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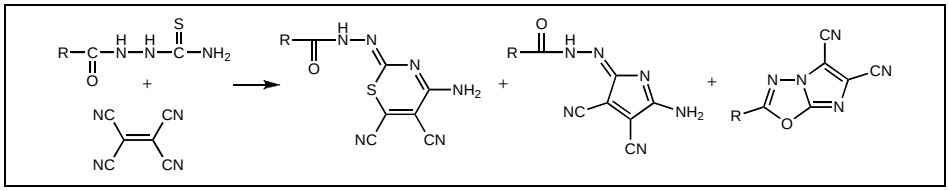

1-Acylthiosemicarbazides **9a**-**d** reacted with ethenetetracarbonitrile (TCNE, **2**) in ethyl acetate with formation of *N*'-(4-amino-5,6-dicyano-2*H*-1,3-thiazin-2-ylidene) substituted hydrazide **10a**-**d**, *N*'-(5-amino-3,4-dicyano-2*H*-pyrrol-2-ylidene)-2-substituted hydrazide **11a**-**d** and 2-substituted imidazo[2,1-*b*][1,3,4]-oxadiazole-5,6-dicarbonitrile **12a**-**d**. Rationales for the conversions observed are presented.

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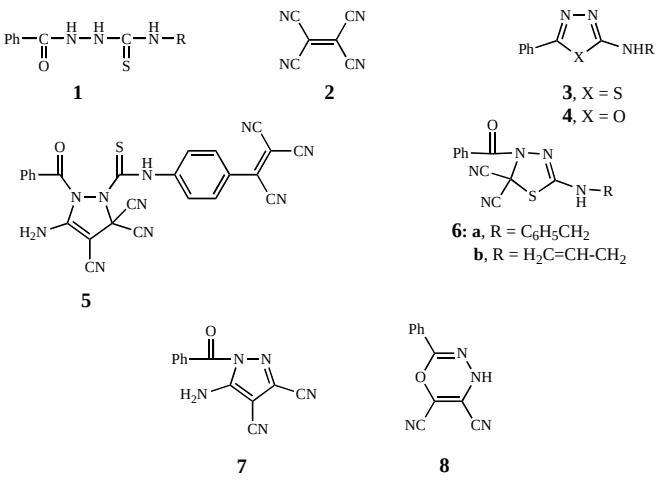
INTRODUCTION

Cyclization of 1-acylthiosemicarbazides may be achieved under various conditions [1-5]. For example, 1-acylthiosemicarbazides were cyclodehydrated with concentrated sulphuric acid [1,2] or methanesulfonic acid [3] to 2-amino-5-aryl-1,3,4-thiadiazols. 3-Mercapto-5-aryl-*s*-triazoles have been obtained by cyclization of 1-aroylthiosemicarbazides under alkaline conditions [4], while their condensation with 2-chlorocyclohexanone furnished 2-aroylhydrazino-4,5,6,7-tetrahydrobenzo-thiazoles [5]. On the other hand, C-triazole-5-oyl-*N*-phenylhydrazonoylbromide reacted with benzoylthio-semicarbazide to give 5-phenylthiazole derivatives [6,7]. Acetylthiosemicarbazide when condensed with 6,8-disubstituted-3-acetyl-coumarins in presence of bromine or using lanthanum catalyst, yielded 2-acetylhydrazino-4-coumarinylthiazole [8]. The reaction of 1-chloro-1,4-diphenyl-2,3-diazabutadiene with acetyl- and with 1-benzoylthiosemicarbazide yielded initially the hydrochlorides of N^2-acetyl- and N^2-benzoyl-Δ^2-1,3,4-thiadiazoline-4-carboxamide hydra-zones, which were converted by NaOH into the corresponding free bases 4-substituted-Δ^2-1,3,4-thiadiazolines [9]. In the medicinal chemistry, acylthiosemicarbazides have been studied for their potential as therapeutic agents for the treatment of hypertension and CNS depression [10] as well as mitochondrial monoamine oxidase inhibitory (MAOI) activity [11,12].

