Monatshefte für Chemie 139, 153–159 (2008)
DOI 10.1007/s00706-007-0764-5
Printed in The Netherlands

Monatshefte für Chemie
Chemical Monthly

Heterocyclic Synthesis with 4-Benzoyl-1-cyanoacetylthiosemicarbazide: Selective Synthesis of Some Thiazole, Triazole, Thiadiazine, Pyrrylthiazole, and Pyrazolo[1,5-*a*]triazine Derivatives

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Received June 26, 2007; accepted July 5, 2007; published online January 11, 2008

Summary. 4-Benzoyl-1-cyanoacetylthiosemicarbazide undergoes coupling reaction with aromatic diazonium chloride to afford (arylhydrazono)thiosemicarbazide, which was reacted with phenacyl bromide regioselectivity to afford the thiazoline. The (arylhydrazono)thiosemicarbazide could be transformed into the pyrazolo[1,5-*a*]triazine. Heterocyclization of 4-benzoyl-1-cyanoacetylthiosemicarbazide with α-haloketones (bromoacetone and phenacyl bromide), ethyl iodide, and ethyl bromoacetate furnished the pyrrylthiazoles, 1,2,4-triazole, and 1,3,4-thiadiazine. The latter was coupled with aromatic diazonium chloride to give the bis(arylhydrazono)-thiadiazine. The mechanism for the formation of the title compounds was suggested and discussed.

Keywords. Thiosemicarbazide; α-Haloketones; Thiazoline; Triazole; Thiadiazine.

Introduction

The cyclization of thiosemicarbazides has been shown to be an excellent strategy for the synthesis of several heterocycles like 1,2,4-triazoles, 1,3,4-thiadiazoles, 1,3,4-oxadiazoles, and (or) 1,3,4-triazines [1–4]. For instance, the cyclization of 1,4-disubstituted thiosemicarbazides resulted in the formation of 1,3,4-thiadiazoles in acidic media [5, 6]. On the other hand, the same thiosemicarbazides underwent a cyclization to yield 1,2,4-triazole derivatives in the presence of sodium hydroxide [7, 8].

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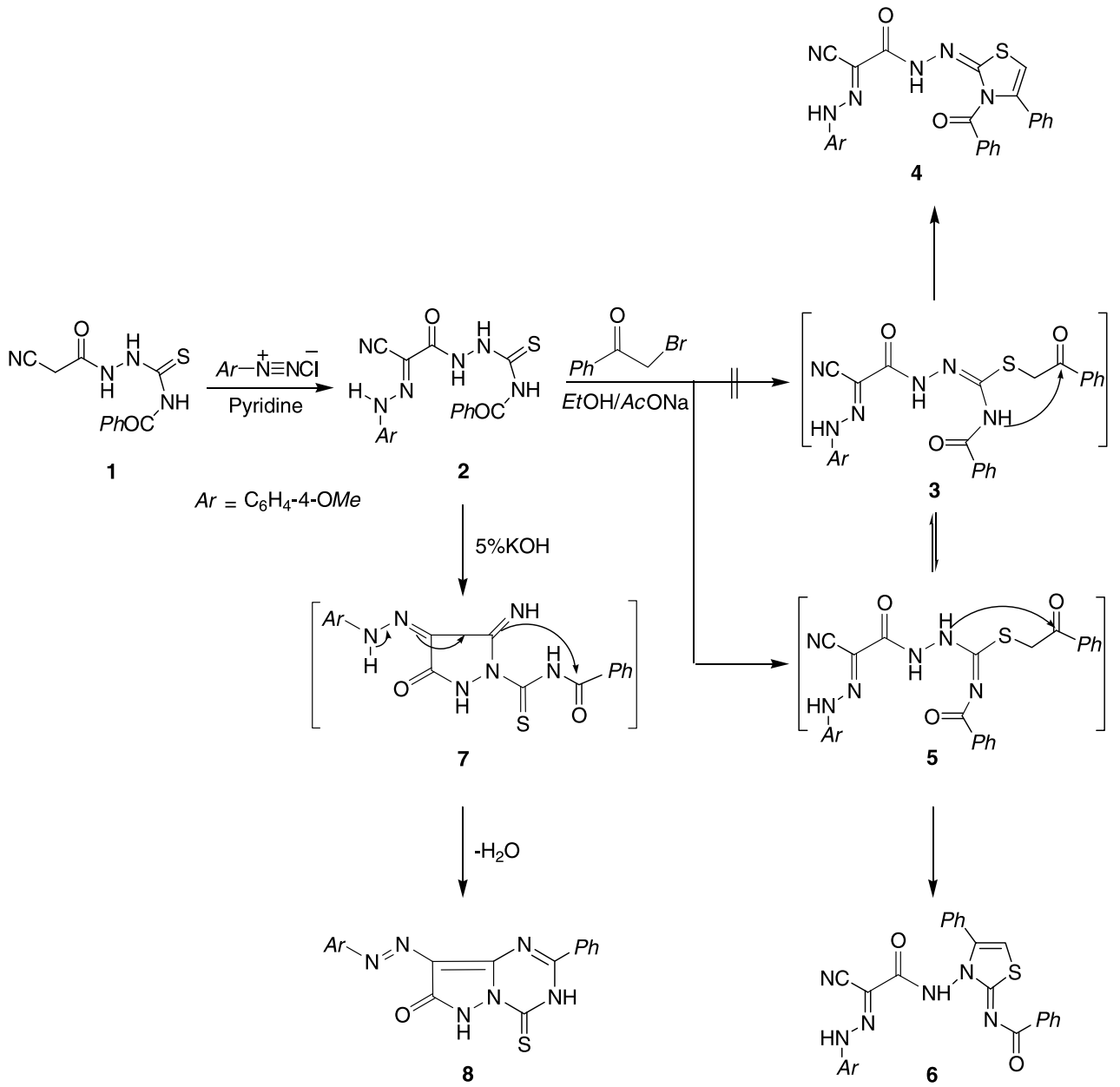
Alkylation of thiosemicarbazides with α-halocarbonyl compounds may result in the formation of five- and six-membered isomeric heterocycles [9]. Although a large number of papers [10–13] deals with the reactions of thiosemicarbazide with α-haloketones, it is rather difficult to predict the structure of the condensation products when new thiosemicarbazides as well as α-haloketones are used. The analysis of literature data shows that in such reactions possible products are thiadiazines, thiazoles, thiazolines, pyrazoles, and other compounds, depending on the nature of the substituent both in the α-halocarbonyl compound and in thiosemicarbazide, as well as on the reaction conditions, *i.e.* the *pH* of the medium, temperature, solvent, reagent addition order, *etc.* [14–17].

