-ethylcarbazole	4-CNC_6H_4
h	Me	Me	2-ClC_6H_4	**q**	Me	C_6H_4-NHPh	4-CNC_6H_4
i	Me	Me	2-$CF_3C_6H_4$	**r**	CO_2Et	Me	4-CNC_6H_4

The newly synthesized compounds **5a-r** were characterized by elemental analyses, MS and NMR. These data, detailed in the Experimental part, are consistent with the suggested structures. It should be mentioned that compounds **5i**,**r** were isolated as a mixture of *Z*- and *E*-isomers. The appearance of the additional isomer for the compounds **5i** and **r** may be explained due to the weakness of the H-bond, which is the driving force for the stabilization of the one isomer (usually Z-isomer). Spatial hindrance for compound **5i** caused by the substituent in *o*-position of the aromatic ring (CF_3) and lower acceptor property of the ester oxygen (COOEt) in comparison with the O-atom of the acyl group for compound **5r** explain the presence of weakened hydrogen bonds in these molecules. This phenomenon are well-known for the different types of hydrazones, including amidrazones.[7,9f]

Reactions of binucleophiles with acetylene carboxylic acid (ACA) derivatives represent an interesting field of heterocyclic chemistry both in the theoretical aspects and in the practical applications of the obtained heterocyclic products.[10] Reactions of ACA derivatives with compounds bearing two or more nitrogen-containing nucleophilic centres have been employed as

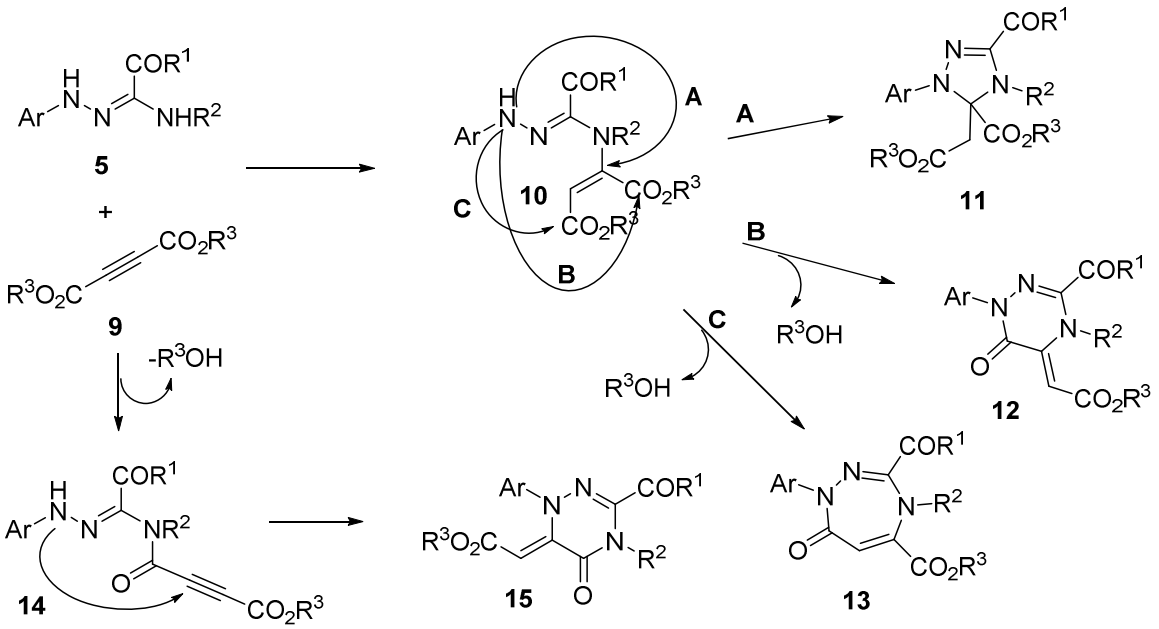
a route for generating a wide variety of heterocyclic compounds.[9f,10-11] There is only one report on the reaction of amidrazones with the latter reagents.[11f] For instance, the reaction between *N*-acyl amidrazones **6** and DEAD leads to the formation of either 2*H*-pyrrole or oxopyridine depending on the reaction conditions and substitution pattern of amidrazone, thus giving either 2*H*-pyrrol-2-ones **7** or pyridin-2-ones **8** (Scheme 3).

Scheme 3. Reaction of amidrazones with DEAD



The amidrazones **5a-r** are polyfunctionalized reagents bearing two nucleophilic and one electrophilic centres. Thus, we can expect the formation of several heterocyclic compounds with different types of azacyclic systems and different degrees of saturation in the products of their interactions with DMAD. Concerning the amidrazones **5a-r**, they could form at least three types of heterocycles, 1-aryl-4,5-dihydro-1*H*-1,2,4-triazoles **11**, 4,5-dihydro-1,2,4-triazin-6(1*H*)-ones **12** and 1,4-dihydro-7*H*-1,2,4-triazepin-7-ones **13** (Scheme 4), *via* the initial attack of the amine nitrogen to the carbon of the triple bond DMAD, followed by cyclization of intermediate **10** in addition (**A**) or condensation (**B**, **C**) processes.

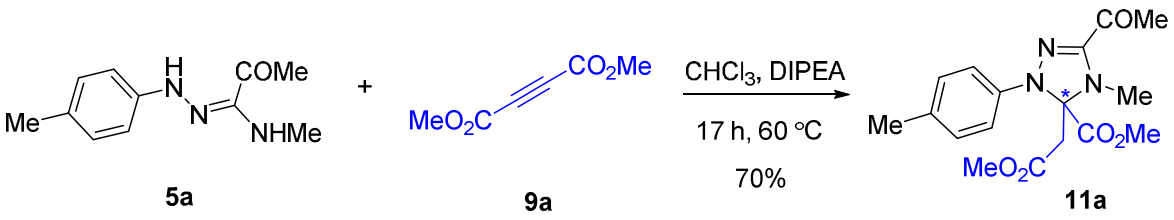
Scheme 4. Possible directions of the reaction of the amidrazones with ACA esters



The presence of the rather active amino group of reagent **5** could afford amides **14** (according to Scheme 3) and then 4,5-dihydro-1,2,4-triazinones **15** as the product of intramolecular cyclization.

Initially, the reaction of amidrazone **5a** with DMAD in the presence of diisopropyl ethylamine (DIPEA) was investigated (Scheme 5). Interestingly, during refluxing of the starting reagents **5a** and **9a** in chloroform in the presence of DIPEA for 17 h, only one product, **11a**, was registered by TLC. 4,5-Dihydrotriazole **11a** was isolated from the reaction mixture by liquid column chromatography.

Scheme 5. Reaction of amidrazone 5a with DMAD

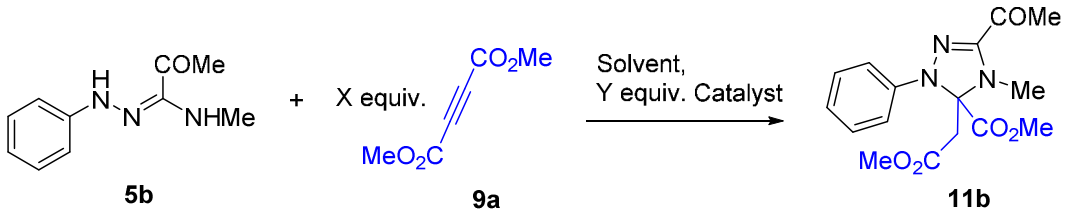


The formation of 4,5-dihydrotriazole **11a** was indicated by its FT-IR spectrum, where the main absorption bands were observed at 1738 cm^{-1} due to the stretching of C=O bonds of two COOMe groups and by the disappearance of the bands at 3263 and 3355 cm^{-1} corresponding to the N-H bonds of hydrazone and amine groups. The ^{1}H NMR spectrum for compound **11a** exhibited

signals of all proton-containing groups. The main particularity of the structure of triazole **11a** is the presence of a C(5)-asymmetric centre, which was induced during the cyclization step. Thus, the signal of the two protons of the CH_2-group linked to this chiral C(5)-atom was observed in the ^1H NMR spectrum as an AB-system at 3.25 ppm. The ^{13}C NMR spectrum displayed additional signals of carbon atoms of two Me-groups from the CO_2Me-fragments at 3.49 and 3.71 ppm, triplet of the CH_2-group at 34.1, quartet of triplets of the C-5-ring sp^3-atom at 88.0 ppm, and quartet and multiplet of the C=O groups at 167.5 and 167.7 ppm. Mass-spectral and elemental analysis data confirmed the structure of compound **11a**. The mass spectrum of compound **11a** showed a molecular ion peak with small intensity (2.5%). The most abundant was one, which corresponded to the elimination of one of the COOMe groups (288).

During the synthetic experiments, we found that the solutions of 4,5-dihydrotriazole **11a** showed blue fluorescence. To obtain a series of these compounds for further detailed investigation of their fluorescent properties, we carried out an optimization of the reaction conditions for the first developed method (Scheme 5). For these purposes, the reaction of amidrazone **5b** and DMAD in the presence of a base and TsOH as a catalyst was selected as the model reaction. The results of this investigation are summarized in Table 1.

Table 1. **Optimization of the conditions for the reaction of amidrazone 5b with DMAD**



5b **9a** **11b**

entry	X, (equiv.)	catalyst	Y, (equiv.)	solvent	T, (°C)	time, (min)	yield[a] of **11b**, (%)
1	2.0	-	-	Toluene	110	1200	No reaction
2	2.0	TEA	2.0	Toluene	110	600	74
3	1.5	DIPEA	1.0	Toluene	110	240	60
4	2.0	DIPEA	2.0	Toluene	110	300	88
5	2.0	NMM	2.0	Toluene	110	600	Trace
6	2.0	DBU	2.0	Toluene	110	600	Trace
7	2.0	DMAP	2.0	Toluene	110	600	Not completed[b]
8	1.0	Py	1.0	Toluene	110	600	Not completed[b]
9	1.0	Py	2.0	Toluene	110	600	Not completed[b]
10	2.0	Py	2.0	Toluene	110	15	95

11	2.0	Py	2.0	$CHCl_3$	60	3600	Not completed[b]
12	2.0	Py	1.0	Toluene	110	180	66[c]
13	1.5	TsOH	0.1	Toluene	110	450	72
14	2.0	TsOH	0.1	Toluene	110	600	74
15	2.0	TsOH	0.5	Toluene	110	450	59
16	1.5	TsOH	0.1	$CHCl_3$	60	320	50
17	2.0	TsOH	0.1	$CHCl_3$	60	720	90

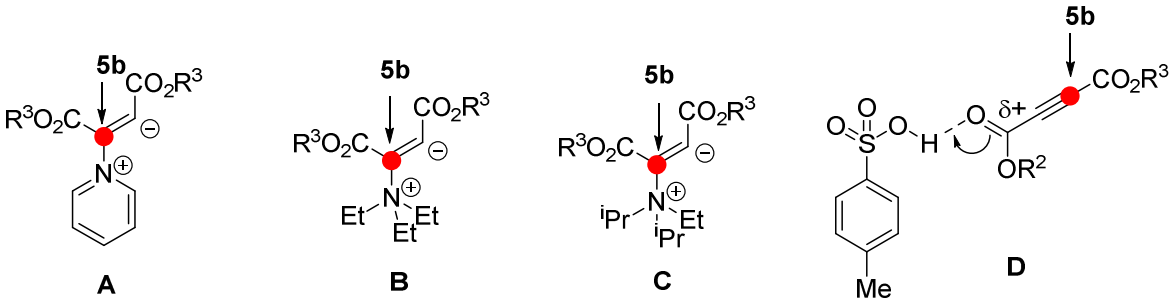
[a] – Isolated yield.

[b] - In the working conditions, the reaction did not complete during a long time. The experiment was therefore interrupted and the product was not separated.

[c] – By-product **16** (see Scheme 7) was isolated in 10% yield.

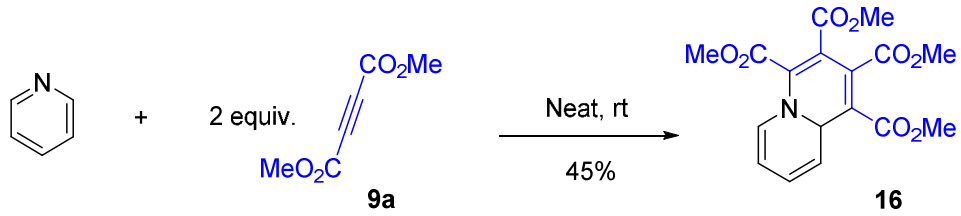
As important activating factors for the reaction, various types of bases (DIPEA, TEA, *N*-methylmorpholine (NMM), 1,8-diazabicyclo[5.4.0]undec-7-en (DBU), pyridine, *N*-dimethylaminopyridine (DMAP)) and different ratios of the reagents in toluene or $CHCl_3$ under reflux were examined (Table 1). After a series of experiments, the optimal conditions were identified as: reflux in toluene in the presence of 2 equiv. of pyridine and usage of 2 equiv. of DMAD (Table 1, entry 10). The use other organic bases, such as TEA, DIPEA, NMM, DBU or DMAP, was less successful (Table 1, entries 2–7). We can suggest that the main reason for the differences in the influences of different organic bases on the investigated reaction might be the spatial availability of the active electrophilic site in the zwitterions **A-B**, which generated an ACA ester *in situ* under the action of an organic base (Scheme 6). These species could be formed by the initial attack of the basic nitrogen atom onto the triple bond in DMAD. This assumption is based on the known fact[12] that for pyridine, this attack proceeds in *trans*-mode and usually is very fast, even at room temperature.

Scheme 6. Possible structures of the active intermediates generated by the interaction of ACA esters with the catalysts



The most accessible point for the next attack by amidine **5b** is the electrophilic centre in zwitterion **A**. It worth nothing that pyridine can react with a second molecule of DMAD to form the product of 1,4-dipolar cycloaddition - tetraethyl 1,3,4,9*a*-tetrahydro-2*H*-quinolizine-1,2,3,4-tetracarboxylate **16** (Scheme 7).[13]

Scheme 7. Reaction of pyridine with DMAD



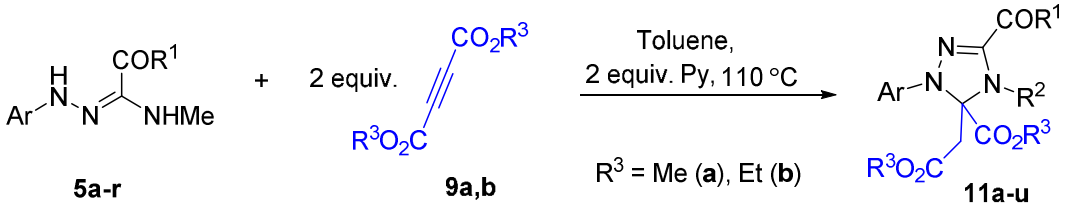
Nevertheless, the implied conditions (Table 1, entry 10) provided an excellent yield of the desired triazole **11b**. This means that molecules of pyridine quickly reacted with DMAD to generate zwitterion **A**, which then reacted with amidine **5b** faster than cycloaddition with another DMAD molecule. The experiment with an excess of DMAD (Table 1, entry 11), which was preferable for the side reaction, generated the by-product **16** in a very small yield (10%).