On the other hand, the interaction of thiosemicarbazide derivatives with ethenetetracarbonitrile (TCNE, **2**) afforded various heterocyclic compounds *via* a single electron transfer mechanism [13-18].

Recently, we have demonstrated that when 1,4-disubstituted thiosemicarbazides **1** are reacted with **2**, 2-substituted-5-phenyl-1,3,4-thiadiazoles **3** and 2-substituted-5-phenyl-1,3,4-oxadiazoles **4** in addition to compounds **5-8** (Chart 1) [17] are formed.

Chart 1



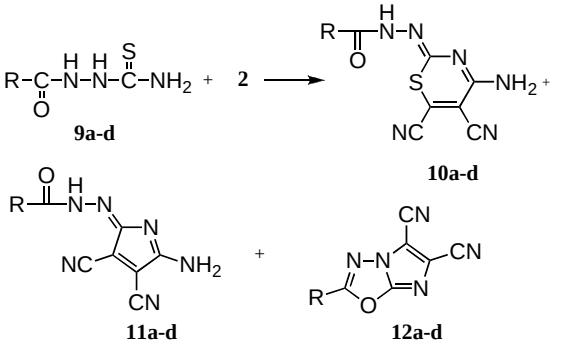
1,3,4: a: R = C_6H_5CO; **b:** R = C_6H_5; **c:** R = $C_6H_5CH_2$; **d:** R = CH_2=$CHCH_2$; **e:** R = EtOOC

As will be outlined in detail below, in this paper we report several heterocyclization of 1-acylthiosemicarba-zide **9a**-**d** using ethenetetracarbonitrile as a reaction mediator and as a building block.

RESULTS AND DISCUSSION

Treatment of **9a**-**d** with two molar equivalents of **2** in ethyl acetate as solvent at room temperature resulted in a brown colouration of the solution that quickly turned into red, and formation of reddish brown precipitate of thiazinylidenebenzoylhydrazide derivatives **10a**-**d** (48-52 %) (Scheme 1). The filtrates were concentrated to dryness and the residue subjected to vacuum sublimation to remove any unreacted **2**. Chromatographic separation of the residue gave numerous zones, from which products **11**

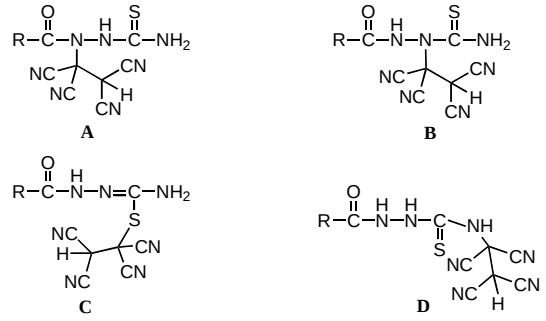
Scheme 1



9-12: **a:** R = CH_3; **b:** R = C_6H_5; **c:** R = 4-HO-C_6H_4; **d:** R = 4-Br-C_6H_4-CH_2

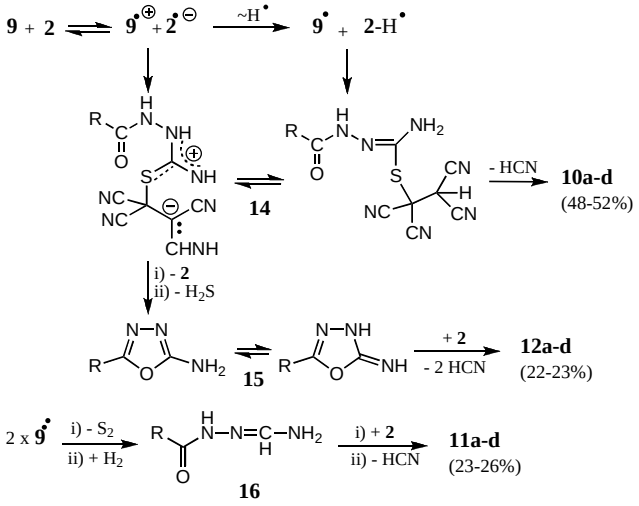
and **12** could be isolated (Scheme 1). In these cases, **2** is "built in" completely or partially into the new structures. The addition of the nucleophilic sites (N-H bonds or S-H) of the starting materials **9a-d** across the C=C double bond of **2** may generate the four primary adducts (**A**, **B**, **C**, **D**) producing from the sites N^1, N^2, SH and NH_2 (Chart 2) and tautomers that are capable of releasing HCN (which effects a net tricyanovinylation) [19,20]. On the other hand, [$\pi^4 + \pi^2$] cycloadditions of **2** with dehydrogenated **9a-d** are not suggested to occur based on the nature of the products formed. Thus, the structures of products **10-12** need to be derived from one suitable precursor out of the previously suggested sites (Scheme 2). Structural assignments of the products **10-12** are based on spectral data and on combustion analyses.