As a part of our program aimed at the development of new simple and efficient procedures for the synthesis of some important heterocyclic systems from thiosemicarbazide derivatives, we have recently reported different successful approaches for the synthesis of thiazole, thiadiazole, and thiobarbituric acid derivatives [18–20].

In continuation of our interest in the synthesis of novel heterocycles of potential biological importance, we report here a facile one-pot selective synthesis of the title compounds *via* reaction of 4-benzoyl-1-cyanoacetylthiosemicarbazide (**1**) with α-halocarbonyl compounds and ethyl iodide.

Results and Discussion

Firstly, we decided to block the active methylene group of **1** before studying the cyclization of **1** after its reaction with phenacyl bromide. A simple and an efficient protocol for blocking of the active methylene group of **1** was the coupling of **1** with 4-methoxybenzenediazonium chloride in pyridine at 0–5°C which furnished the arylhydrazone **2**. Heterocyclization of **2** with phenacyl bromide in boiling ethanol containing freshly fused sodium acetate gave a product of molecular formula $C_{26}H_{20}N_6O_2S$. Two theoretically possible structures were considered (*cf.* structures **4** and **6**). The thiazole structure **6** was considered most likely based on its spectroscopic data. The regiochemistry of **6** was established unequivocally by mass spectroscopy. Its mass spectrum showed a distinct peak at $m/z = 163$ due to the *Ph*CONCS fragment which could only be produced from the regioisomeric structure **6**. While its IR spectrum showed the absence of C=S absorption band and