The activation of the molecule DMAD with TsOH was usually realized by hydrogen bond formation,[14] and it might lead to the generation of complex **D** according to Scheme 6. This complex is less active then zwitterion **A** due to the smaller positive charge located on the carbon electrophilic centre (Table 1, entries 13-17). Increasing the concentration of the acid does not improve the effectiveness of the reaction.

With the optimized reaction conditions on hand, the scope of the method was explored by employing a variety of amidrazones **5a-r** and dimethyl or diethyl esters **9a**,**b**. As shown in Table

2, various 1,2,4-triazoles **11** were obtained from moderate to high yields (52-95%). The reaction was indifferent to the electron-withdrawing or -donating character of groups in the aryl ring and led to 4,5-dihydro-1*H*-1,2,4,-triazoles **11a-u** at good or excellent yields (70-95%) within 10-60 min. An outlier is the reaction of compounds **5o**,**p** with DMAD, which gave **11p**,**s** at 52-56% yields after 8 h. Furthermore, no product was detected when acetylene dicarboxylic acid or mono-ester of ACA - methyl propiolate were employed as reactants. Amidrazone **5r**, which has an ethoxycarbonyl group (COR^1 = CO_2Et), reacted with DMAD to afford 3-ethoxycarbonyltriazoline **11u**. However, this reaction was much longer (17 h) than for amidrazones **5a-q** with an acetyl moiety (COR^1 = COMe) (Table 2, entry 21).

Table 2. Reaction of amidrazones **5a-r** with esters **9a**,**b** under optimized conditions.



5a-r **9a,b** **11a-u**

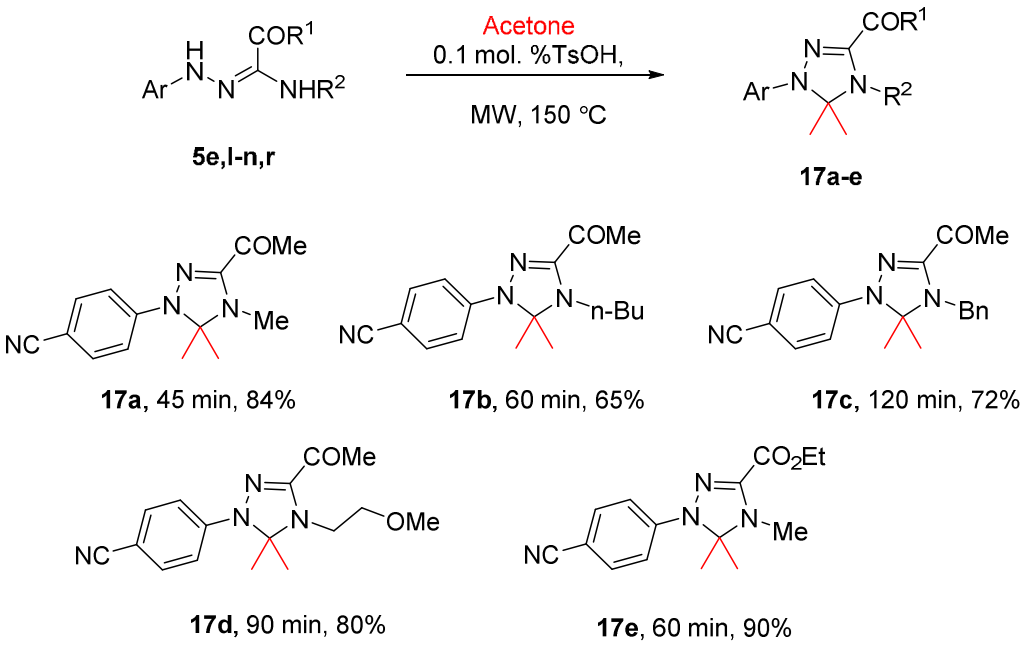
entry	compd					time, (min)	Yield **11**, (%)
	11	Ar	R^1	R^2	R^3		
1	**11a**	4-MeC_6H_4	Me	Me	Me	25	76
2	**11b**	Ph	Me	Me	Me	15	95
3	**11c**	4-FC_6H_4	Me	Me	Me	15	76
4	**11d**	4-ClC_6H_4	Me	Me	Me	15	89
5	**11e**	4-CNC_6H_4	Me	Me	Me	10	92
6	**11f**	3,5-$(CF_3)_2C_6H_3$	Me	Me	Me	30	86
7	**11g**	2-ClC_6H_4	Me	Me	Me	15	92
8	**11h**	2-$CF_3C_6H_4$	Me	Me	Me	60	75
9	**11i**	2-FC_6H_4	Me	Me	Me	10	78
10	**11j**	4-MeC_6H_4	Me	Me	Et	30	70
11	**11k**	Ph	Me	Me	Et	30	72
12	**11l**	4-CNC_6H_4	Me	Me	Et	45	95
13	**11m**	4-CNC_6H_4	Me	*n*-Bu	Me	20	89
14	**11n**	4-CNC_6H_4	Me	$(CH_2)_2OMe$	Me	20	76
15	**11o**	4-CNC_6H_4	Me	Bn	Me	45	64
16	**11p**	4-CNC_6H_4	Me	Cy	Me	480	56
17	**11q**	4-MeC_6H_4	Me	Ph	Me	45	96
18	**11r**	4-CNC_6H_4	Me	Ph	Me	60	74
19	**11s**	4-CNC_6H_4	Me	9-Ethylcarbazol-3-yl	Me	480	52
20	**11t**	4-CNC_6H_4	Me	*N*-Phenylanilin-4-yl	Me	60	85
21	**11u**	4-CNC_6H_4	OEt	Me	Et	1020	62

The products **11a-u** were stable bright yellow-orange solids or oils, and their structures were fully characterized by IR, ^{1}H and ^{13}C NMR spectroscopy, mass-spectrometry, and elemental analysis (Experimental Section, Supporting Information). Additionally, ORTEP diagrams of compounds **11d**,**e**,**g**,**q** determined by single-structure XRD analysis are shown in Figures S45-S48 (Supporting Information), which unambiguously confirm the structures and stereochemistry of compounds **11**.

To check the stability of the obtained triazoles, we refluxed compounds **11b** and **11l** in xylene, EtOH and EtOH with 1-3 equiv. HCl. It was found that both compounds were quite stable for a long time (more than 30 h) under these conditions.

To compare the properties of triazolines **11** with previously synthesized 5,5-dialkyl-4,5-dihydrotriazoles, we reacted amidrazones **5** with large excess of acetone. The literature method[6] for this condensation, which consisted of refluxing amidrazone in acetone in the presence of TSA as a catalyst, was modified. To improve the yield of the desired compounds and to shorten the time of conversion, we applied microwave irradiation. This allowed us to obtain a series of new 5,5-dimethyl-4,5-dihydro-1*H*-1,2,4-triazoles **17a-e** as bright-yellow solids or oils at good yields (Scheme 8).

Scheme 8. Synthesis of 4,5-dihydrotriazoles in the reaction amidrazones with acetone



In the FT-IR spectra of compounds **17a-e**, the NH-stretching vibration observed for amidrazones **5** disappeared and the intensity of the C-H bond stretching at 2990-2830 cm^{-1} increased. ^{1}H NMR spectra for compound **5** did not show the signals of NH-protons (in contrast to the spectra for the starting compounds), but a new singlet at 1.64-1.71 ppm belonging to the six protons of the two Me-groups appeared. Furthermore, ^{13}C NMR, mass and elemental analysis data support the proposed structure of the mentioned compound (Experimental section, Supporting Information).

Photophysical properties of 4,5-dihydro-1*H*-1,2,4-triazoles. The UV-visible properties, fluorescence emission characteristics and photochemical parameters of the target compounds (1×10^{-5} and 1×10^{-6} mol×L^{-1}, correspondingly) are summarized in Table 3. The UV–vis spectra of compounds **11a-u** in acetone exhibited λ_{max} at 377–405 nm (Figure 1). The molar extinction coefficient values for most compounds indicated that the band through the π to π* transition gave the largest contribution in the absorption. The replacement of electron–donating substituents by electron–withdrawing substituents caused a small-scale hypsochromic shift of the absorption peak (blue-shift effect in 15 nm).

The fluorescence spectra of compounds **11a-u** exhibited a maximum emission wavelength at 437–493 nm (acetone). The presence of the electron-withdrawing group in the *para*-or *meta*-

position of the aromatic ring in compounds **11a-f** shifted the emission wavelength to a shorter wavelength region (by 25 nm), *i.e.*, caused a slight blue shift (Table 3, entries 1-6). The Stokes shift of the synthesized compounds **11** was rather large and was in the range of 63-96 nm (3855-5383 cm^{-1}). The Stokes shift values indicated that there was little or no re-absorption of the emitted radiation. An increase of the fluorescence intensity (hyperchromic shift) in compounds **11a-f** and **11j-l** (Table 3, entries 1-6 and 10-12) along with an increase of the electron-withdrawing properties of the substituent in the aromatic ring were also observed. The quantum yields of the derivatives were in the range of 0.01–0.45 and were strongly related to the structure of the investigated compounds.

Table 3. Photophysical Properties of compounds **11a-u** in acetone.

entry	compd	UV-vis[a]		fluorescence[b]		
		λ_{abs}max, (nm)	ε_{max} ($M^{-1}\cdot cm^{-1}$)	λ_{em}max, (nm)	Φ_F[c]	Stokes shift, (nm/cm^{-1})
1	**11a**	403	20600	490	0.060	87/4406
2	**11b**	400	14500	482	0.075	82/4253
3	**11c**	395	10700	481	0.010	86/4526
4	**11d**	399	10700	479	0.040	80/4186
5	**11e**	399	30200	473	0.450	74/3921
6	**11f**	388	7100	465	0.250	77/4268
7	**11g**	377	4400	473	0.053	96/5383
8	**11h**	386	11900	465	0.009	79/4401
9	**11i**	386	10700	472	0.019	86/4720
10	**11j**	405	14200	493	0.094	88/4407
11	**11k**	401	10700	485	0.078	84/4319
12	**11l**	401	17600	474	0.340	73/3841
13	**11m**	403	14200	473	0.406	70/3672
14	**11n**	401	13200	476	0.367	75/3929
15	**11o**	401	16500	472	0.320	71/3751
16	**11p**	403	16100	473	0.270	70/3672
17	**11q**	397	13200	478	0.053	81/4268
18	**11r**	393	29900	462	0.030	69/3800
19	**11s**	396	15500	no	-	-
20	**11t**	396	28700	no	-	-
21	**11u**	374	26100	437	0.020	63/3855

[a]UV-vis absorption wavelengths at room temperature at a concentration of 1×10^{-5} M.

[b]Fluorescence wavelengths at room temperature at a concentration of 1×10^{-6} M.

[c]Fluorescence quantum yields measured using a 0.1 M H_2SO_4 solution of quinine sulphate (Φ_F = 0.55) as a reference.[15]

The electronic effect of substituents in the aromatic ring groups was obvious. The electron-withdrawing substituent (namely CN-group) decreased the Stokes shifts to 74 nm/3921 cm^{-1} and improved the quantum yields up to 0.45 for triazole **11e** (Table 3 entry 5, Figure 1).

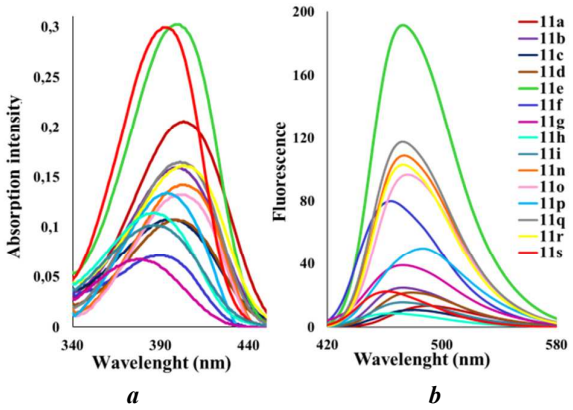


Figure 1. Absorption (***a***) and emission spectra (***b***) of 4,5-dihydro-1,2,4-triazoles **11a-i**,**n-s** in acetone at room temperature.

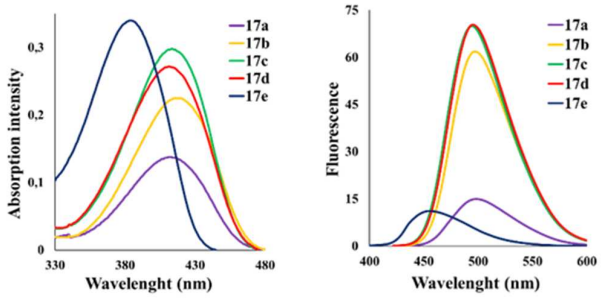
The introduction of substituents at the *ortho*-position of the aromatic ring of triazolines **11g-i** led to a hypsochromic shift of the absorption band due to the strong disruption of the conjugation between the aromatic and 1,2,4-triazoline rings (Table 3 entries 7-9). From the XRD data (Figures S45 and S46), the aromatic and 1,2,4-triazoline rings were more coplanar in the structures of compounds **11** with the *para*-substituted aromatic ring at the N(1)-triazole position and more non-planar for the compounds with the *ortho*-substituted aromatic ring (Figure 47). Replacement of the substituents at the C(3) and N(4) positions of azoles also influenced their photophysical properties. Thus, triazolines **11e**,**m-p** with alkyl substituents at the N(4) atom showed good quantum yields (0.27-0.45) (Table 3, entries 5,13-16), while the aromatic ones, that is, **11q**,**r**, exhibited less fluorescence (Table 3, entries 17, 18). Moreover, triazole **11s** bearing the *N*-ethylcarbazole fragment (which showed blue fluorescence itself) and compound **11t** with the *N*-phenylaniline substituent completely lost the fluorescent properties (Table 3, entries 19-20). It should be mention that for carbazole derivative **11s** and other compounds bearing R^2 = Ar (viz. **11q**, **r**, and **t**), conjugation of the aromatic cycle and triazoline ring in ground state is remarkably

reduced as deducible from the large value of the torsion angle between these two cycles (see XRD for the **11q** in SI, Figure S48).

The spectral characteristics (absorption, emission, molar extinction coefficient (ε) and quantum yields (Φ_F)) for compounds **17a-e** were measured in acetone, and the results are presented in Table 4 and Figure 2.

Table 4. **UV-vis absorption and fluorescence emission properties of compounds 17a-e.**

entry	compd	UV-vis		fluorescence		
		λ_{abs}max, (nm)	ε_{max} ($M^{-1}\cdot cm^{-1}$)	λ_{em}max, (nm)	Φ_F	Stokes shift, (nm/cm^{-1})
1	**17a**	412	13900	499	0.079	87/4231
2	**17b**	417	22500	498	0.169	81/3900
3	**17c**	415	29800	494	0.140	81/3900
4	**17d**	412	27200	495	0.159	83/4070
5	**17e**	384	34000	455	0.020	71/4064



a ***b***

Figure 2. Absorption (***a***) and emission (***b***) spectra of 4,5-dihydro-1,2,3-triazoles **17a-e** in acetone at room temperature.