Chart 2



Compounds 10a-c. The molecular ions in their EI-mass spectra confirm the molecular masses and gross compositions. Further, the following common features of the fragmentation patterns lead to support to the assigned structures: loss of N_2 giving intense (M^+- 28) ions and loss of R-C=O giving rise to the ion m/z = 191 common in the spectra of all four compounds. The ir spectra show characteristic absorptions for the NH_2 and NH groups in the range of 3420-3160, and 2220-2225 cm^{-1} for conjugated CN groups, and bonds characteristic to an

Scheme 2

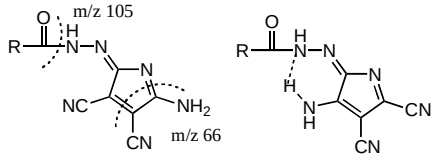


amide CO groups in the range 1695-1685 cm^{-1}. The ^1H nmr spectra show the presence of NH_2 groups as broad signals for 2H between δ = 7.24-7.28 ppm, NH of amide group as a broad signals for 1H between δ = 10.81-10.88 ppm and for additionally **10a**, the expected signals for the acetyl group (δ = 2.37 ppm). The ^{13}C nmr spectra of **10a** showed signals around 118.71-118.93 (CN), 164.18 (C-4), 155.32 (C-2), 121.22 and 121.74 (C-5 and C-6), 173.82 (C=O) and 26.42 (CH_3).

Compounds 11a-d. *N*'-(5-Amino-3,4-dicyano-2*H*-pyrrol-2-ylidene)-4-substituted benzohydrazide **11a-c** were obtained as characteristically orange crystals. Their molecular structure are supported by the following findings: for example **11b**; the gross formula $C_{13}H_8N_6O$ represents a products from one molecule of **9b** and one of **2** with loss of sulphur and one molecule of HCN and formation the pyrrole ring. The presence of an amide group ($\delta_{C=O}$ = 173.56 ppm) and the absence of both thioamide function and or sulphur in **11b** rules out any oxa- or thiacyclic structures. Both a NH_2 (δ_H = 7.38 ppm) and a low field NH group (δ_H = 10.89 ppm) are present. The mass spectrum shows the molecular ion at 264 and fragments at m/z 105 (representing the benzoyl group residue) and 131 (representing 5-amino-3,4-dicyano-pyrrolylidenyl residue) from the cleavage of C_2-N and CO-NH bonds. The amide carbonyl stretch wavenumber (1690 cm^{-1}) points to some degree of electron withdrawal from N_2. The presence of two cyano groups in the spectrum which show characteristic absorption at 2225 cm^{-1} and signals around 118.3 (CN), 155.69 (C-2) and 164.29 ppm (C-5) in the ^{13}C nmr spectra lend further support to the structure assigned **11b**. Structure **11** was accessible only from precursor (**C**) (Chart 2) after elimination of sulphur but not from **A**, **B** and **D**.

While (**C**) would lead to **11** *via* **16**, the isomeric structure **11'** would be accessible from **D** after elimination

of sulphur. The mass spectral fragmentation of the product (see Fig. 1), however, is well in agreement with structure **11** but not with structure **11'**. Furthermore, the ir spectrum of **11b** in dilute CCl_4 did not show the presence of intermolecular H bridge as in structure **11'** (Figure 1).