Scheme 1

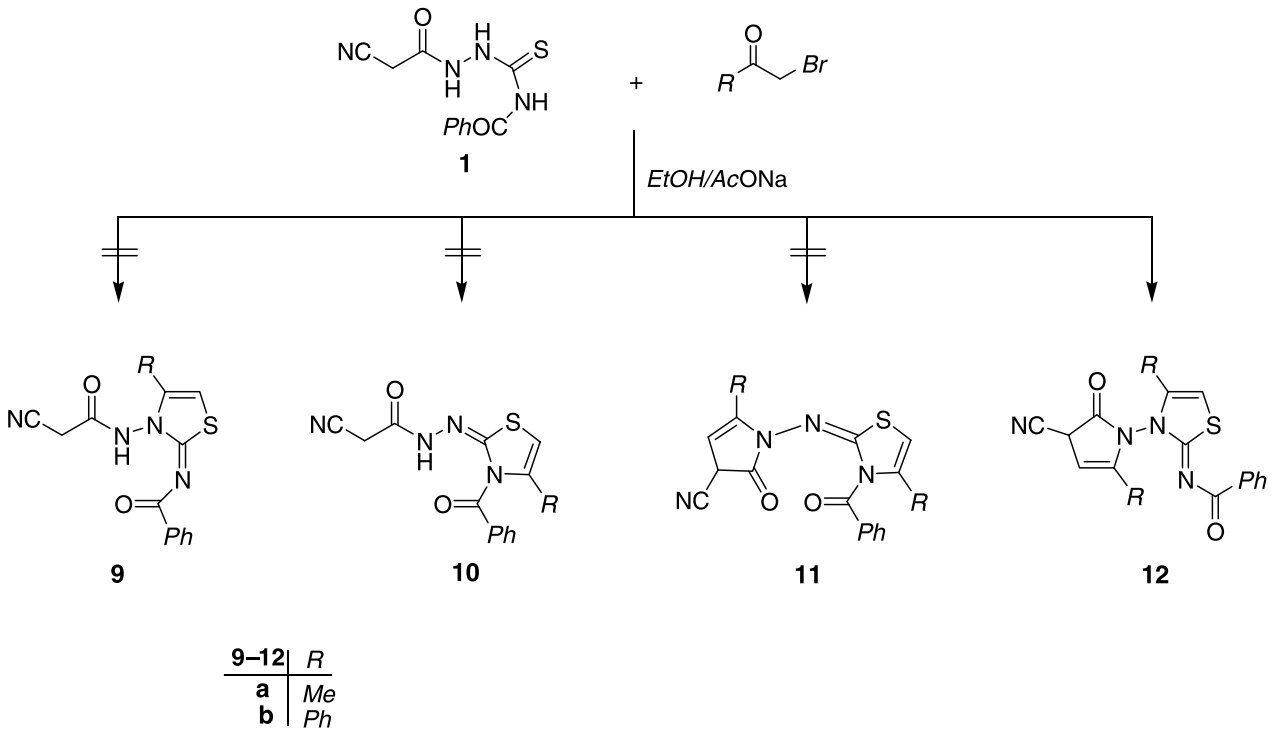
the presence of absorption bands at 3250–3160 cm^{-1} due to two NH functions, at 2210 cm^{-1} due to conjugated C≡N, and at 1665 and 1645 cm^{-1} due to two amidic C=O functions. The ^1H NMR spectrum displayed a sharp singlet signal at $\delta = 6.12$ ppm characteristic to the methine proton of thiazole ring and the disappearance of two singlets characteristic to NH protons.

The mechanistic scenario for the formation of the thiazoline **6** can be interpreted as follows. The acidic character of imido group NH-4 enhances the nucleophilicity of the thiol group to attack the sp^3-carbon of phenacyl bromide to form the non-isolable S-phenacylated intermediate **5** which underwent intramolecular cyclodehydration to form the thiazoline structure **6**. The connectivity for the *Hantzsch* thiazoline synthesis may be interpreted by electronic factors that predispose electron-withdrawing substituent (*i.e.* benzoyl) to maintain conjugative stabilization with the imino nitrogen [21].

When compound **2** was treated with aqueous 5% potassium hydroxide, it underwent intramolecular cyclization to furnish 8-(4-methoxyphenylazo)-2-phenyl-4-thioxo-3,4-dihydro-pyrazolo[1,5-*a*][1,3,5]-triazin-7(6*H*)-one (**8**). The structure of compound **8** was inferred from correct elemental analysis and spectral data. The IR spectrum of **8** showed the absence of C≡N absorption band and indicated the presence of carbonyl stretching at 1645 cm^{-1}. The ^1H NMR spectrum of **8**, in addition to the multiplet at $\delta = 7.58$–8.26 ppm region due to the aromatic protons, exhibited two broad signals for two protons at $\delta = 8.35$ and 9.28 ppm exchangeable with deuterium oxide due to two NH protons and a singlet signal at $\delta = 3.95$ ppm due to the OCH_3 protons. The mass spectrum of **8** showed a molecular ion peak at $m/z = 378$, corresponding to a molecular formula $C_{18}H_{14}N_6O_2S$.

A rationale for the formation of **8** probably involves intramolecular cyclization of **2** by attack of the basic thiosemicarbazide N2 on the nitrile carbon to form the non-isolable intermediate **7** which in turn undergoes intramolecular cyclocondensation by attack of the imino N on the benzoyl C=O group to afford the product **8** (Scheme 1).

Next, we investigated the reactivity of thiosemicarbazide derivative **1** towards bromoacetone as well as phenacyl bromide. Surprisingly, the reaction of compound **1** with bromoacetone and/or phenacyl bromide in boiling ethanol containing a catalytic amount of freshly fused sodium acetate afforded the bisheterocyclic compounds **12** rather than the ex-