Comparison of the photophysical properties of compounds **17a-e** and **11a-u** demonstrated a slight red shift of the absorption λ_{max} and emission λ_{em} by 10-14 and 15-26 nm, respectively. Compound **17a** showed the largest Stokes shift (87 nm/4231 cm^{-1}), while ester **17e** had the lowest Stokes shift (71 nm/4064 cm^{-1}). The fluorescence quantum yields for 4,5-dihydrotriazoles **17a-e** were 0.02-0.169. Thus, we can conclude that triazolines **17a-e** exhibited a decrease of the quantum yield but an increase of the Stokes shift value compared with triazolines **11a-u**. An improvement of quantum yields may be achieved by the elongation of the length of the

substituent at the N(4) triazole atom. Most of compounds **17a-e** exhibited green-yellow fluorescence (Supporting information, Figure S57).

Quantum Mechanical Calculations. To better understand the electronic transition occurring in 4,5-dihydrotriazoles **11** and **17** during the UV-vis absorption and fluorescence emission, further investigation of the photophysical property via calculations at the Density Functional Theory (DFT) level[16] in *vacuo* and in acetone for the representative compounds **11a-g**,**i**,**l**,**m**,**o**,**r**,**u** and **17a-e** was conducted. The UV-vis absorption and fluorescence emission parameters for these compounds were calculated by the TD-DFT method based on the optimized S_0 and S_1 state geometries, respectively (Table 5). The wavelengths of the compounds, which corresponded to the vertical excitation energies of absorption and fluorescence, and the corresponding Stokes' shifts are compared with the experimental values in Tables 3 and 4. It should be noted that the observed wavelengths are in very good agreement with the wavelengths calculated using TD-DFT with 6-311G (d,p).[16]

Table 5. Absorption and emission properties[a] of 4,5-dihydrotriazoles **11a-e**,**g**,**i**,**l**,**m**,**o**,**r**,**u** and **17a-e** in implicit (IEF-PCM) solvated phase (acetone) obtained from quantum chemical calculation.

entry	compd	λ_a	f_{01}	λ_e	f_{10}	$\Delta\nu$	μ_0, D	μ_{1v}	μ_{1r}	$\theta_{0,1v}$	$\theta_{0,1r}$
1	**11a**	403	0.2214	492	0.4330	4.49	5.3	10.6	13.5	15.1	111.7
2	**11b**	401	0.2110	484	0.2981	4.28	5.0	10.1	10.1	17.5	109.0
3	**11c**	395	0.2007	481	0.3957	4.53	4.6	9.0	11.8	30.0	83.5
4	**11d**	398	0.2274	480	0.4471	4.29	4.6	8.9	11.6	33.1	54.4
5	**11e**	399	0.3276	474	0.5689	3.97	6.9	8.9	11.2	33.8	71.9
6	**11g**	378	0.2134	473	0.3120	5.31	6.3	12.0	13.2	1.5	6.6
7	**11i**	387	0.1987	470	0.3144	4.56	6.2	11.9	12.9	2.5	10.0
8	**11l**	402	0.3286	474	0.4951	3.78	7.1	9.1	11.3	33.3	130.7
9	**11m**	403	0.2866	474	0.5738	3.72	7.7	10.0	9.0	17.2	26.0
10	**11o**	401	0.5166	474	0.6083	3.84	8.8	8.8	7.3	36.3	59.7
11	**11r**	395	0.6014	464	0.6963	3.76	9.9	10.9	11.4	27.6	94.0
12	**11u**	375	0.4967	436	0.5726	3.73	10.8	10.7	10.7	23.4	44.6
13	**17a**	411	0.5379	500	0.5941	4.33	7.7	8.7	8.7	37.9	40.3
15	**17b**	416	0.5379	500	0.6016	4.04	7.7	9.3	9.0	30.3	33.1
16	**17c**	413	0.5804	496	0.6166	4.05	7.6	8.8	7.7	37.7	109.6
17	**17d**	412	0.5378	496	0.6798	4.11	7.2	7.9	7.7	42.0	103.3
18	**17e**	386	0.5992	456	0.6713	3.98	9.3	9.2	9.3	28.0	32.9

[a] Computed absorption wavelength (λ_a, nm) and oscillator strength (f_{01}), emission wavelength (λ_e, nm) and oscillator strength (f_{10}), Stokes' shift (Δv, kK), modulus of the electric dipole moments of the ground state (μ_0, D), of the vertical FC excited state (μ_{1v}, D), and of the relaxed excited state (μ_{1r}, D), and angles formed by the dipole moment vectors ($\theta_{0,1v,}$(°) and $\theta_{0,1r}$(°)).

The geometry of the optimized structures is depicted in Figures S49 and S50 (see Supporting Information). It should be noted that the calculation and experimental data (XRD data) for compounds **11d**,**e**,**g** are in good agreement. A deviation between the experimental (XRD) and calculated torsion angles between 4,5-dihydrotriazole and the adjacent aromatic cycle may be explained by the strong internal interactions, which arose in the crystal pattern.

The main important structure feature for the organic compounds, which can influence the processes of absorption and emission, is the conjugation between opposite parts in a molecule. Hence, we analysed the bond length and torsion angle between the aromatic and triazoline rings, which are the most essential parts of the structures of compounds **11** and **17**. The length of the C_{Ar}-$N_{triasole}$ bond was in the range of 1.390-1.433 Å (Table S1, Supporting Information) at the ground state and in most cases was less than the C_{Ar}-N standard bond length (C_{Ar}-N = 1.431 Å[17]) and became shorter for compounds **11d**,**e**, but longer for triazoline **11g** in the excited state. Shortening of this bridge bond was due to its partial double-bond character and indicated an enhancement of the π-bonding interaction between these parts of molecules **11d**,**e**. Moreover, the structure of **11**, especially for compounds **11l**,**m**,**o**,**r**,**u**, bearing the CN-group at position 4 of the aromatic cycle, became more planar with a significant decrease of the torsion angles after photoexcitation. This phenomenon indicated an enhancement of the conjugation in the singlet-excited state.

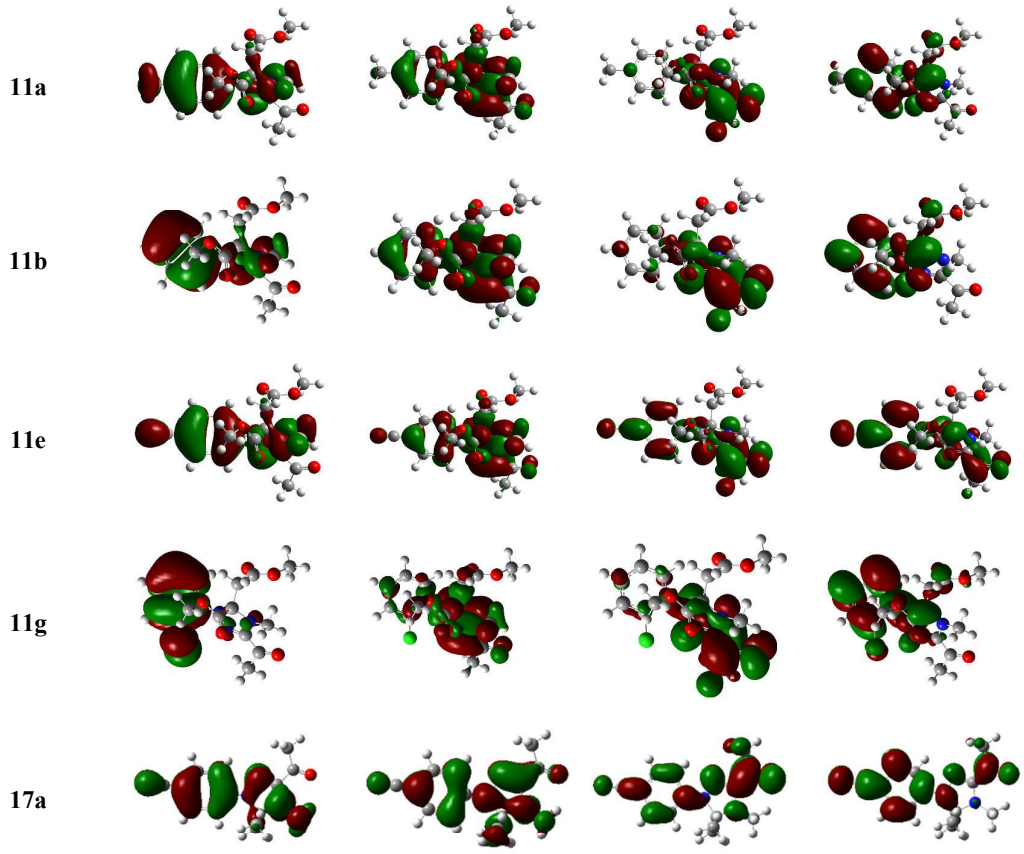
The non-planar geometry was predicted by calculation for compounds **11g**,**i** with the substituent in the *ortho*-position of the aromatic cycle in both the ground and in excited states. This was in accordance with the experimental data (XRD) for triazoline **11g** (Figure S47). As a result, the conjugation systems of these compounds were actually broken into two parts. This

feature may explain the hypsochromic shifts of the long-wavelength bands in the absorption spectra and the decrease of quantum yields (Table 3). It should be noted that the calculated values of the oscillator strength for the adsorption (f_{01}) and for fluorescent emission (f_{10}), which are characteristics of the electron transitions, were the smallest for compounds **11g**,**i** (Table 5, entries 6,7).

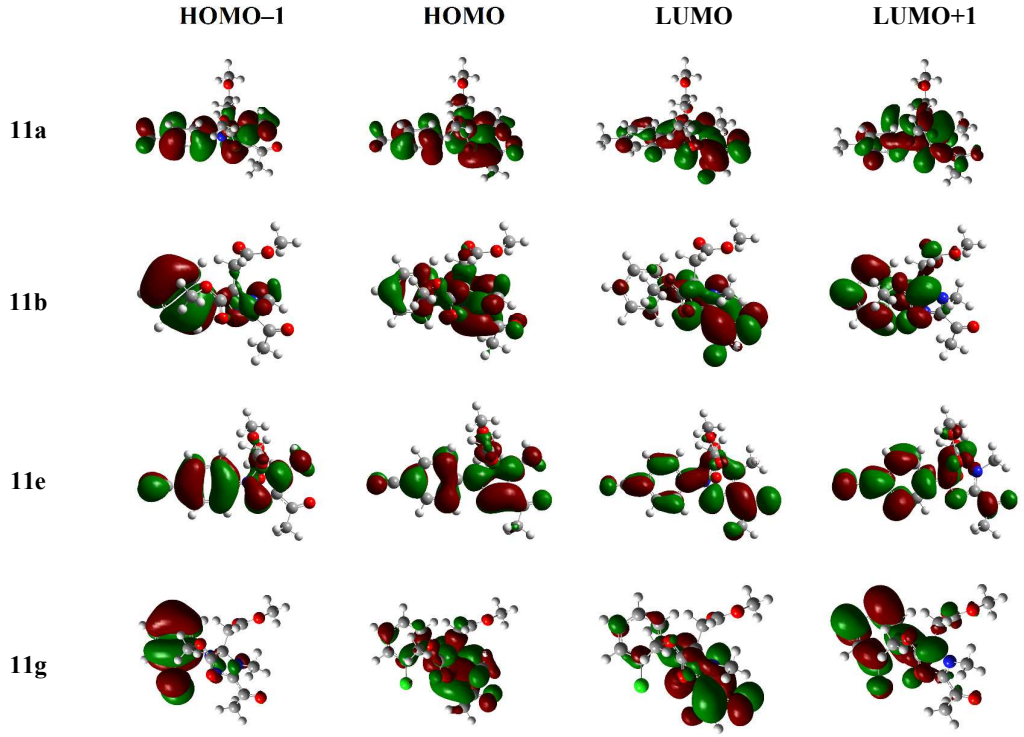
The plots of the frontier molecular orbitals from HOMO-1 to LUMO+1 in the ground and excited states for representative compounds **11a**,**b**,**e**,**g** and **17a** are shown in Figure 3 (more examples are presented in the Supporting information, Figures S51 and S52). The molecular orbitals exhibited differences in the electron density distribution depending on the structure of the investigated triazolines. The most important structural factors were the electronic nature and position of the substituent within the N(1)-aromatic ring. For example, an increase of the electron-accepting character of the substituent in the aromatic cycle in compounds **11a-e** led to an increase of HOMO and LUMO localization on the aromatic ring for both the ground and excited states. This effect demonstrated the expansion of the HOMO and LUMO orbitals onto the aromatic and triazoline rings at the ground and excited states and may cause compounds **11e**,**f**,**l-p** to display the best quantum yields among the investigated compounds **11**. This phenomenon could be due to an enhancement in the probabilities of both the $S_0 \rightarrow S_1$ and $S_1 \rightarrow S_0$ transitions. Moreover, the oscillator strength for the emission (f_{10}) was the largest for the same compounds, and also predicted the better quantum yields.

An increase of conjugation between the two rings in the molecules of compounds **17**, which arose from the more planar structure, led to bathochromic shifts in the absorption and emission spectra, as shown from the calculation data (Figure S54). A more uniform distribution of the frontier molecular orbitals in the molecules of triazolines **17** allowed fluorescence to be retained, although with lesser intensity in comparison with triazoles **11**.

Compound	**Ground state**			
	HOMO–1	**HOMO**	**LUMO**	**LUMO+1**



Excited state



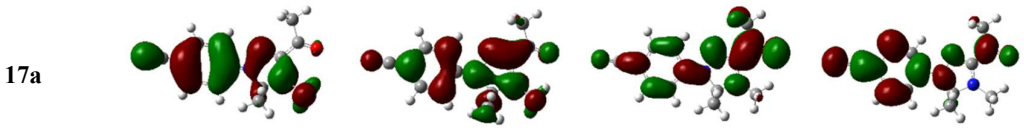


Figure 3. Frontier Molecular Orbitals for triazolines **11a**,**b**,**e**,**g** and **17a** (MOs): HOMO–1, HOMO, LUMO, LUMO+1. (|Isovalue(MO)| = 0.02; |Isovalue(ρ)| = 0.0004.)

CONCLUSIONS

A novel method to synthesize 4,5-dihydro-1*H*-triazoles via nucleophilic addition/cyclization of amidrazones with ACA esters in a sequence of reactions in a simple, atom-economical procedure was proposed and was successand fully used for the preparation of a series of compounds with good yields. All compounds were characterized by FT-IR, ^{1}H and ^{13}C NMR and UV-vis spectral techniques.

Most of the compounds possessed a medium fluorescence-emitting ability with quantum yields up to 0.45 and displayed blue or yellow-green emission depending on the nature of the whole molecule. The optimized geometrical parameters, vibrational frequencies, chemical shifts and some physicochemical properties were calculated using the DFT/B3LYP method with the 6-311 G(d,p) basis set. The theoretical results showed that the optimized geometries can well reproduce the molecular structure of triazolines, and the calculated values of vibrational frequencies showed good agreement with the experimental ones. An analysis of the particularities in the electronic structures of triazoles **11** and **17** (obtained by the calculated absorption and emission characteristics) and 3D patterns of HOMO-1, HOMO, LUMO, LUMO+1 allowed us to establish the relationships between the structure of the investigated compounds and their photophysical properties.

