Synthesis of thiadiazine, imidazothiadiazole, diazospiroundecatetraene and spirothiadiazolopyrimidinocyclohexadiene derivatives from 2,5-dithiobiureas

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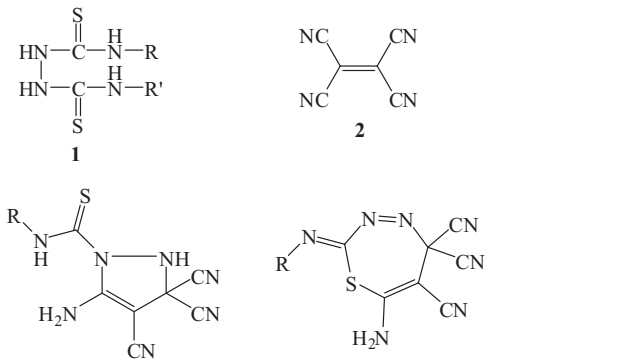
Ethenetetracarbonitrile (**2**, in tetrahydrofuran solution), diethyl (*E*)-2,3-dicyanobutenedioate (**10**, in tetrahydrofuran solution), and 7,7',8,8'-tetracyanoquinodimethane (**16**, in pyridine solution) act on 1-substituted-2,5-dithiobiureas **1a–c**, forming the derivatives of imidazothiadiazole **5a–c**, thiadiazine **11a–c** and **12a–c**, spiro(thiadiazolopyrimidinocyclohexadiene)malononitrile **17a–c** and diazospiroundecatetraene **18a–c**. Rationales for these conversions involving the nucleophilic addition on diycanomethylene carbon atom are presented.

Keywords: ethenetetracarbonitrile**,** diethyl (*E*)-2,3-dicyanobutenedioate and tetracyanoquinodimethane, heterocyclisation of substituted 2,5-dithiobiureas

Ethenetetracarbonitrile (tetracyanoethylene, **2**) is the simplest of percyanoalkenes (cyanocarbons).[1] It shows a great affinity for electrons, and is thus a fairly good dehydrogenating agent towards dihydroheteroaromatic systems.[1] The general chemistry of **2** had been reviewed with emphasis on molecular complexes by an intermolecular charge-transfer interaction,[1-4] tricyanovinylation reactions,[1] additions[1] and cycloaddition reactions[5] as well as cyanation reagents.[6-8] Ethenetetracarbonitrile (**2**) reacted with thiosemicarbazides to give a variety of heterocyclic compounds *via* a single-electron transfer mechanism.[9-16]

Diethyl (*E*)-2,3-dicyanobutenedioate have been discovered to be a viable and versatile alternatives to tetracyanoethylene as building blocks for the synthesis of molecule-based magnets.[17] The reaction of diethyl (*E*)-2,3-dicyanobutenedioate (**10**) with ethylenediamine, *trans*-1,2-diaminocyclohexane afforded piprazinone and quinoxalinone derivatives, respectively.[18] Also, diethyl (*E*)-2,3-dicyanobutenedioate reacted with *o*-phenylenediamine and 2,3-diaminonaphthalene with the formation of quinoxaline and quinoxalinone derivatives.[19] Aminopteridine derivatives and related compounds have been prepared during the reaction of compound **10** with uracil and thiouracil derivatives.[20]

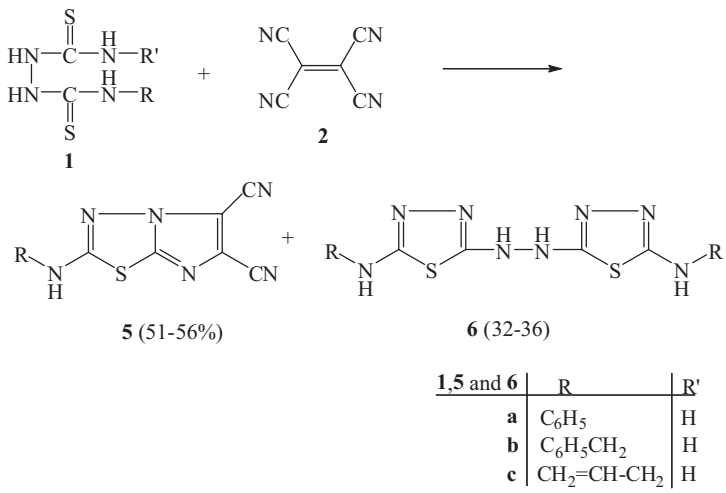
Recently, we have demonstrated that 1,6-disubstituted-2,5-dithiobiureas **1** reacted with **2** to give products **3** and **4**, in addition to disubstituted-1,3,4-thiadiazoles (Fig. 1).[13]