11b, R = Ph **11`**

Figure 1

Compounds 12a-d. Compounds **12a-d** do not contain sulphur but contain five nitrogen atoms, thus for example the molecular mass of **12d** represents a gross composition $C_{13}H_6BrN_5O$ reached from **9d** and **2** after loss H_2S and two HCN. 2-(4-Bromobenzyl)imidazo[2,1-*b*][1,3,4]-oxadiazole-5,6-dicarbonitrile was obtained.

The mass spectrum exhibited a molecular ion at m/z 327/329 (28 %). The ir spectrum showed strong band at 2210 cm^{-1} due to the cyano groups, 2980 (ali-CH) and several peaks at 1640, 1600 cm^{-1} (C=N and aryl C=C). The characteristic absorption of C-O-C fragment at 1090 cm^{-1} [21]. The 300 MHz ^{1}H nmr (in DMSO-d_6) displayed broadened signal at 4.28 (Ph-CH_2) in addition to aromatic protons. The presence of CH_2Ph is also evident from the ^{13}C-DEPT-nmr spectrum exihibiting negative signals at δ = 52.90 ppm. The decoupled carbon spectrum of **12d** showed another signals at 164.33 and 122.78 ppm assigned to (C-2 and C-5,6) respectively.

CONCLUSION

The reactions and the heterocyclic products here provide insight into the spontaneous reactions between the electron donating 1-acylthiosemicarbazides **9a-d** and a suitable electron acceptor **2**. The reaction proceeds through a fairly complex multistep process where two kinds of ring forming reactions are observed. Thus, ethenetetracarbonitrile (**2**) may act as a mediator and as a building block in heterocyclization of thiosemicarbazides. The results reported here supplement the rich chemistry of ethenetetracarbonitrile (**2**).

EXPERIMENTAL

Melting points (uncorrected) were determined in open glass capillaries on a Gallenkamp melting point apparatus. The ir spectra were recorded from potassium bromide disks with a Shimadzu 408 instrument. The 300 MHz ^{1}H and 75 MHz ^{13}C nmr spectra were recorded on Bruker WM 300 instrument, Chemical shifts are expressed as δ (ppm) with tetramethylsilane as internal reference, s = singlet, m = multiplet; ^{13}C assignments have been made with the aid of DEPT 135/90 spectra. The mass spectra [70 eV, electron impact mode] were obtained on an AMD 604 instrument. Elemental analyses were carried out at the Microanalytical Centre, Cairo University, Egypt. Preparative layer chromatography was performed on air dried 1.0 mm thick layers of slurry applied silica gel Merck PF254 on 48 cm wide and 20 cm high glass plates. Zones were detected by their colour or by quenching of indicator fluorescence upon exposure to 254 nm light.

Starting Materials.

Synthesis of 1-(4-bromophenylaceto)thiosemicarbazide (9d). To a stirred solution of thiosemicarbazide (0.91 g, 10 mmol) in 50 ml dry acetone, *p*-bromophenylacetic acid (2.15 g, 10 mmol) was added and the mixture was refluxed for 3 h. A white precipitate was formed, recrystallized from ethanol to give colourless crystals (2.84 g, 85 %), m.p = 93-95 °C

1-Acetylthiosemicarbazide 9a; m.p = 165-167 °C (lit. [22-24] 166 °C).

1-Benzoylthiosemicarbazide 9b; m.p = 195-197 °C (lit. [23-28] 196-199 °C).

1-(4-Hydroxyphenyl)thiosemicarbazide 9c; m.p = 212-214 °C (lit. [29] 214-216 °C).