It should be mentioned that stable small-molecule 4,5-dihydro-1,2,4-triazoline derivatives with photoluminescence efficiency have not been reported earlier. Moreover, to date, the most widely known fluorescent derivatives of 1,2,4-triazoles are their metal-complexes.[2] Thus, we found new fluorescent heterocyclic molecules, which are of interest in many application areas,

such as emitters for electroluminescence devices, molecular probes for biochemical research, fluorescent whitening agents and photoconducting materials.

Further efforts in this work are directed towards the investigation of the fluorosolvatochromic behaviour of 4,5-1*H*-dihydrotriazoles, and the results will be reported in due course.

EXPERIMENTAL SECTION

General. 3-Chloropentane-2,4-dione **1a** and ethyl 2-chloro-3-oxobutanoate **1b**, were commercially available. Hydrazonoyl chlorides were synthezised via the Japp–Klingemann reaction as reported previously.[8] Commercially available chemicals and solvents were used without further purification. The products were purified by column chromatography on silica gel (0.035–0.070, 60 Å) and re-crystallized from ethanol.

Microwave-heated reactions were carried out in an Anton Paar Monowave 300 microwave synthesis reactor in sealed microwave Pyrex vessels (2-5 mL). The temperature was controlled by external IR sensor. The pressure were monitored by an integrated hydraulic pressure sensor. ^{1}H NMR and ^{13}C NMR spectra were recorded at 400 MHz for ^{1}H and 100 MHz for ^{13}C spectrometer in DMSO-d_6 or $CDCl_3$. Chemical shifts (δ scale) are reported in parts per million (ppm) relative to TMS in ^{1}H NMR and to the residual solvent signals in ^{13}C NMR spectra. The ^{13}C NMR signal patterns for compound **11a** were analysed by Gate and for all compounds by APT (attached proton test) and are described as follows: + for secondary or quaternary carbon atom (positive signal), - for primary or tertiary carbon atom (negative signal). The values of the coupling constants (*J*) are given in Hertz (Hz). The signal splitting patterns are described as a singlet (s), doublet (d), triplet (t), quartet (q), sextet (sext), quintet (quin), multiplet (m), broad (br), doublet of doublets (dd), doublet of triplets (dt) or AA'XX' - spin system of *para*-substituted benzene with two different substituents. Mass spectra were recorded with a mass-spectrometer using the electron ionisation (EI) technique (40-200 °C, 70 eV). The abbreviation $[M]^+$ refers to the molecular ion. The IR spectra were obtained with a FT-IR ATR (attenuated total reflection, ZnSe) spectrometer in the 4000-400 cm^{-1} region. Elemental analysis was carried out using a

CHNS/O analyser. Melting points were determined using a microscopic melting point meter without correction. The reactions were monitored by analytical thin-layer chromatography (TLC) on aluminium-backed silica-gel plates (Sorbfil UV–254). Visualization of the components was accomplished by short wavelength UV-light (254 nm).

The absorption and emission spectra were recorded in acetone using 10.00-mm quartz cells at room temperature. The excitation wavelength was at the absorption maxima. Atmospheric oxygen contained in the solutions was not removed. The concentrations of the compounds in solution were 1.0×10^{-5} M and 1.0×10^{-6} M for absorption and fluorescence measurements, respectively. The relative fluorescence quantum yields (Φ_F) were determined using quinine sulphate (1×10^{-5} M) in 0.1 M H_2SO_4 as a standard ($\Phi_F = 0.546$).[15]

Suitable single crystals of 4,5-dihydro-1,2,4-triazoles **11d**,**e**,**g**,**q** for XRD structural analysis were obtained by slow evaporation of a solution of the compounds in chloroform at room temperature. XRD data were obtained on a CCD area detector diffractometer using the standard procedure (MoK-irradiation, graphite monochromator, ω-scanning with 1^o step, T = 295(2) K). Empirical absorption correction was applied. Using Olex2,[18] the structure was solved with the Superflip[19] structure solution program using Charge Flipping and refined with the ShelXL[20] refinement package using Least Squares minimization in anisotropic approximation for non-hydrogen atoms. The H-atoms were added at the calculated position and refined in the "rider" model. CCDC 1495198, 1495196, 1495197 and 1495508 for **11d**,**e**,**g**,**q** contain the supplementary data for this paper. These data can be obtained free of charge from the Cambridge Crystallographic Data Centre via link www.ccdc.cam.ac.uk/data_request/cif.

Computational Details. The ground state molecular geometry of the compounds under investigation was fully optimized at the Density Functional Theory (DFT) level, both *in vacuo* and in solvents (*vide infra*). The harmonic vibrational frequencies and thermochemicals were computed. The ground state geometry optimization and harmonic vibrational frequencies calculations were carried out using the hybrid Becke, three-parameter, Lee-Yang-Parr exchange-

correlation functional B3LYP,[16a] coupled with the 6−311++G** basis set. The D3 version of Grimme's dispersion with Becke-Johnson damping[16b] was always used. Solvent effects were taken into account by the implicit Polarizable Continuum Model in its Integral Equation Formalism (IEF−PCM).[21] The PCM molecular cavity was built according to the Universal Force Field (UFF)[22] radii, within the value used in the last implementation of the PCM (based on a continuum surface charge formalism). Standard values for the dielectric constants and refractive indexes were assumed. Both *in vacuo* and in solvents, the UV-vis spectra were also simulated using TD-DFT by employing the long-range corrected CAM-B3LYP[16c] hybrid functional level coupled with the 6-311+G** basis set. $S_0 \rightarrow S_n$ (n = 1 to 5) transitions were accounted for. In the case of the solvated phase, state-specific (SS)[23] treatment of solvent effects was considered, both within the non-equilibrium (neq) and equilibrium (eq) solvation regimes.[24] Electronic absorption spectra were simulated by considering the first five singlet excited electronic states. The vibronic progressions[24a,25] of all non-dark electronic transitions were also simulated, including Duschinsky and Herzberg–Teller effects. The first singlet excited state $S(\pi,\pi^*)$ state geometry was optimized using analytical gradients and the first transitions $S_1 \rightarrow S_0$ of the emission transition. Also in this case, SS (both eq and neq) treatment of solvent effects was considered and the electronic emission band was simulated by accounting for the vibronic progressions, as done in the absorption. The atomic charge population analysis, electric multiple moments and electronic were also computed within the CHelpG procedure[26] for both ground and S_1 excited (vertical and relaxed) states. The frontier Molecular Orbitals (MOs), were also computed and plotted. All calculations were performed using the GAUSSIAN09 code.[27]

General procedure for the synthesis of amidrazones 5. A solution of arylhydrazonoyl chloride (1 mmol), aromatic or aliphatic amine (1 mmol) and 0.17 ml (1 mmol) DIPEA in dioxane (20 ml) was stirring at 25-60 ^{o}C for 2-8 h until the TLC analysis indicated the total consumption of the starting arylhydrazonoyl chloride. The solution was poured into a mixture of water and crushed ice. The precipitated solid was filtered, washed with water and dried.

***N*-Methyl-2-oxo-*N′*-(*p*-tolyl)propanehydrazonamide (5a).** Yellow powder (172 mg, 84%). R_f = 0.62 (Hex/EtOAc, 1:1), 0.67 (Hex/$CHCl_3$, 1:5); mp 100-101 ºC. IR (cm^{-1}): 3355, 3268 (N-H), 2919, 2888, 2822 (C-H), 1658 (C=O). ^{1}H NMR (400 MHz, DMSO-d_6): δ 2.25 (s, 3H), 2.38 (s, 3H), 2.84 (d, J = 4.2 Hz, 3H), 5.06 (q, J = 4.2 Hz, 1H), 1H), 7.02 and 6.96 (AA'XX', J = 8.6 Hz, 4H), 8.86 (s, 1H). ^{13}C NMR (100 MHz, DMSO-d_6): δ (-) 20.2, (-) 24.7, (-) 30.4, (-) 112.9, (+) 128.0, (-) 129.4, (+) 142.3, (+) 143.1, (+) 193.6. Anal. Calcd for $C_{11}H_{15}N_3O$: C, 64.37; H, 7.37; N, 20.47. Found: C, 64.13; H, 7.25; N, 20.22. EIMS (70 eV) *m/z*: M^+ 205 (100).

***N*-Methyl-2-oxo-*N′*-phenylpropanehydrazonamide (5b).** Yellow powder (141 mg, 74%). R_f = 0.66 (Hex/EtOAc, 1:1), 0.60 (Hex/$CHCl_3$, 1:5); mp 110-111 ºC. IR (cm^{-1}): 3374, 3308 (N-H), 3004, 2938, 2917 (C-H), 1658 (C=O). ^{1}H NMR (400 MHz, DMSO-d_6): δ 2.40 (s, 3H), 2.85-2.87 (m, 3H), 5.20 (br. s, 1H), 6.73 (t, J = 7.7 Hz, 1H), 7.19-7.08 (m, 4H), 8.97 (s, 1H). ^{13}C NMR (100 MHz, DMSO-d_6): δ (-) 25.1, (-) 30.5, (-) 112.9, (-) 119.4, (-) 128.9, (+) 142.6, (+) 145.4, (+) 193.8. Anal. Calcd for $C_{10}H_{13}N_3O$: C, 62.81; H, 6.85; N, 21.97. Found: C, 62.73; H, 6.71; N 21.87. EIMS (70 eV) *m/z*: M^+ 191 (100).

***N′*-(4-Fluorophenyl)-*N*-methyl-2-oxopropanehydrazonamide (5c).** Yellow powder. (127 mg, 61%). R_f = 0.64 (Hex/EtOAc, 1:1), 0.51 (Hex/$CHCl_3$, 1:5); mp 85-86 ºC. IR (cm^{-1}): 3389, 3313 (N-H), 3035, 2993, 2938 (C-H), 1657 (C=O). ^{1}H NMR (400 MHz, DMSO-d_6): δ 2.39 (s, 3H), 2.84 (s, 3H), 5.15 (br. s, 1H), 6.93 (t, J = 8.8 Hz, 2H), 7.08-7.14 (m, 2H), 9.00 (s, 1H). ^{13}C NMR (100 MHz, DMSO-d_6): δ (-) 24.9, (-) 30.4, (-) 113.9 (d, $J_{C\text{-}F}$ = 7.5 Hz), (-) 115.4 (d, $J_{C\text{-}F}$ = 22.3 Hz), (+) 142.1 (d, $J_{C\text{-}F}$ = 1.5 Hz), (+) 142.7, (+) 156.2 (d, $J_{C\text{-}F}$ = 233.3 Hz), (+) 193.7. Anal. Calcd for $C_{10}H_{12}FN_3O$: C, 57.41; H, 5.78; N, 20.08. Found: C, 57.21; H, 5.88; N, 20.29. EIMS (70 eV) *m/z*: M^+ 209 (100).

***N′*-(4-Chlorophenyl)-*N*-methyl-2-oxopropanehydrazonamide (5d).** Yellow powder (171 mg, 76%). R_f = 0.66 (Hex/EtOAc, 1:1), 0.58 (Hex/$CHCl_3$, 1:5); mp 100-101 ºC. IR (cm^{-1}): 3342, 3250 (N-H), 2884 (C-H), 1659 (C=O). ^{1}H NMR (400 MHz, DMSO-d_6): δ 2.39 (c, 3H), 2.87 (d, J = 4.8 Hz, 3H), 5.24 (q, J = 4.8 Hz, 1H), 7.13 and 7.49 (AA'XX', J = 9.2 Hz, 4H), 9.08 (s, 1H).

^{13}C NMR (100 MHz, DMSO-d_6): δ (-) 25.1, (-) 30.4, (-) 114.3, (+) 122.6, (-) 128.7, (+) 143.0, (+) 144.4, (+) 193.9. Anal. Calcd for $C_{10}H_{12}ClN_3O$: C, 53.22; H, 5.36; N, 18.62. Found: C, 52.95; H, 5.51; N, 18.44. EIMS (70 eV) *m/z*: M^+ 225 (100).

***N′*-(4-Cyanophenyl)-*N*-methyl-2-oxopropanehydrazonamide (5e).** Yellow-brown powder (149 mg, 69%). R_f = 0.44 (Hex/EtOAc, 1:1), 0.50 (Hex/$CHCl_3$, 1:5); mp 150-151 ºC. IR (cm^{-1}): 3385, 3251 (N-H), 2993, 2969, 2931 (C-H), 2213 (C≡N), 1677 (C=O). ^{1}H NMR (400 MHz, DMSO-d_6): δ 2.41 (s, 3H), 2.89 (d, *J* = 5.0 Hz, 3H), 5.70 (q, *J* = 5.0 Hz, 1H), 7.19 and 7.61 (AA'XX', *J* = 8.6 Hz, 4H), 9.58 (s, 1H). ^{13}C NMR (100 MHz, DMSO-d_6): δ (-) 25.5, (-) 30.4, (+) 99.6, (-) 112.8, (+) 120.0, (-) 133.4, (+) 144.1, (+) 148.9, (+) 194.4. Anal. Calcd for $C_{11}H_{12}N_4O$: C, 61.10; H, 5.59; N, 25.91. Found: C, 61.39; H, 5.69; N, 25.76. EIMS (70 eV) *m/z*: M^+ 216 (76).

***N′*-(3,5-Bis(trifluoromethyl)phenyl)-*N*-methyl-2-oxopropanehydrazonamide (5f).** Pale-brown powder (275 mg, 84%). R_f = 0.63 (Hex/EtOAc, 1:1), 0.62 (Hex/$CHCl_3$, 1:5); mp 104-105 ºC. IR (cm^{-1}): 3331, 3297 (N-H), 2916, 2887, 2819 (C-H), 1672 (C=O). ^{1}H NMR (400 MHz, DMSO-d_6) δ: 2.42 (s, 3H,), 2.90 (d, *J* = 5.2 Hz, 3H), 5.50 (q, *J* = 4.8 Hz, 1H), 7.17 (s, 1H), 7.56 (s, 2H), 9.57 (s, 1H). ^{13}C NMR (100 MHz, DMSO-d_6): δ (-) 25.2, (-) 30.3, (-) 110.8, (-) 112.2, (+) 123.4 (q, $J_{C\text{-}F}$ =271.1 Hz), (+) 131.0 (q, $J_{C\text{-}F}$ = 32.3 Hz), 1(+) 44.6, (+) 147.1, (+) 194.3. Anal. Calcd for $C_{12}H_{11}F_6N_3O$: C, 44.05; H, 3.39; N, 12.84. Found: C, 44.26; H, 3.52; N, 12.62. EIMS (70 eV) *m/z*: M^+ 327 (53).