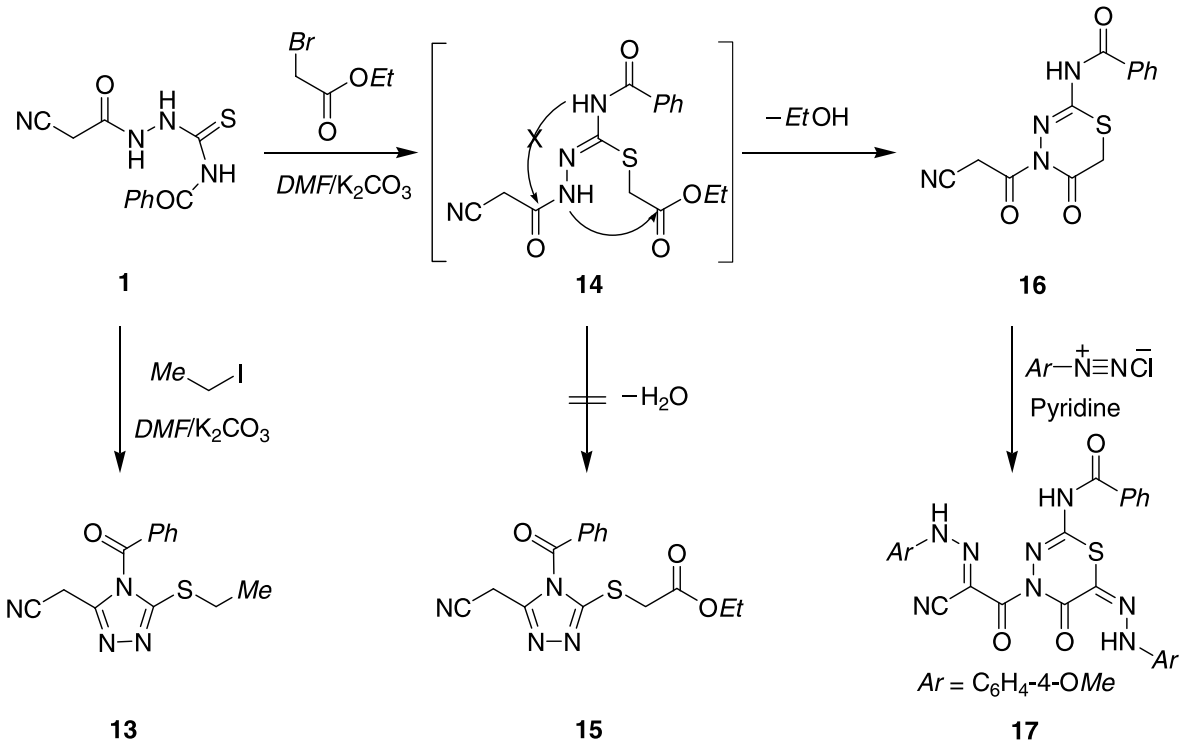
Scheme 2

pected thiazole derivatives **9**, **10**, and **11**. The chemical structure of compounds **12** was elucidated on the basis of elemental analysis and spectral data.

For example, the originally expected structures **9b** and **10b** were excluded on the basis of elemental analysis and spectral data. The mass spectrum showed a molecular ion peak at $m/z = 462$, corresponding to a molecular formula $C_{27}H_{18}N_4O_2S$ which was different from molecular formula of structures **9b** and **10b**. Moreover, the IR spectrum displayed the absence of NH and C=S absorption bands and the presence of C≡N absorption band at 2237 cm^{-1} and two C=O stretching vibrations at 1665 and 1647 cm^{-1}. Also, the ^1H NMR spectrum showed the absence of signals characteristic to NH and activated methylene protons and the presence of two doublet signals at $\delta = 4.64$ and 5.67 ppm specific for two adjacent pyrrolinone protons and a singlet signal at $\delta = 6.66$ ppm specific for thiazoline proton. These spectroscopic data were in accordance with two other theoretically possible structures **11b** and **12b**. The IR and ^1H NMR data in our hands could not differentiate between structures **11b** and **12b**. However, the mass spectrum proved to be a helpful tool for differentiating the two structures. Thus, the mass spectrum showed a distinct peak at $m/z = 163$ attributable to *Ph*CONCS fragment which could be only obtained from **12b**.

It is worthwhile to mention that when thiosemicarbazide derivative **1** and α-haloketones (bromoacetone and phenacyl bromide) were reacted in 1:1 and/or 1:2 molar ratio under similar conditions, the same bisheterocyclic product **12** was obtained, but the yield was reduced to one half when an equimolar amount was used.

1,2,4-Triazoles are considered to be very interesting heterocyclic ring systems because of their biological and pharmaceutical importance [22–24]. There are known drugs containing the 1,2,4-triazole moiety [25–27]. In the present work we explore the synthetic potentional of **1** to obtain some novel triazoles. Thus, the reaction of **1** with ethyl iodide in *DMF* at room temperature and in the presence of anhydrous potassium carbonate gave 1,2,4-triazole derivative **13**. The structure of **13** was established on the basis of its elemental analysis and spectral data. Thus, its IR spectrum revealed the presence of absorption bands at 2225 cm^{-1} attributable to C≡N and at 1660 cm^{-1} attributable to C=O stretching and the absence of NH and C=S absorption



Scheme 3

bands. Moreover its ^{1}H NMR spectrum showed no broad signals assignable to NH function and the presence of a singlet signal at $\delta = 4.69$ ppm distinctive for activated methylene protons, quartet signal at $\delta = 3.03$ ppm assignable to SCH_2 protons, triplet signal at $\delta = 1.16$ ppm assignable to CH_3 protons, and multiplet signal at $\delta = 7.41$–7.94 ppm assignable to aromatic protons. Its mass spectrum showed molecular ion peak (M^+) at $m/z = 272$, corresponding to a molecular formula $C_{13}H_{12}N_4OS$.