Reaction of 1-acylthiosemicarbazides 9a-d with 2. A solution of **9a-d** (1 mmol) in 25 ml of dry ethyl acetate was added dropwise with stirring at room temperature to **2** (2.0 mmol) in ethyl acetate (10 ml). The reaction mixture colour changed gradually from brown to red, and the mixture was left standing for 48 h. at room temperature, during which time a crystalline reddish brown product separated. The resulting solid material was filtered and the precipitate was washed with ethanol, dried and recrystallized from sutiable solvent to give *N*'-(4-amino-5,6-dicyano-2*H*-1,3-thiazin-2-ylidene) substituted hydrazide **11a-d**. The filtrate was concentrated to dryness and the residue was sublimed at 80 °C under vacuum to remove unreacted **2**, then subjected to PLC (100 mg per plate) using cyclohexane/ethyl acetate (1:1) as eluent to give numerous coloured zones, the two intense of which were removed and extracted. The fastest migrating zone (R_f = 0.56, orange) contained *N*'-(5-amino-3,4-dicyano-2*H*-pyrrol-2-ylidene) substituted hydrazide **10a-d**, while the slowest moving zone (R_f = 0.32, brown) contained 2-(substituted)imidazo[2,1-*b*][1,3,4]-oxadiazole-5,6-dicarbonitrile **12a-d**. Extraction of the zones with acetone and concentration gave residues, which were rechromatographed to improve purification.

***N*'-(4-Amino-5,6-dicyano-2*H*-1,3-thiazine-2-ylidene)aceto-hydrazide (10a).** This compound had mp 198-200°, red crystals from acetonitrile, yield 115 mg (49 %); ir: 3390, 3220 (NH_2, NH), 2225 (CN), 1690 (CO) and 1635 (C=N) cm^{-1}; ^{1}H nmr (DMSO-d_6): δ 2.37 (s, 3H, CH_3), 7.28 (br, 2H, NH_2), 10.81 (br, 1H, NH); ^{13}C nmr (DMSO-d_6): δ 26.42 (CH_3), 118.71, 118.93 (CN), 121.22, 121.74 (C-5 and C-6), 155.32 (C-2), 164.18 (C-4) and 173.82 (CO); EI-MS m/z: % 234 (M^+, 11), 206 ($M-N_2]^+$, 33), 191 ($[M-CH_3CO]^+$, 68), 137 (29), 121 (18), 93 (100). *Anal.* Calcd. for $C_8H_6N_6OS$ (234.24): C, 41.02; H, 2.58; N, 35.88; S, 13.69. Found: C, 41.19; H, 2.46; N, 36.02; S, 13.57

***N*'-(4-Amino-5,6-dicyano-2*H*-1,3-thiazine-2-ylidene)benzo-hydrazide (10b).** This compound had mp 262-264°, reddish brown crystals from methanol, yield 137 mg (51 %); ir: 3420, 3160 (NH_2, NH), 2220 (CN), 1695 (CO) and 1640 (C=N) and 1600 (aryl) cm^{-1}; ^{1}H nmr (DMSO-d_6): δ 7.24 (br, 2H, NH_2), 7.44-7.95 (m, 5H, phenyl-H), 10.88 (br, 1H, NH); ^{13}C nmr (DMSO-d_6): δ 118.52, 118.81 (CN), 121.14, 121.66 (C-5 and C-

6), 127.84, 128.96, 132.82 (phenyl-CH), 142.56 (phenyl-C-1), 155.76 (C-2), 163.94 (C-4) and 173.96 (CO); EI-MS m/z: % 269 (M^+, 26), 268 ($M-N_2]^+$, 24), 191 ([M-PhCO]$^+$, 56), 175 (12), 149 (29), 105 (76), 77 (100). *Anal.* Calcd. for $C_{13}H_8N_6OS$ (296.31): C, 52.70; H, 2.72; N, 28.36; S, 10.82. Found: C, 52.56; H, 2.83; N, 28.41; S, 10.63.