***N′*-(2-Fluorophenyl)-*N*-methyl-2-oxopropanehydrazonamide (5g).** Pale-brown powder (146 mg, 70%). R_f = 0.58 (Hex/EtOAc, 1:1), 0.82 (Hex/$CHCl_3$, 1:5); mp 66-67 ºC. IR (cm^{-1}): 3352, 3300 (N-H), 2978, 2953, 2929 (C-H), 1671 (C=O). ^{1}H NMR (400 MHz, DMSO-d_6): δ 2.42 (s, 3H), 2.93 (d, *J* = 4.9 Hz, 3H), 5.78 (br. s, 1H), 6.71-6.77 (m, 1H), 6.98-7.08 (m, 2H), 7.46 (m, 1H), 8.31 (s, 1H). ^{13}C NMR (100 MHz, DMSO-d_6): δ (-) 25.9, (-) 30.4, (-) 114.7, (-) 114.9 (d, $J_{C\text{-}F}$= 20.9 Hz), (-) 119.0 (d, $J_{C\text{-}F}$= 6.7 Hz), (-) 124.8 (d, $J_{C\text{-}F}$= 3.2 Hz), (+) 133.6 (d, $J_{C\text{-}F}$= 9.7 Hz),

(+) 143.6, (+) 149.9 (d, $J_{C\text{-}F}$ = 238.3 Hz), (+) 194.5. Anal. Calcd for $C_{10}H_{12}FN_3O$: C, 57.41; H, 5.78; N, 20.08. Found: C, 57.24; H, 5.63; N, 20.31. EIMS (70 eV) *m/z*: M^+ 209 (54).

***N′*-(2-Chlorophenyl)-*N*-methyl-2-oxopropanehydrazonamide (5h).** Yellow powder (196 mg, 87%). R_f = 0.69 (Hex/EtOAc, 1:1), 0.73 (Hex/$CHCl_3$, 1:5); mp 67-68 ºC. IR (cm^{-1}): 3344 (N-H), 2925, 2883, 2877 (C-H), 1678 (C=O). ^{1}H NMR (400 MHz, DMSO-d_6): δ 2.43 (s, 3H), 2.92 (d, *J* = 5.3 Hz, 3H), 5.78 (br. s, 1H), 6.81 (d, *J* = 7.8 Hz, 1H), 7.23 (t, *J* = 7.2 Hz, 1H), 7.28 (d, *J* = 7.3 Hz, 1H), 7.50 (d, *J* = 7.8 Hz, 1H). ^{13}C NMR (100 MHz, DMSO-d_6): δ (-) 25.4, (-) 30.4, (-) 114.7, (+) 117.4, (-) 120.3, (-) 128.0, (-) 129.1, (+) 141.3, (+) 144.3, (+) 194.4. Anal. Calcd for $C_{10}H_{12}ClN_3O$: C, 53.22; H, 5.36; N, 18.62. Found: C, 53.41; H, 5.50; N, 18.78. EIMS (70 eV) *m/z*: M^+ 225 (78).

***N*-Methyl-2-oxo-*N′*-(2-(trifluoromethyl)phenyl)propanehydrazonamide (5i).** Pale-brown powder (223 mg, 86%). R_f = 0.64 (Hex/EtOAc, 1:1), 0.78 (Hex/$CHCl_3$, 1:5); mp 83-84 ºC. IR (cm^{-1}): 3364 (N-H), 2972, 2950, 2917 (C-H), 1683 (C=O). ^{1}H NMR (400 MHz, DMSO-d_6): δ 2.40 and 2.42 (two s, 3H), 2.73 and 2.85 (two d, *J* = 5.0 Hz, 3H), 5.63 and 5.98 (two br s, 1H), 6.76 and 6.96 (two t, *J* = 7.6 Hz, 1H), 7.36-7.46 and 7.47-7.56 (two m, 2H), 7.59-7.62 and 7.68-7.72 (two m, 1H), 8.03 and 9.03 (two s, 1H). ^{13}C NMR (100 MHz, DMSO-d_6): δ (-) 24.9, (-) 30.3, (+) 112.5, (q, $^2J_{C\text{-}F}$ = 29.4 Hz), (-) 115.4, (-) 119.5, (+) 124.6 (q, $^1J_{C\text{-}F}$ = 270.6 Hz), (-) 126.1, (-) 133.6, (+) 142.4, (+) 145.0, (+) 194.2. Anal. Calcd for $C_{11}H_{12}F_3N_3O$: C, 50.97; H, 4.67; N, 16.21. Found: C, 50.74; H, 4.78; N, 16.52. EIMS (70 eV) *m/z*: M^+ 259 (100). (*Z*,*E*-isomers - 5:1).

2-Oxo-*N*-phenyl-*N′*-*p*-tolylpropanehydrazonamide (5j). Yellow powder (246 mg, 92%). R_f = 0.77 (Hex/EtOAc, 1:1), 0.67 (Hex/$CHCl_3$, 1:5); mp 238-239 °C. IR (cm^{-1}): 3324, 3250 (N-H), 3026, 2989, 2943 (C-H), 1670 (C=O). ^{1}H NMR (400 MHz, DMSO-d_6): δ 2.28 (s, 3H), 2.50 (s, 3H), 6.56 (d, *J* = 7.7 Hz, m, 2H), 6.75 (t, *J* = 7.2 Hz, 1H), 7.03 (d, *J* = 7.8 Hz, 2H), 7.10-7.16 (m, 4H), 7.59 (s, 1H), 9.26 (s, 1H). ^{13}C NMR (100 MHz, DMSO-d_6): δ (-) 20.3, (-) 24.7, (-) 113.9, (-) 115.6, (-) 118.9, (-) 128.5, (-) 129.5, (+) 129.8, (+) 135.6, (+) 141.5, (+) 142.6, (+)

192.7. Anal. Calcd for $C_{16}H_{17}N_3O$: C, 71.89; H, 6.41; N, 15.72. Found: C, 71.60; H, 6.62; N, 15.91. EIMS (70 eV) *m/z*: M^+ 267 (88).

***N′*-(4-Cyanophenyl)-2-oxo-*N*-phenylpropanehydrazonamide (5k).** Yellow powder (239 mg, 86%). R_f = 0.53 (Hex/EtOAc, 1:1), 0.55 (Hex/$CHCl_3$, 1:5); mp 160-161 ºC. IR (cm^{-1}): 3331, 3240 (N-H), 3001, 2967 (C-H), 2221 (C≡N), 1676 (C=O). ^{1}H NMR (400 MHz, DMSO-d_6): δ 2.53 (s, 3H), 6.60 (d, *J* = 7.8 Hz, 2H), 6.80 (t, *J* = 7.3 Hz, 1H), 7.14 (t, *J* = 7.8 Hz, 2H), 7.35 and 7.56 (AA'XX', *J* = 8.7 Hz, 4H), 8.18 (s, 1H), 9.88 (s, 1H). ^{13}C NMR (100 MHz, DMSO-d_6): δ (-) 25.1, (+) 101.5, (-) 113.9, (-) 116.4, (-) 119.6, (+) 119.7, (-) 128.5, (-) 133.5, (+) 138.0, (+) 141.6, (+) 147.7, (+) 193.4. Anal. Calcd for $C_{16}H_{14}N_4O$: C, 69.05; H, 5.07; N, 20.13. Found: C, 69.32; H, 5.25; N, 20.40. EIMS (70 eV) *m/z*: M^+ 278 (24).

***N*-Butyl-*N′*-(4-cyanophenyl)-2-oxopropanehydrazonamide (5l).** Brown oil (232 mg, 90%). R_f = 0.65 (Hex/EtOAc, 1:1), 0.51 (Hex/$CHCl_3$, 1:5). IR (cm^{-1}): 3333, 3321 (N-H), 2959, 2931, 2872 (C-H), 2216 (C≡N), 1680 (C=O). ^{1}H NMR (400 MHz, DMSO-d_6): δ 0.92 (t, *J* = 7.2 Hz, 3H), 1.29-1.36 (m, 2H), 1.38-1.45 (m, 2H), 2.42 (s, 3H), 3.30 (q, *J* = 6.8 Hz, 2H), 5.42 (t, *J* = 6.1 Hz, 1H), 7.18 and 7.50 (AA'XX', *J* = 8.8 Hz, 4H), 9.55 (s, 1H). ^{13}C NMR (100 MHz, DMSO-d_6): δ (-) 13.6, (+) 19.3, (-) 25.4, (+) 32.9, (+) 42.7, (-) 115.1, (+) 119.2, (-) 133.7, (+) 143.1, (+) 146.2, (+) 148.9, (+) 194.5. Anal. Calcd for $C_{14}H_{18}N_4O$: C, 65.09; H, 7.02; N, 21.69. Found: C, 65.29; H, 7.33; N, 21.71. EIMS (70 eV) *m/z*: M^+ 258 (69).

***N′*-(4-Cyanophenyl)-*N*-(2-methoxyethyl)-2-oxopropanehydrazonamide (5m).** Yellow powder, (216 mg, 83%). R_f = 0.41 (Hex/EtOAc, 1:1), 0.38 (Hex/$CHCl_3$, 1:5); m.p. 115-116 ºC. IR (cm^{-1}): 3349, 3238 (N-H), 2938, 2929, 2901 (C-H), 2211 (C≡N), 1671 (C=O); ^{1}H NMR (400 MHz, DMSO-d_6): δ 2.41 (s, 3H), 3.33 (s, 3H), 3.36-3-45 (m, 4H), 5.62-5.67 (t, *J* = 6.0 Hz, 1H), 7.16 and 7.50 (AA'XX', *J* = 8.7 Hz, 4H), 9.69 (s, 1H). ^{13}C NMR (100 MHz, DMSO-d_6): δ (-) 25.4, (+) 42.4, (-) 58.0, (+) 72.4, (+) 99.7, (-) 112.8, (+) 119.9, (-) 133.5, (+) 143.2, (+) 148.7, (+) 194.3. Anal. Calcd for $C_{13}H_{16}N_4O_2$: C, 59.99; H, 6.20; N, 21.52. Found: C, 59.68; H, 6.34; N, 21.73. EIMS (70 eV) *m/z*: M^+ 260 (49).

***N*-Benzyl-*N′*-(4-cyanophenyl)-2-oxopropanehydrazonamide (5n).** Yellow powder (237 mg, 81%). R_f = 0.63 (Hex/EtOAc, 1:1), 0.53 (Hex/$CHCl_3$, 1:5); mp 85-86 ºC. IR (cm^{-1}): 3351, 3290 (N-H), 3065, 2965, 2920 (C-H), 2220 (C≡N), 1663 (C=O). ^{1}H NMR (400 MHz, DMSO-d_6): δ 2.35 (s, 3H), 4.53 (d, J = 6.4 Hz, 2H), 6.04 (t, J = 6.4 Hz, 1H), 7.17 and 7.51 (AA'XX', J = 8.8 Hz, 4H), 7.21-7.32 (m, 5H), 9.68 (s, 1H). ^{13}C NMR (100 MHz, DMSO-d_6): δ (-) 25.6, (+) 46.5, (+) 99.9, (-) 112.9, (+) 119.9, (-) 126.9, (-) 127.3, (-) 128.3, (-) 133.4, (+) 140.3, (+) 142.7, (+) 148.7, (+) 194.3. Anal. Calcd for $C_{17}H_{16}N_4O$: C, 69.85; H, 5.52; N, 19.17. Found: C, 69.58; H, 5.69; N, 19.34. EIMS (70 eV) *m/z*: M^+ 292 (11).

***N′*-(4-Cyanophenyl)-*N*-cyclohexyl-2-oxopropanehydrazonamide (5o).** Pale-yellow powder (250 mg, 88%). R_f = 0.63 (Hex/EtOAc, 1:1), 0.69 (Hex/$CHCl_3$, 1:5); mp 135-136 ºC. IR, (cm^{-1}): 3319, 3221 (N-H), 2966, 2956, 2918 (C-H), 2218 (C≡N), 1687 (C=O). ^{1}H NMR (400 MHz, DMSO-d_6): δ 1.07-1.35 (m, 5H), 1.55-1.87 (m, 5H), 2.42 (s, 3H), 3.36-3.75 (m, 1H), 5.11 (d, J = 8.9 Hz, 1H), 7.20 and 7.51 (AA'XX', J = 8.7 Hz, 4H), 9.59 (s, 1H). ^{13}C NMR (100 MHz, DMSO-d_6): δ (+) 24.6, (+) 25.1, (-) 25.7, (+) 34.1, (-) 51.0, (+) 99.8, (-) 112.9, (+) 119.9, (-) 133.5, (+) 142.4, (+) 148.7, (+) 194.5. Anal. Calcd for $C_{16}H_{20}N_4O$: C, 67.58; H, 7.09; N, 19.70. Found: C, 67.34; H, 7.21; N, 19.93. EIMS (70 eV) *m/z*: M^+ 284 (60).

***N′*-(4-Cyanophenyl)-*N*-(9-ethyl-9*H*-carbazol-2-yl)-2-oxopropanehydrazonamide (5p).** Dark-brown powder (340 mg, 86%). R_f = 0.63 (Hex/EtOAc, 1:1), 0.51 (Hex/$CHCl_3$, 1:5); mp 178-179 ºC. IR (cm^{-1}): 3333 (N-H), 2972, 2931, 2913 (C-H), 2222 (C≡N), 1673 (C=O). ^{1}H NMR (400 MHz, DMSO-d_6): δ 1.38 (t, J = 7.1 Hz, 3H), 2.58 (s, 3H), 4.38 (q, J = 7.1 Hz, 2H), 6.92 (dd, J = 8.4, 2.0 Hz, 1H), 7.09 (t, J = 7.2 Hz, 1H), 7.28 and 7.53 (AA'XX', J = 8.8 Hz, 4H), 7.33-7.39 (m, 3H), 7.41-7.46 (m, 1H), 7.90-7.94 (m, 2H), 9.55 (s, 1H). ^{13}C NMR (100 MHz, DMSO-d_6,): δ (-) 13.7, (-) 25.4, (+) 36.9, (+) 101.4, (-) 109.4, (-) 114.1, (-) 118.4, (-) 118.6, (+) 120.3, (-) 120.7, (+) 122.4, (+) 122.6, (-) 126.0, (+) 133.9, (-) 134.0, (+) 135.6, (+) 139.6, (+) 140.4, (+) 148.4, (+) 193.7. Anal. Calcd for $C_{24}H_{21}N_5O$: C, 72.89; H, 5.35; N, 17.71. Found: C, 72.60; H, 5.23; N, 17.91. EIMS (70 eV) *m/z*: M^+ 395 (50).