On the other hand, reacting of compound **1** with ethyl bromoacetate in *DMF* at room temperature and in the presence of anhydrous potassium carbonate afforded the unexpected thiadiazinone derivative **16** instead of the 1,2,4-triazole derivative **15** (see Scheme 3). Formation of **16** is assumed to take place through the non-isolable intermediate **14** which underwent cyclization by loss of ethanol. The formation of **16** is in accordance with the previously reported formation of similar system [28].

The structure **16** was established for the reaction product based on its analytical and spectral data. Thus, its IR spectrum exhibited the presence of absorption bands at 3210 cm^{-1} characteristic to NH function, at 2228 cm^{-1} characteristic to C≡N function, and at 1662, 1668, and 1678 characteristic to three amidic C=O functions and no absorption bands characteristic to ester and C=S functions. Whereas its ^{1}H NMR spectrum discovered the presence of two singlets assignable to cyanomethylene protons and methylene protons of 1,2,4-thiadiazine ring at $\delta = 4.65$ and 4.29 ppm in addition to a broad signal at $\delta = 11.14$ ppm assignable to NH proton. Its mass spectrum showed a molecular ion peak at $m/z = 302$, corresponding to a molecular formula $C_{13}H_{10}N_4O_3S$.

The structure of the product **16** was further confirmed from the following behavior. It undergoes the coupling reaction with two molar amounts of the aromatic diazonium chloride to afford the colored bishydrazone derivative **17**.

The structure of product **17** was confirmed on the basis of elemental analysis and spectral data. The IR spectrum exhibited absorption bands at 3454–3190 cm^{-1} region characteristic to NH group, 2210 cm^{-1} characteristic to conjugated C≡N group, and 1678, 1661, and 1655 cm^{-1} characteristic to three amidic C=O groups. The ^{1}H NMR spectrum revealed the presence of two new singlets at $\delta = 3.88$ and 3.95 ppm characteristic for two methoxy protons and the absence of signals characteristic to cyanomethylene protons and methylene protons of 1,2,4-thiadiazine ring. The mass spectrum showed a molecular ion peak (M^+) at $m/z = 598$.

In conclusion, we developed a facile and selective procedure for preparation of novel monoheterocycles namely thiazoline, triazole, thiadiazine, and fused heterocycles like pyrazolo[1,5-*a*]triazine as well as bisheterocyles *via* reaction of 4-benzoyl-1-cyanoacetylthiosemicarbazide with α-halocarbonyl compounds and ethyl iodide.

Experimental

All melting points were measured on an electrothermal Gallenkamp melting apparatus. Elemental analyses data (in accord with the calculated values) were obtained from the microanalytical unit, Cairo University, Cairo, Egypt. IR spectra were recorded for KBr discs on a Mattson 5000 FTIR spectrophotometer. ^{1}H NMR spectra were measured on a Bruker AC 300 (300 MHz) in *DMSO*-d_6 as solvent, using *TMS* as an internal standard, and chemical shifts are expressed as δ. Mass spectra were determined on a Finnigan Incos 500 spectrometer (70 eV). All reactions were followed by TLC (silica gel, aluminum sheets 60 F_{254}, Merck). 4-Benzoyl-1-cyanoacetyl-thiosemicarbazide (**1**) was prepared according to the published procedure [29].

2-(2-(Benzoylcarbamothioyl)hydrazinyl)-N′-(4-methoxyphenyl)-2-oxoacetohydrazonoyl cyanide (**2**, $C_{18}H_{16}N_6O_3S$)
To a cold solution of 2.62 g **1** (1 mmol) in 30 cm^3 pyridine was added dropwise a cold solution of *p*-methoxyphenyldiazonium chloride (1 mmol) [prepared by addition of 0.7 g $NaNO_2$ in 10 cm^3 H_2O to 1.23 g *p*-anisidine (1 mmol) in 3 cm^3 conc. HCl at 0–5°C under stirring] while stirring. The addition took about 30 min, after which stirring was continued for further 1 h. The colored solid precipitate was collected by filtration, washed with cold water, and recrystallized from a mixture of *Et*OH-*DMF* (2:1) to afford the title compound. Pale red crystals; yield 82%; mp 234–235°C; IR (KBr): $\bar{\nu} = 3300$–3190 (4NH), 2206 (C≡N), 1665, 1655 (2C=O), 1582 (C=N) cm^{-1}; ^{1}H NMR (*DMSO*-d_6): $\delta = 3.90$ (s, OCH_3), 6.98 (s, br, 2NH), 7.17–7.87 (m, 5*Ar*–H), 8.12, 8.23 (two d, $J = 8.0$ Hz, 4*Ar*–H), 10.51 (s, br, NH), 12.44 (s, br, NH) ppm; MS (EI, 70 eV): m/z (%) = 396 (M^+, 14.4), 319 (3.2), 276 (19.1), 232 (27.9), 202 (39.7), 174 (47.0), 148 (34.6), 105 (100), 77 (67.7), 51 (32.4).