***N*'-(4-Amino-5,6-dicyano-2*H*-1,3-thiazine-2-ylidene)-4-hydroxybenzohydrazide (10c).** This compound had mp 310-312°, reddish brown crystals from methanol, yield 162 mg (52 %); ir: 3400-3190 (OH, NH_2 and NH), 2225 (CN), 1685 (CO), 1635 (C=N) and 1610 (aryl) cm^{-1}; ^{1}H nmr (DMSO-d_6): δ 6.90-7.10 (dd, 2H, phenyl-H), 7.28 (br, 2H, NH_2), 7.88-7.92 (m, 2H, phenyl-H), 9.12 (br, 1H, OH), 10.84 (br, 1H, NH); ^{13}C nmr (DMSO-d_6): δ 118.41, 118.76 (CN), 121.42, 121.63 (C-5 and C-6), 126.24, 128.93 (phenyl-CH), 136.82 (phenyl-C-1), 151.81 (phenyl-C-4), 164.12 (C-4), 172.88 (CO); EI-MS m/z: % 312 (M^+, 22), 284 ($M-N_2]^+$, 26), 191 ([M-4-HO-C_6H_4CO]$^+$, 56), 121 (74), 93 (100), 77 (46), 77 (100). *Anal.* Calcd. for $C_{13}H_8N_6O_2S$ (312.31): C, 50.00; H, 2.58; N, 26.91; S, 10.27. Found: C, 49.84; H, 2.42; N, 27.11; S, 10.09.

***N*'-(4-Amino-5,6-dicyano-2*H*-1,3-thiazine-2-ylidene)-2-(4-bromophenyl)acetohydrazide (10d).** This compound had mp 285-287°, deep red crystals from acetonitrile, yield 187 mg (48 %); ir: 3410-3215 (NH_2 and NH), 2220 (CN), 1690 (CO), 1635 (C=N) and 1610 (aryl) cm^{-1}; ^{1}H nmr (DMSO-d_6): δ 4.26 (s, 2H, CH_2), 6.95-7.12 (m, 2H, phenyl-H), 7.26 (br, 2H, NH_2), 7.68-7.73 (m, 2H, phenyl-H), 10.82 (br, 1H, NH); ^{13}C nmr (DMSO-d_6): δ 52.88 (CH_2), 118.36, 118.62 (CN), 121.32, 121.61 (C-5 and C-6), 131.94, 131.96, 132.12 (phenyl-CH), 134.76 (phenyl-C-1), 135.12 (phenyl-C-4), 155.18 (C-2), 164.36 (C-4), 173.12 (CO); EI-MS m/z: % 391 (15), 389 (M^+, 13), 360 ($M-N_2]^+$, 18), 191 ([M-(4-Br-$C_6H_4CH_2$CO)]$^+$, 61), 137 (12), 91 (100), 77 (56). *Anal.* Calcd. For $C_{14}H_9BrN_6OS$ (389.23): C, 43.20; H, 2.33; Br, 20.53; N, 21.59; S, 8.24. Found: C, 43.36; H, 2.19; Br, 20.68; N, 21.41; S, 8.39.

***N*'-(5-Amino-3,4-dicyano-2*H*-pyrrol-2-ylidene)acetohydrazide (11a).** This compound had mp 158-160°, orange crystals from ethanol, yield 51 mg (25 %); ir: 3360, 3210 (NH_2, NH), 2210 (CN), 1685 (CO) and 1625 (C=N) cm^{-1}; ^{1}H nmr (DMSO-d_6): δ 2.34 (s, 3H, CH_3), 7.41 (br, 2H, NH_2), 10.76 (br, 1H, NH); ^{13}C nmr (DMSO-d_6): δ 26.35 (CH_3), 118.82, 119.31 (CN), 127.12 (C-4), 128.26 (C-3), 155.64 (C-2), 164.31 (C-5) and 173.44 (CO); EI-MS m/z: % 202 (M^+, 11), 174 (24), 131 (19), 66 (28), 43 (100). *Anal.* Calcd. for $C_8H_6N_6O$ (202.17): C, 47.53; H, 2.99; N, 41.57. Found: C, 47.68; H, 3.12; N, 41.41.