***N'*-(4-Cyanophenyl)-2-oxo-*N*-(4-(phenylamino)phenyl)propanehydrazonamide (5q).** Dark-brown powder (317 mg, 86%) R_f = 0.61 (Hex/EtOAc, 1:1), 0.35 (Hex/$CHCl_3$, 1:5); mp 135-136 ºC. IR (cm^{-1}): 3377, 3338, 3275 (N-H), 2969, 2943, 2853 (C-H), 2216 (C≡N), 1682 (C=O). ^{1}H NMR (400 MHz, DMSO-d_6): δ 2.53 (s, 3H), 6.58 (d, J = 7.8 Hz, 2H), 6.68 (t, J = 7.2 Hz, 1H), 6.92 and 6.96 (AA'XX', J = 7.6 Hz, 4H), 7.12 (t, J = 7.2 Hz, 2H), 7.31 and 7.56 (AA'XX', J = 8.8 Hz, 4H), 7.69 (s, 1H), 7.80 (s, 1H), 9.64 (s, 1H). ^{13}C NMR (100 MHz, DMSO-d_6,): δ (-) 25.2, (+) 101.1, (-) 113.7, (-) 114.9, (-) 118.2, (-) 119.3, (+) 119.8, (-) 129.0, (-) 133.5, (+) 134.8, (+) 136.2, (+) 138.5, (+) 144.9, (+) 147.8, (+) 193.6. Anal. Calcd for $C_{22}H_{19}N_5O$: C, 71.53; H, 5.18; N, 18.96. Found: C, 71.31; H, 5.24; N, 18.71. EIMS (70 eV) *m/z*: M^+ 369 (50).

Ethyl 2-(2-(4-cyanophenyl)hydrazono)-2-(methylamino)acetate (5r). Yellow powder (219 mg, 89%). R_f = 0.57 (Hex/EtOAc, 1:1), 0.51 (Hex/$CHCl_3$, 1:5); mp 135-136 ºC. IR (cm^{-1}): 3394, 3298 (N-H), 2983, 2946, 2936 (C-H), 2207 (C≡N), 1702, 1604 (C=O). ^{1}H NMR (400 MHz, DMSO-d_6): δ 1.32-1.41 (m, 3H), 2.72-2.76 and 2.86-2.90 (two m, 3H), 4.27 and 4.35 (two q, J = 7.2 Hz, 2H), 5.86 and 6.07 (two br s, 1H), 7.00-7.08 (m, 2H), 7.40-7.49 (m, 2H), 9.17 and 10.40 (two s, 1H) (*ratio of isomeres* - 1:1.2). ^{13}C NMR (100 MHz, DMSO-d_6,): δ (-) 13.9/13.8, (-) 30.2/28.2, (+) 61.1/61.8, (+) 98.7/97.6, (+) 112.3/111.7, (-) 120.4/120.1, (-) 133.3/133.2, (+) 140.1/138.0, (+) 149.3/149.2, (+) 161.8/159.8. Anal. Calcd for $C_{12}H_{14}N_4O_2$: C, 58.53; H, 5.73; N, 22.75. Found: C, 58.36; H, 5.53; N, 22.47. EIMS (70 eV) *m/z*: M^+ 246 (59).

General Procedure (GP) for the synthesis of 4,5-dihydro-1*H*-1,2,4-triazoles 11a-u.

A solution containing 1.0 mmol of amidrazone **5**, 0.16 mL (2 mmol) of pyridine and 2.0 mmol of esters **5a** or **5b** in 20 ml of toluene was heated under reflux until the TLC analysis indicated total consumption of the starting hydrazone. Toluene was evaporated, and the residue was purified by liquid column chromatography (hexane/ethyl acetate 4:1 or 3:2).

Methyl 3-acetyl-5-(2-methoxy-2-oxoethyl)-4-methyl-1-*p*-tolyl-4,5-dihydro-1*H*-1,2,4-triazole-5-carboxylate (11a). Bright yellow powder (243 mg, 70%). R_f = 0.26 (Hex/EtOAc, 4:1), 0.66 (Hex/EtOAc, 1:1); mp 80-81 ºC. IR (cm^{-1}): 3010, 2979, 2954 (C-H), 1737, 1669 (C=O). ^{1}H

NMR (400 MHz, DMSO-d_6): δ 2.27 (s, 3H), 2.42 (s, 3H), 3.04 (s, 3H), 3.21 and 3.29 (AB, J = 16.0 Hz, 2H), 3.49 (s, 3H), 3.71 (s, 3H), 6.88 and 7.03 (AA'XX', J = 8.5 Hz, 4H). ^{13}C NMR (100 MHz, DMSO-d_6): δ 20.2 (qt, ^1J = 125.4, ^3J = 4.2 Hz), 26.3 (q, ^1J = 128.2 Hz), 29.3 (q, ^1J = 128.5 Hz), 34.1 (t, ^1J = 131.1 Hz), 51.2 (q, ^1J = 146.4 Hz), 52.7 (q, ^1J = 147.8 Hz), 88.0 (m), 115.0 (dd, ^1J = 160.0 Hz, ^2J = 5.5 Hz), 129.1 (ddq, ^1J = 157.5 Hz, ^2J = 4.4 Hz, ^3J = 7.1 Hz), 130.1 (q, ^2J = 6.2 Hz), 138.6 (t, ^2J = 8.7 Hz), 144.6 (s), 167.5 (q, ^3J = 3.7 Hz), 167.7 (m), 187.8 (q, ^2J = 6.2 Hz). Anal. Calcd for $C_{17}H_{21}N_3O_5$: C, 58.78; H, 6.09; N, 12.10. Found: C, 58.62; H, 6.15; N, 12.01. EIMS (70 eV) *m/z*: M^+ 347 (2.4), 288 (100).

Methyl 3-acetyl-5-(2-methoxy-2-oxoethyl)-4-methyl-1-phenyl-4,5-dihydro-1*H*-1,2,4-triazole-5-carboxylate (11b). Yellow powder (316 mg, 95%). R_f = 0.36 (Hex/EtOAc, 4:1), 0.60 (Hex/EtOAc, 1:1); mp 110-111 ºC. IR (cm^{-1}): 3062, 2948 (C-H), 1732, 1668 (C=O). ^{1}H NMR (400 MHz, DMSO-d_6): δ 2.43 (s, 3H), 3.05 (s, 3H); 3.33 and 3.24 (AB, J = 15.3 Hz, 2H), 3.47 (s, 3H), 3.72 (s, 3H), 6.91 (t, J = 8.0 Hz, 1H), 6.98 (d, J = 8.3 Hz, 2H), 7.24 (t, J = 8.3 Hz, 2H). ^{13}C NMR (100 MHz, DMSO-d_6): δ (-) 26.3, (-) 29.3, (+) 33.9, (-) 51.2, (-) 52.8, (+) 87.7, (-) 114.5, (-) 120.9, (-) 128.7, (+) 140.9, (+) 144.7, (+) 167.5, (+) 167.7, (+) 187.9. Anal. Calcd for $C_{16}H_{19}N_3O_5$: C, 57.65; H, 5.75; N, 12.61. Found: C, 57.81; H, 6.01; N, 12.40. EIMS (70 eV) *m/z*: M^+ 333 (2.6), 274 (100).

Methyl 3-acetyl-1-(4-fluorophenyl)-5-(2-methoxy-2-oxoethyl)-4-methyl-4,5-dihydro-1*H*-1,2,4-triazole-5-carboxylate (11c). Orange powder (333 mg, 95%). R_f = 0.36 (Hex/EtOAc, 4:1), 0.58 (Hex/EtOAc, 1:1); mp 90-91 ºC. IR (cm^{-1}): 2958, 2869, 2856 (C-H), 1720, 1680 (C=O). ^{1}H NMR (400 MHz, DMSO-d_6): δ 2.41 (s, 3H), 3.04 (s, 3H), 3.28 and 3.22 (AB, J = 16.0 Hz, 2H), 3.48 (s, 3H), 3.71 (s, 3H), 7.00-7.04 (m, 4H). ^{13}C NMR (100 MHz, DMSO-d_6): δ (-) 26.6, (-) 29.6, (+) 34.4, (-) 51.6, (-) 53.2, (+) 88.6, (-) 115.8 (d, ^2J = 22.5 Hz), (-) 117.3 (d, ^2J = 22.5 Hz), (+) 137.8 (d, ^4J = 2.1 Hz), (+) 145.3, (+) 157.3 (d, ^1J = 237.3 Hz), (+) 167.6, (+) 168.1, (+) 188.9. Anal. Calcd for $C_{16}H_{18}FN_3O_5$: C, 54.70; H, 5.16; N, 11.96. Found: C, 54.40; H, 5.33; N, 11.75. EIMS (70 eV) *m/z*: M^+ 351 (3.8), 293 (100).

Methyl 3-acetyl-1-(4-chlorophenyl)-5-(2-methoxy-2-oxoethyl)-4-methyl-4,5-dihydro-1*H*-1,2,4-triazole-5-carboxylate (11d). Bright yellow powder (327 mg, 89%). R_f = 0.32 (Hex/EtOAc, 4:1), 0.61 (Hex/EtOAc, 1:1); mp 110-111 ºC. IR (cm^{-1}): 2954, 2923, 2851 (C-H), 1732, 1682 (C=O). ^{1}H NMR (400 MHz, DMSO-d_6): δ 2.45 (s, 3H), 3.08 (s, 3H), 3.35 and 3.25 (AB, J = 16.4 Hz, 2H), 3.51 (s, 3H), 3.76 (s, 3H), 7.23 and 6.99 (AA'XX', J = 9.1 Hz, 4H). ^{13}C NMR (100 MHz, DMSO-d_6) δ: (-) 26.4, (-) 29.2, (+) 33.8, (-) 51.3, (-) 52.9, (+) 87.6, (-) 115.8, (+) 125.1, (-) 128.6, (+) 139.7, (+) 144.8, (+) 167.3, (+) 167.4, (+) 188.0. Anal. Calcd for $C_{16}H_{18}ClN_3O_5$: C, 52.25; H, 4.93; N, 11.43. Found: C, 52.15; H, 4.80; N, 11.33. EIMS (70 eV) *m/z*: M^+ 367 (2.2), 308 (100).

Methyl 3-acetyl-1-(4-cyanophenyl)-5-(2-methoxy-2-oxoethyl)-4-methyl-4,5-dihydro-1*H*-1,2,4-triazole-5-carboxylate (11e). Bright orange powder (222 mg, 62%). R_f = 0.14 (Hex/EtOAc, 4:1), 0.61 (Hex/EtOAc, 1:1); mp 138-139 ºC. IR (cm^{-1}): 2952, 2857 (C-H), 2214 (C≡N), 1734, 1684 (C=O). ^{1}H NMR (400 MHz, DMSO-d_6) δ: 2.45 (s, 3H), 3.07 (s, 3H), 3.42 and 3.51 (AB, J = 16.4 Hz, 2H), 3.45 (s, 3H), 3.76 (s, 3H), 7.12 and 7.69 (AA'XX', J = 8.9 Hz, 4H). ^{13}C NMR (100 MHz, DMSO-d_6): δ (-) 26.9, (-) 29.3, (+) 33.7, (+) 51.7, (+) 53.7, (+) 86.9, (+) 101.6, (-) 113.8, (+) 119.3, (-) 133.5, (+) 144.0, (+) 145.8, (+) 166.9, (+) 167.8, (+) 189.2. Anal. Calcd for $C_{17}H_{18}N_4O_5$: C, 56.98; H, 5.06; N, 15.63. Found: C, 56.75; H, 5.23; N, 15.42. EIMS (70 eV) *m/z*: M^+ 358 (0.6), 299 (100). C, 56.98; H, 5.06; N, 15.63.

Methyl 3-acetyl-1-(3,5-bis(trifluoromethyl)phenyl)-5-(2-methoxy-2-oxoethyl)-4-methyl-4,5-dihydro-1*H*-1,2,4-triazole-5-carboxylate (11f). Orange oil (403 mg, 86%). R_f = 0.32 (Hex/EtOAc, 4:1), 0.61 (Hex/EtOAc, 1:1). IR (cm^{-1}): 2957, 2928, 2851 (C-H), 1742, 1693 (C=O). ^{1}H NMR (400 MHz, DMSO-d_6): δ 2.48 (s, 3H), 3.10 (s, 3H), 3.43 and 3.51 (AB, J = 16.4 Hz, 2H), 3.46 (s, 3H), 3.77 (s, 3H), 7.50 (s, 2H), 7.58 (s, 1H). ^{13}C NMR (100 MHz, DMSO-d_6): δ (-) 27.1, (-) 29.5, (+) 33.9, (-) 51.8, (-) 53.7, (+) 87.4, (-) 113.1, (-) 113.7, (+) 123.1 (q, ^1J = 271.4 Hz), (+) 131.3 (q, ^2J = 32.7 Hz), (+) 142.5, (+) 146.1, (+) 167.0, (+) 167.8, (+) 189.4. Anal.

Calcd for $C_{18}H_{17}F_6N_3O_5$: C, 46.06; H, 3.65; N, 8.95. Found: C, 46.21; H, 3.78; N, 8.76. EIMS (70 eV) *m/z*: M^+ 469 (0.4), 410 (100).

Methyl 3-acetyl-1-(2-chlorophenyl)-5-(2-methoxy-2-oxoethyl)-4-methyl-4,5-dihydro-1*H*-1,2,4-triazole-5-carboxylate (11g). Yellow powder (338 mg, 92%). R_f = 0.30 (Hex/EtOAc, 4:1), 0.66 (Hex/EtOAc, 1:1); mp 117-118 ºC. IR (cm^{-1}): 3007, 2980, 2952 (C-H), 1731, 1678 (C=O). ^{1}H NMR (400 MHz, DMSO-d_6): δ 2.42 (s, 3H), 2.93 and 3.27 (AB, J = 17.3 Hz, 2H), 3.05 (s, 3H), 3.44 (s, 3H), 3.70 (s, 3H), 7.20-7.24 (m, 1H), 7.29-7.42 (m, 3H). ^{13}C NMR (100 MHz, DMSO-d_6): δ (-) 26.9, (-) 29.8, (+) 35.2, (-) 51.5, (-) 52.7, (+) 89.4, (-) 127.6, (-) 127.7, (-) 128.4, (-) 130.3, (+) 139.3, (+) 146.9, (+) 167.7, (+) 168.3, (+) 189.5. Anal. Calcd for $C_{16}H_{18}ClN_3O_5$: C, 52.25; H, 4.93; N, 11.43. Found: C, 52.46; H, 4.73; N 11.51. EIMS (70 eV) *m/z*: M^+ 367 (0.1), 308 (100).

Methyl 3-acetyl-5-(2-methoxy-2-oxoethyl)-4-methyl-1-(2-(trifluoromethyl)phenyl)-4,5-dihydro-1*H*-1,2,4-triazole-5-carboxylate (11h). Orange oil (301 mg, 75%). R_f = 0.31 (Hex/EtOAc, 4:1), 0.55 (Hex/EtOAc, 1:1). IR (cm^{-1}): 3003, 2955, 2927 (C-H), 1738, 1682 (C=O); ^{1}H NMR (400 MHz, DMSO-d_6): δ 2.34 (s, 3H), 3.06 (s, 3H), 3.27 and 3.33 (AB, J = 16.0 Hz, 2H), 3.46 (s, 3H), 3.70 (s, 3H), 7.07 (d, J = 8.2 Hz, 1H), 7.35 (t, J = 7.6 Hz, 1H), 7.59 (t, J = 7.3, 1H), 7.77 (d, J = 8.0, 1H). ^{13}C NMR (100 MHz, DMSO-d_6): δ (-) 26.9, (-) 30.1, (+) 35.8, (-) 52.1, (-) 53.4, (+) 89.4, (-) 120.1, (+) 122.1 (q, ^1J = 30.7 Hz), (-) 122.5, (+) 124.2 (q, ^2J = 271 Hz), (-) 129.1, (-) 133.4, (+) 139.2, (+) 146.2, (+) 167.9, (+) 168.4, (+) 189.6. Anal. Calcd for $C_{17}H_{18}F_3N_3O_5$: C, 50.88; H, 4.52; N, 10.47. Found: C, 50.63; H, 4.74; N 10.52. EIMS (70 eV) *m/z*: M^+ 401 (0.1), 308 (100).