1,**3** and **4**	R	R'
a	C_6H_5	C_6H_5
b	$C_6H_5CH_2$	$C_6H_5CH_2$
c	CH_2=CH-CH_2	CH_2=CH-CH_2

Fig. 1

As well be outlined in detail below, in this paper we reported several heterocyclisation of 1-substituted-2,5-dithiobiureas **1a–c** using ethenetetracarbonitrile (**2**) either as a reaction mediator or as a building block, diethyl (*E*)-2,3-dicyanobutenedioate (**10**) and 7,7',8,8'-tetracyanoquinodimethane (**16**) as π-acceptors.



1,**5** and **6**	R	R'
a	C_6H_5	H
b	$C_6H_5CH_2$	H
c	CH_2=CH-CH_2	H

Scheme 1

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Results and discussion

Addition of doubled molar amounts of **2** to solutions of **1a–c** in tetrahydrofuran (THF) with admission of air resulted in a pink colouration of the solution which quickly turned into brown. This behaviour may be explained as due to initial formation of unstable charge-transfer (CT) complexes followed by chemical reaction. Monitoring of the reaction by visible spectroscopy failed since the reaction is fast and also at lower concentration no significant colour changes were observed. After concentration of the reaction mixture, the residue was subjected to vacuum sublimation to remove any unreacted TCNE. Chromatographic separations of the residue gave numerous coloured zones. From the two most intense zones, products **5a–c** and **6a–c** could be isolated (Scheme 1).

The structures of **5a–c** are supported by characteristic IR, ^{1}H and ^{13}C NMR as well as mass spectral data by the following findings: The gross formula of **5a**, $C_{12}H_6N_6S$ represents a product from one molecule of **1a** and one molecule of **2** with loss of (H_2S + 2HCN). The IR spectrum of **5a** shows absorption characteristic of NH, CN and C=N groups at 3380, 2215 and 1635 cm^{-1}, respectively. The low-field NH attached to phenyl group is present at δ_H = 9.76 ppm. In its ^{13}C NMR spectrum, C-2, C-5, C-6 and C-4a resonate at δ_C = 156.88, 122.24, 122.26 and 154.53 ppm, respectively. Further peaks at 118.11 and 118.14 ppm (CN), besides the aromatic carbons support the assigned structure.

The formations of **9** did not take place in the absence of **2** hence its presence is definitely required for the cyclisation observed. Charge-transfer complexes may (but not necessarily) play an intermediate role. Since the cyclisation involves intramolecular nucleophilic attacks on either of the thiocarbonyl groups. It is conceivable that **2** accelerates the process through intermediates **7** and **8** (Scheme 2), activating the respective C=S bonds toward nucleophilic addition. After cyclisation and formation of intermediates **9**, **2** is released with liberation of H_2S.

Two routes could be suggested, the first one is the tendency of **2** to effect tetracyanoethylation the intermediate **9** followed by the elimination two molecules of HCN and formation the imidazothiadiazole derivatives **5a–c**. The second route is the formation of the intermediate **9**$^{\bullet}$ to give the product **6a–c** (Scheme 2). Thus, ethenetetracarbonitrile (**2**) may act either as a mediator or as a building block in heterocyclisation of compounds **1a–c**.

The ^{1}H NMR spectrum of **6b** showed two broad signals with the ratio 1:1 centred at 6.57 and 8.87 ppm, due to hydrazine-NH and phenyl-NH protons. The signal around 4.61 in ^{1}H NMR and 52.58 ppm in ^{13}C NMR spectra due to benzylic-CH_2 further supports the structure assigned to **6b**. The ^{13}C-DEPT NMR spectrum exhibiting negative signal at δ = 52.58 ppm. The decoupled carbon spectrum of **6b** showed signals at δ = 155.48 and 154.21 ppm due to thiazole-C-2 and C-5, respectively, besides the aromatic carbons. The IR spectrum of **6b** showed absorption bands at 3385–3360, 1625 and 1600 due to NH, C=N and (ArC=C) groups.