2-(2-(Benzoylimino)-4-phenylthiazol-3(2H)-ylamino)-N′-(4-methoxyphenyl)-2-oxoacetohydrazonoyl cyanide
(**6**, $C_{26}H_{20}N_6O_3S$)
A mixture of 1.98 g **2** (5 mmol) and 0.99 g phenacyl bromide (5 mmol) in 30 cm^3 absolute ethanol containing freshly fused sodium acetate (75 mmol) was refluxed for 6 h. The reaction mixture was allowed to cool, and then poured onto crushed ice, and the separated solid filtered off, dried well, and recrystallized from ethanol to give compound **6**. Orange crystals;

yield 71%; mp 255–256°C; IR (KBr): $\bar{\nu} = 3250–3160$ (2NH), 2210 (C≡N), 1665, 1647 (2C=O), 1592 (C=N) cm^{-1}; ^1H NMR (*DMSO*-d_6): $\delta = 3.98$ (s, OCH_3), 6.12 (s, thiazole C_5-H), 7.26–7.90 (m, 5*Ar*–H), 7.95, 8.06 (two d, $J = 8.0$ Hz, each 2H, 4*Ar*–H), 8.60 (s, NH), 10.20 (s, br, NH) ppm; MS (EI, 70 eV): m/z (%) = 496 (M^+, 20.6), 419 (7.1), 319 (10.6), 374 (12.9), 365 (22.6), 322 (16.6), 294 (27.1), 175 (14.3), 163 (41.7), 122 (7.5), 107 (5.4), 105 (100), 77 (62.9), 51 (28.5).

8-(4-Methoxyphenylazo)-2-phenyl-4-thioxo-3,4-dihydropyrazolo[1,5-a][1,3,5]triazin-7(6H)-one (**8**, $C_{18}H_{14}N_6O_2S$)
A solution of 1.98 g **2** (5 mmol) in 15 cm^3 ethanol was treated with 20 cm^3 aqueous 5% potassium hydroxide, then refluxed for 2 h, left to cool, diluted with water, and acidified with dilute HCl. The solid product formed was collected by filtration, dried well, and crystallized from a mixture of *Et*OH-$CHCl_3$ (1:1) to give compound **8**. Brown crystals; yield 72%; mp 277–278°C; IR (KBr): $\bar{\nu} = 3300–3100$ (2NH), 1645 (C=O), 1582 (N=N) cm^{-1}; ^1H NMR (*DMSO*-d_6): $\delta = 3.95$ (s, OCH_3), 7.26–7.88 (m, 5*Ar*–H), 8.05, 8.26 (two d, $J = 7.8$ Hz, 4*Ar*–H), 8.35 (s, br, NH), 9.28 (s, br, NH) ppm; MS (EI, 70 eV): m/z (%) = 378 (M^+, 9.1), 350 (14.3), 243 (20.3), 148 (30.9), 118 (100), 77 (35.1), 51 (13.9).

Synthesis of Bisheterocyclic Compounds ***12a–12b***
A mixture of 2.62 g **1** (1 mmol) and the appropriate α-haloketone (bromoacetone or phenacyl bromide) (2 mmol) in 30 cm^3 absolute ethanol containing 2 g freshly fused sodium acetate (25 mmol) was refluxed for 6 h, then allowed to cool. The precipitate that formed was filtered off, washed with water, dried, and recrystallized from ethanol to give the bisheterocyclic compounds **12a**–**12b**.

N-(3-(3-Cyano-5-methyl-2-oxo-2,3-dihydro-1H-pyrrol-1-yl)-4-methylthiazol-2(3H)-ylidene)benzamide
(**12a**, $C_{17}H_{14}N_4O_2S$)
Brown crystals; yield 68%; mp 272–273°C; IR (KBr): $\bar{\nu} =$ 2235 (C≡N), 1665 (C=O), 1645 (ring C=O), 1592 (C=N) cm^{-1}; ^1H NMR (*DMSO*-d_6): $\delta = 2.08$ (s, CH_3), 2.21 (s, CH_3), 4.49 (d, $J = 2.5$ Hz, pyrrole C_3-H), 5.56 (d, $J = 2.5$ Hz, pyrrole C_4-H), 6.23 (s, thiazole C_5-H), 7.47–7.94 (m, 5*Ar*–H) ppm; MS (EI, 70 eV): m/z (%) = 338 (M^+, 9.8), 233 (6.5), 218 (15.2), 190 (19.6), 163 (8.2), 121 (4.3), 105 (100), 77 (43.5), 51 (16.9).