Methyl 3-acetyl-1-(2-fluorophenyl)-5-(2-methoxy-2-oxoethyl)-4-methyl-4,5-dihydro-1*H*-1,2,4-triazole-5-carboxylate (11i). Orange oil (274 mg, 78%). R_f = 0.43 (Hex/EtOAc, 4:1), 0.64 (Hex/EtOAc, 1:1). IR (cm^{-1}): 2999, 2954, 2923 (C-H), 1739, 1682 (C=O). ^{1}H NMR (400 MHz, DMSO-d_6): δ 2.41 (s, 3H), 2.84 and 3.41 (AB, J = 17.6 Hz, 2H), 3.03 (s, 3H), 3.39 (s, 3H), 3.74 (s, 3H), 7.07-7.13 (m, 1H), 7.16-7.24 (m, 2H), 7.42-7.47 (m, 1H). ^{13}C NMR (100 MHz, DMSO-

d_6): δ (-) 26.8, (-) 29.5, (+) 34.6, (-) 52.5, (-) 53.0, (+) 88.7, (-) 116.0 (d, J = 20.4 Hz), (-) 122.7, (-) 124.7 (d, J = 7.8 Hz), (-) 125.1 (d, J = 2.9 Hz), (+) 129.3 (d, J = 9.8 Hz), (+) 145.8, (+) 151.3 (d, ^1J = 240.2 Hz), (+) 167.6, (+) 168.2, (+) 189.1. Anal. Calcd for $C_{16}H_{18}FN_3O_5$: C, 54.70; H, 5.16; N, 11.96. Found: C, 54.45; H, 5.33; N, 11.72. EIMS (70 eV) *m/z*: M^+ 351 (0.5), 292 (100).

Ethyl 3-acetyl-5-(2-ethoxy-2-oxoethyl)-4-methyl-1-*p*-tolyl-4,5-dihydro-1*H*-1,2,4-triazole-5-carboxylate (11j). Orange oil (266 mg, 71%). R_f = 0.30 (Hex/EtOAc, 4:1), 0.69 (Hex/EtOAc, 1:1). IR (cm^{-1}): 2981, 2934, 2869 (C-H), 1734, 1676 (C=O). ^{1}H NMR (400 MHz, DMSO-d_6): δ 1.05 (t, J = 7.0 Hz, 3H), 1.14 (t, J = 7.0 Hz, 3H), 2.28 (s, 3H, Me), 2.42 (s, 3H), 3.07 (s, 3H), 3.19 and 3.29 (AB, J = 15.6 Hz, 2H), 3.95 (dq, J = 7.0 Hz, J = 1.8 Hz, 2H), 4.18-4.35 (m, 2H), 6.92 and 7.05 (AA'XX', J = 8.5 Hz, 4H). ^{13}C NMR (100 MHz, DMSO-d_6): δ (-) 13.7, (-) 13.7, (-) 20.1, (-) 26.5, (+) 29.5, (+) 35.0, (+) 60.0, (+) 62.3, (+) 88.4, (-) 115.3, (-) 129.4, (+) 130.3, (+) 138.8, (+) 144.9, (+) 167.2, (+) 167.7, (+) 188.7. Anal. Calcd for $C_{19}H_{25}N_3O_5$: C, 60.79; H, 6.71; N, 11.19. Found: C, 60.67; H, 6.88; N, 11.03. EIMS (70 eV) *m/z*: M^+ 375 (0.9), 302 (100).

Ethyl 3-acetyl-5-(2-ethoxy-2-oxoethyl)-4-methyl-1-phenyl-4,5-dihydro-1*H*-1,2,4-triazole-5-carboxylate (11k). Orange oil (264 mg, 73%). R_f = 0.44 (Hex/EtOAc, 4:1), 0.71 (Hex/EtOAc, 1:1). IR (cm^{-1}): 2982, 2932 (C-H), 1734, 1678 (C=O). ^{1}H NMR (400 MHz, DMSO-d_6): δ 0.98 (t, J = 7.2 Hz, 3H), 1.07 (t, J = 7.2 Hz, 3H), 2.42 (s, 3H), 3.06 (s, 3H), 3.30 and 3.38 (AB, J = 16.0 Hz, 2H), 3.92 (dq, J = 7.2, J = 1.2 Hz, 2H), 4.15-4.24 (m, 2H), 6.94 (t, J = 7.2 Hz, 1H), 7.04 (d, J = 8.0 Hz, 2H), 7.29 (t, J = 7.6 Hz, 2H). ^{13}C NMR (100 MHz, DMSO-d_6): δ (-) 13.7, (-) 13.7, (-) 26.6, (+) 29.4, (+) 34.9, (+) 60.1, (+) 62.4, (+) 88.1, (-) 114.8, (-) 121.1, (-) 129.0, (+) 141.1, (+) 145.0, (+) 167.1, (+) 167.6, (+) 188.8. Anal. Calcd for $C_{18}H_{23}N_3O_5$: C, 59.82; H, 6.41; N, 11.63. Found: C, 59.63; H, 6.67; N, 11.32. EIMS (70 eV) *m/z*: M^+ 361 (1.7), 288 (100).

Ethyl 3-acetyl-1-(4-cyanophenyl)-5-(2-ethoxy-2-oxoethyl)-4-methyl-4,5-dihydro-1*H*-1,2,4-triazole-5-carboxylate (11l). Orange oil (367 mg, 95%). R_f = 0.19 (Hex/EtOAc, 4:1), 0.64 (Hex/EtOAc, 1:1). IR (cm^{-1}): 2983, 2936, 2907 (C-H), 2220 (C≡N), 1735, 1690 (C=O). ^{1}H NMR (400 MHz, DMSO-d_6): δ 0.96 (t, J = 7.1 Hz), 1.11 (t, J = 7.1 Hz), 2.45 (s, 3H), 3.09 (s,

3H), 3.37 and 3.48 (AB, J = 16.0 Hz), 3.88-3.96 (m), 4.18-4.35 (m, 2H), 7.13 and 7.70 (AA'XX', J = 8.9, 4H). ^{13}C NMR (100 MHz, DMSO-d_6): δ (-) 13.6, (-) 13.7, (-) 26.9, (-) 29.2, (+) 34.3, (+) 60.2, (+) 62.9, (+) 87.1, (+) 101.5, (-) 113.9, (+) 119.3, (-) 133.4, (+) 144.1, (+) 145.7, (+) 166.2, (+) 167.4, (+) 189.2. Anal. Calcd for $C_{19}H_{22}N_4O_5$: C, 59.06; H, 5.74; N, 14.50. Found: C, 59.23; H, 5.62; N, 14.35. EIMS (70 eV) *m/z*: M^+ 386 (0.5), 313 (100).

Methyl 3-acetyl-4-butyl-1-(4-cyanophenyl)-5-(2-methoxy-2-oxoethyl)-4,5-dihydro-1*H*-1,2,4-triazole-5-carboxylate (11m). Bright orange powder (356 mg, 89%). R_f = 0.25 (Hex/EtOAc, 4:1), 0.61 (Hex/EtOAc, 1:1); mp 68-69 ºC. IR (cm^{-1}): 2957, 2934, 2875 (C-H), 2218 (C≡N), 1736, 1688 (C=O). ^{1}H NMR (400 MHz, $CDCl_3$): δ 0.93 (t, J = 7.2 Hz, 3H), 1.25-1.37 (m, 2H), 1.38-1.51 (m, 2H), 2.53 (s, 3H), 3.29 and 3.43 (AB, J = 16.4 Hz, 2H), 3.34-3.40 (m, 1H), 3.56 (s, 3H), 3.58-3.65 (m, 1H), 3.79 (s, 3H), 7.04 and 7.54 (AA'XX', J = 8.9 Hz, 4H). ^{13}C NMR (100 MHz, $CDCl_3$): δ (-) 13.7, (+) 19.9, (-) 27.3, (+) 31.8, (+) 34.6, (+) 43.4, (-) 52.0, (+) 53.6, (+) 86.7, (+) 102.9, (-) 113.6, (+) 119.4, (-) 133.5, (+) 144.1, (+) 146.0, (+) 167.9, (+) 169.0, (+) 189.4. Anal. Calcd for $C_{20}H_{24}N_4O_5$: C, 59.99; H, 6.04; N, 13.99. Found: C, 59.77; H, 6.28, N, 13.64. EIMS (70 eV) *m/z*: M^+ 400 (0.7), 341 (100).

Methyl 3-acetyl-1-(4-cyanophenyl)-5-(2-methoxy-2-oxoethyl)-4-(2-methoxyethyl)-4,5-dihydro-1*H*-1,2,4-triazole-5-carboxylate (11n). Bright yellow powder (306 mg, 76%). R_f = 0.14 (Hex/EtOAc, 4:1), 0.42 (Hex/EtOAc, 1:1); mp 97-98 ºC. IR (cm^{-1}): 2993, 2952, 2938 (C-H), 2218 (C≡N), 1735, 1692 (C=O). ^{1}H NMR (400 MHz, $CDCl_3$): δ 2.55 (s, 3H), 3.28 (s, 3H), 3.48 (s, 2H), 3.52 (t, J = 4.8 Hz, 2H), 3.56 (s, 3H), 3.64-3.69 (m, 2H), 3.79 (s, 3H), 7.11 and 7.54 (AA'XX', J = 8.9 Hz, 4H). ^{13}C NMR (100 MHz, $CDCl_3$): δ (+) 27.3, (+) 34.1, (-) 44.0, (-) 51.8, (-) 53.5, (-) 58.7, (+) 72.3, (+) 103.1, (-) 114.0, (+) 119.4, (+) 133.4, (+) 144.3, (+) 146.1, (+) 168.2, (+) 168.3, (+) 189.7. Anal. Calcd for $C_{19}H_{22}N_4O_6$: C, 56.71; H, 5.51; N, 13.92. Found: C, 56.53; H, 5.21; N, 13.69. EIMS (70 eV) *m/z*: M^+ 402 (0.2), 343 (80.5).

Methyl 3-acetyl-4-benzyl-1-(4-cyanophenyl)-5-(2-methoxy-2-oxoethyl)-4,5-dihydro-1*H*-1,2,4-triazole-5-carboxylate (11o). Bright yellow powder (278 mg, 64%). R_f = 0.14

(Hex/EtOAc, 4:1), 0.50 (Hex/EtOAc, 1:1); mp 48-49 ºC. IR (cm^{-1}): 3006, 2995, 2955 (C-H), 2218 (C≡N), 1732, 1680 (C=O). ^{1}H NMR (400 MHz, DMSO-d_6) δ: 2.55 (s, 3H), 3.21 (s, 3H), 3.44 (s, 3H), 3.46 (s, 2H), 4.62 and 5.15 (AB, J = 16.8 Hz, 2H), 7.07 and 7.68 (AA'XX', J = 9.2 Hz, 4H), 7.19-7.28 (m, 3H), 7.29-7.35 (m, 2H). ^{13}C NMR (100 MHz, DMSO-d_6): δ (-) 27.2, (+) 33.4, (+) 45.7, (-) 51.7, (-) 53.0, (+) 85.9, (+) 101.5, (-) 113.7, (+) 119.3, (-) 127.3, (-) 127.4, (-) 128.1, (-) 133.6, (+) 136.6, (+) 143.6, (+) 145.3, (+) 166.8, (+) 167.8, (+) 189.4. Anal. Calcd for $C_{23}H_{22}N_4O_5$: C, 63.59; H, 5.10; N, 12.90. Found: C, 63.75; H, 5.33; N, 12.78. EIMS (70 eV) *m/z*: M^+ 434 (0.1), 375 (12.9).

Methyl 3-acetyl-1-(4-cyanophenyl)-4-cyclohexyl-5-(2-methoxy-2-oxoethyl)-4,5-dihydro-1*H*-1,2,4-triazole-5-carboxylate (11p). Bright yellow powder (239 mg, 56%). R_f = 0.35 (Hex/EtOAc, 4:1), 0.71 (Hex/EtOAc, 1:1); mp 116-117 ºC. IR (cm^{-1}): 2949, 2934, 2918 (C-H), 2216 (C≡N), 1735, 1678 (C=O). ^{1}H NMR (400 MHz, DMSO-d_6): δ 1.02-1.33 (m, 3H), 1.47-1.59 (m, 2H), 1.63-1.76 (m, 4H), 1.85-1.97 (m, 1H), 2.49 (s, 3H), 3.17-3.29 (m, 1H), 3.33 and 3.60 (AB, J = 16.8 Hz, 2H), 3.45 (s, 3H), 3.74 (s, 3H), 7.07 and 7.69 (AA'XX', J = 8.9 Hz, 4H). ^{13}C NMR (100 MHz, DMSO-d_6): δ (+) 24.6, (+) 25.7, (-) 27.8, (+) 30.7, (+) 31.0, (-) 51.6, (-) 53.6, (-) 55.0, (+) 86.8, (+) 101.4, (-) 113.6, (+) 119.3, (-) 133.6, (+) 143.6, (+) 146.7, (+) 167.7, (+) 168.3, (+) 188.9. Anal. Calcd for $C_{22}H_{26}N_4O_5$: C, 61.96; H, 6.15; N, 13.14. Found: C, 61.72; H, 6.21; N, 13.37. EIMS (70 eV) *m/z*: M^+ 426 (0.4), 367 (22.7).

Methyl 3-acetyl-5-(2-methoxy-2-oxoethyl)-4-phenyl-1-*p*-tolyl-4,5-dihydro-1*H*-1,2,4-triazole-5-carboxylate (11q): Bright yellow powder (393 mg, 96%). R_f = 0.30 (Hex/EtOAc, 4:1), 0.64 (Hex/EtOAc, 1:1); mp 150-151ºC. IR (cm^{-1}): 3070, 3042, 2992 (C-H), 1732, 1673 (C=O). ^{1}H NMR (400 MHz, DMSO-d_6): δ 2.25 (s, 3H), 2.46 (s, 3H), 3.10 and 3.52 (AB, J = 16.7 Hz, 2H), 3.47 (s, 3H), 3.55 (s, 3H), 6.97 (d, J = 7.6 Hz, 2H), 7.06 and 7.14 (AA'XX', J = 8.4 Hz, 4H), 7.26-7.37 (m, 4H). ^{13}C NMR (100 MHz, DMSO-d_6): δ (-) 20.2, (-) 26.5, (+) 36.5, (-) 51.6, (-) 53.2, (+) 88.5, (-) 114.9, (-) 126.7, (-) 127.0, (-) 128.8, (-) 129.7, (+) 130.7, (+) 137.5, (+) 138.3,

(+) 144.3, (+) 167.7, (+) 167.9, (+) 186.4. Anal. Calcd for $C_{22}H_{23}N_3O_5$: C, 64.54; H, 5.66; N, 10.26. Found: C, 64.73; H, 5.41; N, 10.02. EIMS (70 eV) *m/z*: M^+ 409 (0.8), 350 (100).