***N*'-(5-Amino-3,4-dicyano-2*H*-pyrrol-2-ylidene)benzohydrazide (11b).** This compound had mp 212-214 °, yellowish brown crystals from acetonitrile, yield 69 mg (26 %); ir: 3370, 3225 (NH_2, NH), 2215 (CN), 1690 (CO) and 1630 (C=N), 1600 (aryl) cm^{-1}; ^{1}H nmr (DMSO-d_6): δ 7.38 (br, 2H, NH_2), 7.44-7.95 (m, 5H, phenyl-H), 10.89 (br, 1H, NH); ^{13}C nmr (DMSO-d_6): δ 118.42, 118.86 (CN), 127.16 (C-4), 128.52 (C-3), 128.93, 129.26, 131.21 (phenyl-CH), 136.28 (phenyl C-1), 155.69 (C-2), 164.29 (C-5) and 173.56 (CO); EI-MS m/z: % 264 (M^+, 32), 236 ($M-N_2]^+$, 13), 159 ([M-PHCO]$^+$, 18), 105 (100), 66 (22), 42 (52). *Anal.* Calcd. for $C_{13}H_8N_6O$ (264.24): C, 59.09; H, 3.05; N, 31.80. Found: C, 58.94; H, 3.21; N, 31.61.

***N*'-(5-Amino-3,4-dicyano-2*H*-pyrrol-2-ylidene)-4-hydroxybenzohydrazide (11c).** This compound had mp 190-192°, yellowish brown crystals from acetonitrile, yield 67 mg (24 %); ir: 3395-3230 (OH, NH_2 and NH), 2220 (CN), 1685 (CO), 1630 (C=N), 1610 (aryl) cm^{-1}; ^{1}H nmr (DMSO-d_6): δ 6.93 (dd, 2H, aryl-H), 7.41 (br, 2H, NH_2), 7.78-7.84 (m, 2H, aryl-H), 9.19 (br, 1H, OH), 10.84 (br, 1H, NH); ^{13}C nmr (DMSO-d_6): δ 118.62, 118.93 (CN), 127.56 (C-4), 128.72 (C-3), 128.92, 130.12 (phenyl-CH), 136.84 (phenyl C-1), 152.34 (phenyl-C-4), 156.12 (C-2), 164.62 (C-5) and 173.67 (CO); EI-MS m/z %: 280 (M^+, 17), 252 (11), 159 (36), 121 (33), 93 (100), 77 (76), 66 (23). *Anal.* Calcd. for $C_{13}H_8N_6O_2$ (280.24): C, 55.72; H, 2.88; N, 29.99. Found: C, 55.86; H, 2.69; N, 30.14.

***N*'-(5-Amino-3,4-dicyano-2*H*-pyrrol-2-ylidene)-2-(4-bromophenyl)acetohydrazide (11d).** This compound had mp 133-35°, orange crystals from ethanol, yield 82 mg (23 %); ir: 3386, 3260 (NH_2 and NH), 2215 (CN), 1690 (CO), 1630, 1620 (C=N), 1600 (aryl) cm^{-1}; ^{1}H nmr (DMSO-d_6): δ 4.23 (s, 2H, CH_2), 6.95-7.11 (m, 2H, phenyl-H), 7.39 (br, 2H, NH_2), 7.70-7.74 (m, 2H, aryl-H), 10.86 (br, 1H, NH); ^{13}C nmr (DMSO-d_6): δ 52.84 (CH_2), 118.66, 118.93 (CN), 127.77, 128.18 (C-3, C-4), 131.92, 132.22 (phenyl-CH), 135.71 (phenyl-C-1), 136.12 (phenyl-C-4), 155.88 (C-2), 164.44 (C-5) and 173.61 (CO); EI-MS m/z: % 358 (M^+, 32), 356 (29), 330 (11), 278 (26), 198 (44), 160 (27), 91 (74), 77 (100), 66 (36). *Anal.* Calcd. for $C_{14}H_9BrN_6O$ (357.16): C, 47.08; H, 2.54; Br, 22.37; N, 23.53. Found: C, 46.88; H, 2.37; Br, 22.53; N, 23.69.