N-(3-(3-Cyano-2-oxo-5-phenyl-2,3-dihydro-1H-pyrrol-1-yl)-4-phenylthiazol-2(3H)-ylidene)benzamide
(**12b**, $C_{27}H_{18}N_4O_2S$)
Green crystals; yield 74%; mp 287–288°C; IR (KBr): $\bar{\nu} =$ 2237 (C≡N), 1665 (C=O), 1647 (ring C=O), 1596 (C=N) cm^{-1}; ^1H NMR (*DMSO*-d_6): $\delta = 4.64$ (d, $J = 2.6$ Hz, pyrrole C_3-H), 5.67 (d, $J = 2.6$ Hz, pyrrole C_4-H), 6.66 (s, thiazole C_5-H), 7.26–7.99 (m, 15*Ar*–H) ppm; MS (EI, 70 eV): m/z (%) = 462 (M^+, 9.8), 357 (M^+-*Ph*CO, 19.9), 299 (24.6), 279 (3.3), 271 (12.8), 245 (23.5), 183 (15.7), 163 (7.4), 155 (19.4), 134 (14.7), 105 (100), 81 (14.8), 78 (26.7), 77 (61.8), 53 (24.8), 51 (17.6).

2-(4-Benzoyl-5-ethylsulfanyl-4H-1,2,4-triazol-3-yl)-acetonitrile (**13**, $C_{13}H_{12}N_4OS$)
To a cold suspension of 1.38 g anhydrous K_2CO_3 (1 mmol) in 30 cm^3 *DMF*, 2.62 g **1** (1 mmol) were added, followed by addition of 1.55 g ethyl iodide (1 mmol). The mixture was stirred at room temperature for 24 h. The reaction mixture was then triturated with 50 cm^3 cold water, and acidified with dilute HCl. The resultant solid product, so precipitated, was collected by filtration, dried well, and crystallized from ethanol to give compound **13**. Yellow crystals; yield 65%; mp 232–233°C; IR (KBr): $\bar{\nu} = 2245$ (C≡N), 1682 (C=O) cm^{-1}; ^1H NMR (*DMSO*-d_6): $\delta = 1.16$ (t, $J = 7.5$ Hz, CH_3), 3.03 (q, $J = 7.5$ Hz, SCH_2), 4.69 (s, $NCCH_2$), 7.41–7.94 (m, 5*Ar*–H) ppm; MS (EI, 70 eV): m/z (%) = 272 (M^+, 16.0), 211 (31.5), 167 (23.9), 138 (34.8), 105 (100), 77 (38.9), 51 (15.6).

N-(4-(2-Cyanoacetyl)-5-oxo-5,6-dihydro-4H-1,3,4-thiadiazin-2-yl)benzamide (**16**, $C_{13}H_{10}N_4O_3S$)
To a cold suspension of 1.38 g anhydrous K_2CO_3 (1 mmol) in 30 cm^3 *DMF*, 2.62 g **1** (1 mmol) were added, followed by addition of 1.65 g ethyl bromoacetate (1 mmol). The mixture was stirred at room temperature for 20 h. The reaction mixture was then triturated with 50 cm^3 cold water, and few drops of dilute HCl were added till $pH = 7$. The resultant solid product, so precipitated, was collected by filtration, dried well, and crystallized from ethanol to give compound **16**. Orange crystals; yield 61%; mp 255–256°C; IR (KBr): $\bar{\nu} = 3234$ (NH), 2232 (C≡N), 1672, 1660, 1645 (3C=O) cm^{-1}; ^1H NMR (*DMSO*-d_6): $\delta = 4.29$ (s, thiadiazine ring CH_2), 4.65 (s, $NCCH_2$), 7.51–7.94 (m, 5*Ar*–H), 11.14 (s, NH) ppm; MS (EI, 70 eV): m/z (%) = 302 (M^+, 32.2), 262 (16.9), 170 (23.0), 154 (49.6), 105 (100), 77 (71.7), 51 (16.8).