Methyl 3-acetyl-1-(4-cyanophenyl)-5-(2-methoxy-2-oxoethyl)-4-phenyl-4,5-dihydro-1*H*-1,2,4-triazole-5-carboxylate (11r): Yellow powder (239 mg, 56%). R_f = 0.11 (Hex/EtOAc, 4:1), 0.47 (Hex/EtOAc, 1:1); mp 136-137 ºC. IR (cm^{-1}): 3005, 2955 (C-H), 2216 (C≡N), 1738, 1691 (C=O). ^{1}H NMR (400 MHz, DMSO-d_6) δ: 2.50 (s, 3H), 3.14 and 3.67 (AB, *J* = 16.8 Hz, 2H), 3.49 (s, 3H), 3.59 (s, 3H), 7.11 (d, *J* = 7.2 Hz, 2H), 7.16 and 7.74 (AA'XX', *J* = 8.4 Hz, 4H), 7.31-7.43 (m, 3H). ^{13}C NMR (100 MHz, DMSO-d_6): δ (-) 26.8, (+) 36.2, (-) 51.8, (-) 53.5, (+) 87.8, (+) 102.2, (-) 114.0, (-) 119.1, (-) 127.2, (-) 127.8, (-) 129.1, (+) 133.7, (+) 136.6, (+) 143.8, (+) 145.6, (+) 166.7, (+) 167.7, (+) 187.0. Anal. Calcd for $C_{22}H_{20}N_4O_5$: C, 62.85; H, 4.79; N, 13.33. Found: C, 62.72; H, 4.55; N, 13.11. EIMS (70 eV) *m/z*: M^+ 420 (0.5), 361 (100).

Methyl 3-acetyl-1-(4-cyanophenyl)-4-(9-ethyl-9*H*-carbazol-2-yl)-5-(2-methoxy-2-oxoethyl)-4,5-dihydro-1*H*-1,2,4-triazole-5-carboxylate (11s). Yellow powder (279 mg, 52%). R_f = 0.09 (Hex/EtOAc, 4:1), 0.51 (Hex/EtOAc, 1:1); mp 205-206 ºC. IR (cm^{-1}): 2982, 2952, 2921 (C-H), 2219 (C≡N), 1733, 1693 (C=O). ^{1}H NMR (400 MHz, DMSO-d_6): δ 1.35 (t, *J* = 7.1 Hz, 3H), 2.50 (s, 3H), 3.20 and 3.67 (AB, *J* = 16.8 Hz, 2H), 3.55 (s, 3H), 3.61 (s, 3H), 4.46 (q, *J* = 7.1 Hz, 2H), 7.18 and 7.74 (AA'XX', *J* = 8.8 Hz, 4H), 7.20-7.25 (m, 2H), 7.50 (t, *J* = 7.2 Hz, 1H), 7.63 (m, 2H), 7.92 (s, 1H), 8.17 (d, *J* = 7.6 Hz, 1H). ^{13}C NMR (100 MHz, DMSO-d_6): δ (-) 13.7, (-) 26.9, (+) 36.2, (+) 37.1, (-) 51.8, (-) 53.5, (+) 87.1, (+) 101.9, (-) 109.4, (-) 113.8, (+) 119.1, (-) 119.2, (-) 119.9, (-) 120.5, (+) 121.8, (+) 122.3, (-) 125.7, (-) 126.3, (+) 127.6, (-) 133.6, (+) 138.7, (+) 140.1, (+) 144.1, (+) 146.0, (+) 166.9, (+) 167.9, (+) 187.2. Anal. Calcd for $C_{30}H_{27}N_5O_5$: C, 67.09; H, 5.06; N, 13.03. Found: C, 67.27; H, 5.33; N, 13.38. EIMS (70 eV) *m/z*: M^+ 537 (0.5), 478 (100).

Methyl 3-acetyl-1-(4-cyanophenyl)-5-(2-methoxy-2-oxoethyl)-4-(4-(phenylamino)phenyl)-4,5-dihydro-1*H*-1,2,4-triazole-5-carboxylate (11t). Yellow powder (434 mg, 85%). R_f = 0.21 (Hex/EtOAc, 4:1), 0.42 (Hex/EtOAc, 1:1); mp 188-189 ºC. IR (cm^{-1}): 3370 (N-H), 2948, 2941,

2931 (C-H), 2224 (C≡N), 1734, 1688 (C=O). ^{1}H NMR (400 MHz, DMSO-d_6): δ 2.47 (s, 3H), 3.11 and 3.64 (AB, J = 16.7 Hz), 3.51 (s, 3H), 3.63 (s, 3H), 6.88 (t, J = 7.3 Hz, 1H), 6.96 and 7.03 (AA'XX', J = 8.8 Hz, 4H), 7.10-7.16 (m, 4H), 7.27 (t, J = 7.6 Hz, 2H), 7.73 (d, J = 9.2 Hz, 2H), 8.35 (s, 1H). ^{13}C NMR (100 MHz, DMSO-d_6): δ (-) 26.9, (+) 35.9, (-) 51.8, (-) 53.6, (+) 87.7, (+) 101.8, (-) 113.7, (-) 115.9, (-) 117.6, (+) 119.3, (-) 120.5, (+) 127.2, (-) 128.7, (-) 129.2, (-) 133.7, (+) 142.5, (+) 143.5, (+) 143.9, (+) 145.7, (+) 166.9, (+) 167.8, (+) 187.2. Anal. Calcd for $C_{28}H_{25}N_5O_5$: C, 65.74; H, 4.93; N, 13.69. Found: C, 65.56; H, 4.73; N, 13.38. EIMS (70 eV) *m/z*: M^+ 511 (0.8), 452 (100).

3-Ethyl 5-methyl 1-(4-cyanophenyl)-5-(2-methoxy-2-oxoethyl)-4-methyl-4,5-dihydro-1*H*-1,2,4-triazole-3,5-dicarboxylate (11u): Skin color powder (240 mg, 62%). R_f = 0.12 (Hex/EtOAc, 4:1), 0.47 (Hex/EtOAc, 1:1); mp 111-112 ºC. IR (cm^{-1}): 2992, 2956, 2930 (C-H), 2217 (C≡N), 1737, 1690 (C=O). ^{1}H NMR (400 MHz, DMSO-d_6): δ 1.31 (t, J = 7.1 Hz, 3H), 3.05 (s, 3H), 3.43 and 3.53 (AB, J = 16.4 Hz, 2H), 3.46 (s, 3H), 3.75 (s, 3H), 4.32 (q, J = 7.1, 2H), 7.03 and 7.66 (AA'XX', J = 8.9 Hz, 4H). ^{13}C NMR (100 MHz, DMSO-d_6): δ (-) 13.8, (-) 29.4, (+) 33.8, (-) 51.7, (-) 53.7, (+) 62.0, (+) 86.4, (+) 101.0, (-) 113.5, (+) 119.4, (-) 133.5, (+) 141.4, (+) 144.3, (+) 157.6, (+) 166.9, (+) 167.8. Anal. Calcd for $C_{18}H_{20}N_4O_6$: C, 55.67; H, 5.19; N, 14.43. Found: C, 55.47; H, 5.33; N, 14.19. EIMS (70 eV) *m/z*: M^+ 388 (0.9), 329 (100).

General procedure (GP) for the synthesis of 4,5-dihydrotriazoles 17a-e. A solution of amidrazones (1.0 mmol) and TsOH (0.1 mmol) in 1 ml of acetone was added in a 10-mL glass vial equipped with a small magnetic stirring bar. The reaction vial was sealed with a Teflon crimp top and stirred at 150 °C for 45 min to 2 h under microwave-irradiation (300 W). After completion of the reaction, the vial was cooled to 70 °C by air jet cooling before it was opened. The solvent was removed under reduced pressure and the crude product was purified by chromatography on a silica gel column (hexane : ethyl acetate 4 : 1, 3 : 2).

4-(3-Acetyl-4,5,5-trimethyl-4,5-dihydro-1*H*-1,2,4-triazol-1-yl)benzonitrile (17a). Dark orange powder, m.p. 123-124 ºC. (215 mg, 84%). R_f = 0.39 (Hex/EtOAc, 3:2), R_f = 0.53

(Hex/EtOAc, 1:1). IR, ν_{max}, cm^{-1}: 2985, 2957, 2922 (C-H), 2210 (C≡N), 1682 (C=O). ^1H NMR (400 MHz, DMSO-d_6): δ 1.69 (s, 6H), 2.43 (s, 3H), 3.04 (s, 3H), 7.31-7.38 (m, 2H), 7.52-7.61 (m, 2H). ^{13}C NMR (100 MHz, DMSO-d_6): δ (-) 21.9, (-) 26.8, (-) 27.8, (+) 86.7, (+) 100.1, (-) 114.5, (+) 119.7, (-) 133.2, (+) 145.0, (+) 146.8, (+) 190.2. Anal. Calcd for $C_{14}H_{16}N_4O$: C 65.61, H 6.29, N 21.86%. Found: C 65.71, H 6.40, N 21.50. MS-EI *m/z*: 256.

4-(3-Acetyl-4-*n*-butyl-5,5-dimethyl-4,5-dihydro-1*H*-1,2,4-triazol-1-yl)benzonitrile (17b): Orange oil (194 mg, 65%). R_f = 0.51 (Hex/EtOAc, 3:2), 0.69 (Hex/EtOAc, 1:1). IR (cm^{-1}): 2959, 2934, 2872 (C-H), 2217 (C≡N), 1683 (C=O). ^1H NMR (400 MHz, DMSO-d_6): δ 0.95 (t, *J* = 7.2 Hz, 3H), 1.33 (m, 2H), 1.47-1.55 (m, 2H), 1.71 (s, 6H), 2.43 (s, 3H), 3.34 and 3.35 (dd, J = 7.8, J = 8.0, 2H), 7.34 and 7.53 (AA'XX', *J* = 8.9 Hz, 4H). ^{13}C NMR (100 MHz, DMSO-d_6): δ (-) 13.6, (+) 19.6, (+) 23.5, (+) 26.8, (+) 33.8, (+) 41.1, (+) 86.8, (+) 100.0, (-) 114.5, (+) 119.7, (-) 133.2, (+) 144.9, (+) 146.2, (+) 189.9. Anal. Calcd for $C_{17}H_{22}N_4O$: C, 68.43; H, 7.43; N, 18.78. Found: C, 68.75; H, 7.26; N 18.62. EIMS (70 eV) *m/z*: M^+ 298 (14.7), 283 (100).

4-(3-Acetyl-4-benzyl-5,5-dimethyl-4,5-dihydro-1*H*-1,2,4-triazol-1-yl)benzonitrile (17c). Dark orange powder (239 mg, 72%). R_f = 0.41 (Hex/EtOAc, 3:2), 0.64 (Hex/EtOAc, 1:1); mp 143-144 ºC. IR (cm^{-1}): 3064, 2991, 2923, 2851 (C-H), 2214 (C≡N), 1686 (C=O). ^1H NMR (400 MHz, DMSO-d_6): δ 1.64 (s, 6H), 2.48 (s, 3H), 4.79 (s, 2H), 7.18-7.23 (m, 1H), 7.24-7.33 (m, 4H), 7.36 and 7.54 (AA'XX', *J* = 8.8 Hz, 4H). ^{13}C NMR (100 MHz, DMSO-d_6): δ (-) 23.5, (-) 26.8, (+) 44.3, (+) 87.0, (+) 100.3, (-) 114.6, (+) 119.7, (-) 126.5, (-) 126.7, (-) 128.2, (-) 133.2, (+) 140.1, (+) 144.9, (+) 146.1, (+) 189.9. Anal. Calcd for $C_{20}H_{20}N_4O$: C, 72.27; H, 6.06; N, 16.86. Found: C, 72.53; H, 6.23; N, 16.57. EIMS (70 eV) *m/z*: M^+ 332 (3.0), 317 (14.2).

4-(3-Acetyl-4-(2-methoxyethyl)-5,5-dimethyl-4,5-dihydro-1*H*-1,2,4-triazol-1-yl)benzonitrile (17d). Orange oil (240 mg, 80%). R_f = 0.39 (Hex/EtOAc, 3:2), 0.46 (Hex/EtOAc, 1:1). IR (cm^{-1}): 2990, 2975, 2929 (C-H), 2207 (C≡N), 1679 (C=O). ^1H NMR (400 MHz, DMSO-d_6): δ 1.71 (s, 6H), 2.43 (s, 3H), 3.30 (s, 3H), 3.44 (t, *J* = 5.6 Hz, 2H), 3.55 (t, *J* = 5.6 Hz, 2H), 7.34 and 7.53 (AA'XX', *J* = 9.0 Hz, 4H). ^{13}C NMR (100 MHz, DMSO-d_6): δ (-) 13.9, (-) 21.9, (-) 28.0, (+)

61.5, (+) 86.0, (+) 99.5, (-) 114.1, (+) 119.8, (-) 133.1, (+) 142.3, (+) 145.4, (+) 158.5. Anal. Calca for $C_{16}H_{20}N_4O_2$: C, 63.98; H, 6.71; N, 18.65. Found: C, 63.72; H, 6.57; N 18.42. EIMS (70 eV) *m/z*: M^+ 300 (13.6), 285 (100).

Ethyl 1-(4-cyanophenyl)-4,5,5-trimethyl-4,5-dihydro-1*H*-1,2,4-triazole-3-carboxylate (17e). Yellow powder (257 mg, 90%). R_f = 0.35 (Hex/EtOAc, 3:2), 0.50 (Hex/EtOAc, 1:1); m.p. 134-135 ºC. IR (cm^{-1}): 2990, 2943 (C-H), 2207 (C≡N), 1715, 1687 (C=O). ^{1}H NMR (400 MHz, DMSO-d_6): δ 1.37 (t, *J* = 7.1 Hz, 3H), 1.70 (s, 6H), 3.03 (s, 3H), 4.30 (q, *J* = 7.1 Hz, 2H), 7.28 and 7.51 (AA'XX', *J* = 8.9 Hz, 4H). ^{13}C NMR (100 MHz, DMSO-d_6): δ (-) 23.5, (-) 26.9, (-) 58.2, (+) 72.1, (+) 86.7, (+) 100.1, (-) 114.5, (+) 119.7, (-) 133.2, (+) 145.0, (+) 146.6, (+) 190.1. Anal. Calcd for $C_{15}H_{18}N_4O_2$: C, 62.92; H, 6.34; N, 19.57. Found: C, 62.74; H, 6.22; N, 19.62. EIMS (70 eV) *m/z*: M^+ 286 (15.1), 271 (91.4).

ASSOCIATED CONTENT

Supporting Information

The Supporting Information is available free of charge on the ACS Publication website at DOI:

^{1}H and ^{13}C NMR spectra of all new compounds; X-ray crystallographic data; Computational results and Cartesian coordinates (PDF).

Crystalographic data of **11d**,**e**,**g**,**q** (CIF)

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Notes

The authors declare no competing financial interest.

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