2-Methylimidazo[2,1-*b*][1,3,4]oxadiazole-5,6-dicarbonitrile (12a). This compound had m.p = 225-227°, brown crystals from acetonitrile, yield 40 mg (23 %); ir: 2985 (ali, CH), 2210 (CN), 1640 (C=N), 1085 (C-O-C) cm^{-1}; ^{1}H nmr (DMSO-d_6): δ 2.16 (s, 3H, CH_3); ^{13}C nmr (DMSO-d_6): δ 24.62 (CH_3), 117.97 (CN), 127.77, 123.63 (C-5 and C-6), 156.12 (C-7'), 164.12 (C-2); EI-MS m/z: % 173 (M^+, 22), 158 (19), 97 (100), 69 (63). *Anal.* Calcd. for $C_7H_3N_5O$ (173.13): C, 48.56; H, 1.75; N, 40.45. Found: C, 48.71; H, 1.90; N, 40.26.

2-Phenylimidazo[2,1-*b*][1,3,4]oxadiazole-5,6-dicarbonitrile (12b). This compound had mp 241-243°, brown crystals from methanol, yield 54 mg (23 %); ir: 3090 (aryl-CH), 2215 (CN), 1635 (C=N), 1610 (aryl), 1090 (C-O-C) cm^{-1}; ^{1}H nmr (DMSO-d_6): δ 7.34-7.68 (m, 5H, phenyl-CH); ^{13}C nmr (DMSO-d_6): δ 118.12 (CN), 123.56 (C-5 and C-6), 128.96, 129.93, 131.14 (phenyl-CH), 136.12 (phenyl-C-1), 156.26 (C-7'), 164.34 (C-2); EI-MS m/z: % 235 (M^+, 32), 159 (28), 131 (12), 77 (100). *Anal.* Calcd. for $C_{12}H_5N_5O$ (235.20): C, 61.28; H, 2.14; N, 29.78. Found: C, 61.39; H, 1.93; N, 29.57.

2-(4-Hydroxyphenyl)imidazo[2,1-*b*][1,3,4]oxadiazole-5,6-dicarbonitrile (12c). This compound had mp 222-223°, brown crystals from acetonitrile, yield 55 mg (22 %); ir: 3490 (OH), 2215 (CN), 1640 (C=N), 1610 (aryl), 1085 (C-O-C) cm^{-1}; ^{1}H nmr (DMSO-d_6): δ 6.88-7.48 (m, 4H, phenyl-CH), 9.18 (br, 1H, OH); ^{13}C nmr (DMSO-d_6): δ 118.64 (CN), 122.65 (C-5 and C-6), 128.65, 130.64 (phenyl-CH), 135.42 (phenyl-C-1), 151.68 (phenyl-C-4), 156.22 (C-7'), 164.36 (C-2); EI-MS m/z: % 251 (M^+, 36), 175 (18), 147 (12), 93 (100), 77 (66). *Anal.* Calcd. for $C_{12}H_5N_5O_2$ (251.20): C, 57.38; H, 2.01; N, 27.88. Found: C, 57.56; H, 2.16; N, 27.67.

2-(4-Bromobenzoyl)imidazo[2,1-*b*][1,3,4]oxadiazole-5,6-dicarbonitrile (12d). This compound had mp 266-268 °C, pale brown crystals from methanol, yield 75 mg (23 %); ir: 2980 (ali-CH), 2210 (CN), 1640 (C=N), 1600 (aryl), 1090 (C-O-C) cm^{-1}; ^{1}H nmr (DMSO-d_6): δ 4.28 (s, 2H, CH_2), 6.95-7.47 (m, 4H, phenyl-H); ^{13}C nmr (DMSO-d_6): δ 52.90 (CH_2), 118.66 (CN), 122.78 (C-5 and C-6), 131.32, 131.67 (phenyl-CH), 136.14 (phenyl-C-4), 139.15 (phenyl-C-1), 156.12 (C-7'), 164.33 (C-2); EI-MS m/z: % 329 (M^+, 28), 327 (25), 251 (36), 175 (23), 147

(13), 91 (67), 77 (100). *Anal.* Calcd. for $C_{13}H_6BrN_5O$ (328.12): C, 47.59; H, 1.84; Br, 24.35; N, 21.34. Found: C, 47.73; H, 1.65; Br, 24.14; N, 21.51.

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