2-(2-Benzamido-6-(2-(4-methoxyphenyl)-hydrazono)-5-oxo-5,6-dihydro-4H-1,3,4-thiadiazin-4-yl)-N′-(4-methoxyphenyl)-2-oxoacetohydrazonoyl cyanide (**17**, $C_{25}H_{18}N_8O_3S$)
A well stirred solution of 0.62 g *p*-anisidine (5 mmol) in 1.5 cm^3 concentrated HCl and 3 cm^3 H_2O was cooled in an ice-bath at 0–5°C and diazotized with the solution of 0.35 g $NaNO_2$ in 5 cm^3 H_2O. Then, the above cold diazonium solution was added dropwise to a well stirred cold solution of 0.75 g **16** (25 mmol) in 25 cm^3 pyridine. The reaction mixture was stirred for 2 h until complete coupling reaction was reached. The solid product obtained, was filtered off, washed with cold water, and recrystallized from a mixture of *Et*OH–*DMF* (1:1) to give compound **17**. Red crystals; yield 82%; mp 283–284°C; IR (KBr): $\bar{\nu} = 3325–3185$ (3 NH), 2212 (C≡N), 1664, 1652, 1643 (3C=O), 1625 (C=N) cm^{-1}; ^1H NMR (*DMSO*-d_6): $\delta = 3.88$ (s, OCH_3), 3.95 (s, OCH_3), 7.28–7.81 (m, 5*Ar*–H), 7.85, 7.94 (two d, $J = 7.9$ Hz, 4*Ar*–H), 8.15, 8.25 (two d, $J = 8.0$ Hz, 4*Ar*–H), 9.74 (s, br, 2NH), 10.87 (s, br, NH) ppm; MS (EI, 70 eV): m/z (%) = 570 (M^+, 13.7), 406 (8.6), 284 (14.6), 174 (16.6), 122 (25.7), 105 (100), 77 (61.1), 51 (16.9).

References

[1] Suni MM, Nair VA, Joshua CP (2001) Tetrahedron **57**: 2003
[2] Hassan AA, El-Shaieb KM, Shaker RM, Döpp D (2005) Heteroatom Chem **16**: 12
[3] Raslan MA, Khalil MA (2003) Heteroatom Chem **14**: 114
[4] Demirbas N, Karaoglu SA, Demirbas A, Sancak K (2004) Eur J Med Chem **39**: 793
[5] Collin X, Sauleau A, Coulon J (2003) Bioorg Med Chem **13**: 2601
[6] Karakus S, Rollas S (2002) IL Farmaco **57**: 577
[7] Varvaresou A, Siatra-Papastaikoudi T, Tsotinis A, Tsantili-Kakoulidou A, Vamvakides A (1998) IL Farmaco **53**: 320
[8] Kücükgüzel SG, Rollas S, Erdeniz H, Kiraz M (1999) Eur J Med Chem **34**: 153
[9] Mustafa SM, Nair VA, Chittoor JP, Krishnapillai S (2004) Mini Rev Organic Chem **1**: 375
[10] Suni MM, Nair VA, Joshua CP (2001) Tetrahedron Lett **42**: 97
[11] Mamedov VA, Nuretdinov IA, Sibgatullina FG (1991) Russ Chem Bull **49**: 2470
[12] Novikova AP, Perova NM, Egorova LG, Bragina EI (1991) Chem Heterocyclic Compd **27**: 666
[13] Mamedov VA, Berdnikov EA, Valeeva VN, Ismaev IE, Rizvanov ICh, Antokhina LA, Nuretdinov IA, Chernov PP (1993) Russ Chem Bull **42**: 1879
[14] Mohareb RM, Ho JZ, Mohamed AA (2007) Phosphorus Sulfur Silicon **182**: 1661
[15] Basyouni WM, El-Bayouki KA (2005) J Chem Res **7**: 356
[16] Mohareb RM, Sherif SM (1997) Heteroatom Chem **8**: 77
[17] Jia G, Li Z (1997) Heteroatom Chem **8**: 71
[18] Bondock S, Khalifa W, Fadda AA (2007) Eur J Med Chem **42**: 948
[19] Abdel-Latif E, Bondock S (2006) Heteroatom Chem **17**: 299
[20] Bondock S, Tarhoni AE, Fadda AA (2007) Phosphorus Sulfur Silicon **182**: 1915
[21] Laurent DR, Gao Q, Wu D, Serrano-Wu MH (2004) Tetrahedron Lett **45**: 1907
[22] Katritzky AR, Pastor A, Voronkov M, Steel PJ (2000) Org Lett **2**: 429
[23] Katritzky AR, Qi M, Feng D, Zhang G, Griffith MC, Watson K (1999) Org Lett **1**: 1189
[24] Park JS, Yu KA, Kang TH, Kim S, Suh YG (2007) Bioorg Med Chem Lett **17**: 3486
[25] Al-Soud YA, Al-Dweri MA, Al-Masoudi NA (2004) IL Farmaco **59**: 775
[26] Shaker RM, Abdel-Latif FF (1997) J Chem Res (S) 294
[27] Mathew V, Keshavayya J, Vaidya VP, Giles D (2007) Eur J Med Chem **42**: 823
[28] Mekheimer RA, Shaker RM (1999) J Chem Res (S) 76
[29] Elmoghayar MRH, Abdalla SO, Nasr MYA (1984) J Heterocyclic Chem **21**: 781