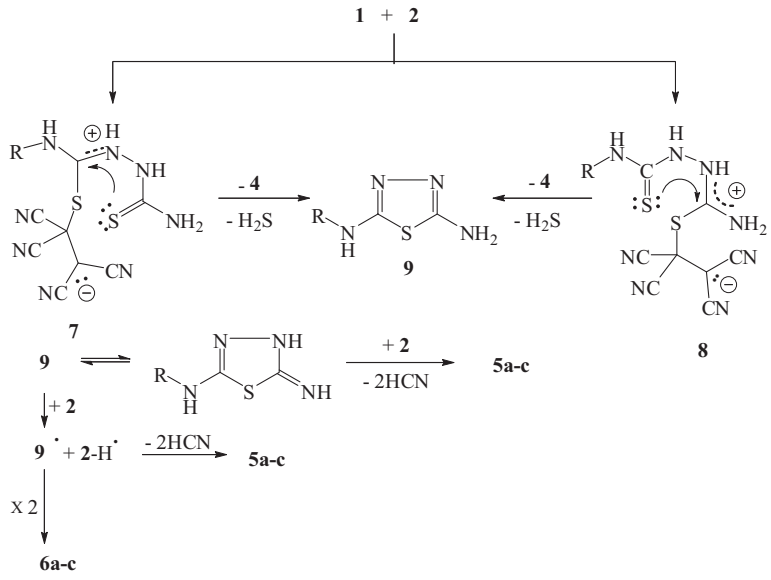
The molecular ions of **6a–c** in their EI-mass spectra confirm the molecular masses and the gross compositions. Furthermore, the following common features of the fragmentation patterns support the assigned structure: Loss of N_2 giving intense (M^+-28) ions and loss of RNCS giving rise to the ion *m/z* = 261 common in the spectra of all three compounds. The odd electron fragments represented the three isothiocyanates indicating that the charge during fragmentation may remain with the isothiocyanate fragments.

We now report a convenient method for one-step synthesis of thiadiazine **11a–c** and **12a–c** derivatives. This method consists of the reaction of **1a–c** with **10** (in a 1:2 molar ratio). The weaker acceptor **10**, was expected to react similarly to **2** with the donors **1a–c**. The reaction was carried out in THF at room temperature and nearly two days were required to achieve conversion of 96% for **1a–c** and medium yields of **11** and **12** were observed (Scheme 3).

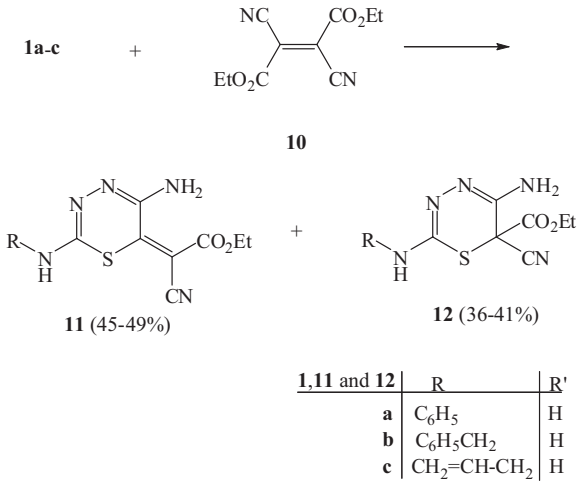
Recombination of **1a–c**$^{\bullet}$ ion radical under abstraction of two hydrogen protons by **10**$^{\bullet}$ to give the dimer **A** along with **10**-H$^{\bullet}$. Elimination of a molecule of S_2 from the dimer **A** afforded the radical **13**$^{\bullet}$. Combination of the radicals **13**$^{\bullet}$ and **10**-H$^{\bullet}$ gave the adduct **14**. The resulting adduct **14** undergoes elimination of one molecule of ethyl formate followed by intramolecular nucleophilic attack to the ethylenic double bond with the elimination of HCN to form the thiadiazine derivatives **11a–c**.

On the other hand, the thiadiazines **12a–c** were obtained from cyclisation of the adduct **14** *via* an elimination a molecule of ethyl cyanoacetate (Scheme 4).

The IR spectrum of **11b** showed absorption bands due to NH_2 and NH stretching vibration at 3350 and 3225 cm^{-1}, an α,β-unsaturated nitrile CN at 2225, carbonyl ester at 1685 and C=N group at 1620 cm^{-1}. ^{1}H NMR spectrum of **11b** in DMSO-



Scheme 2



Scheme 3

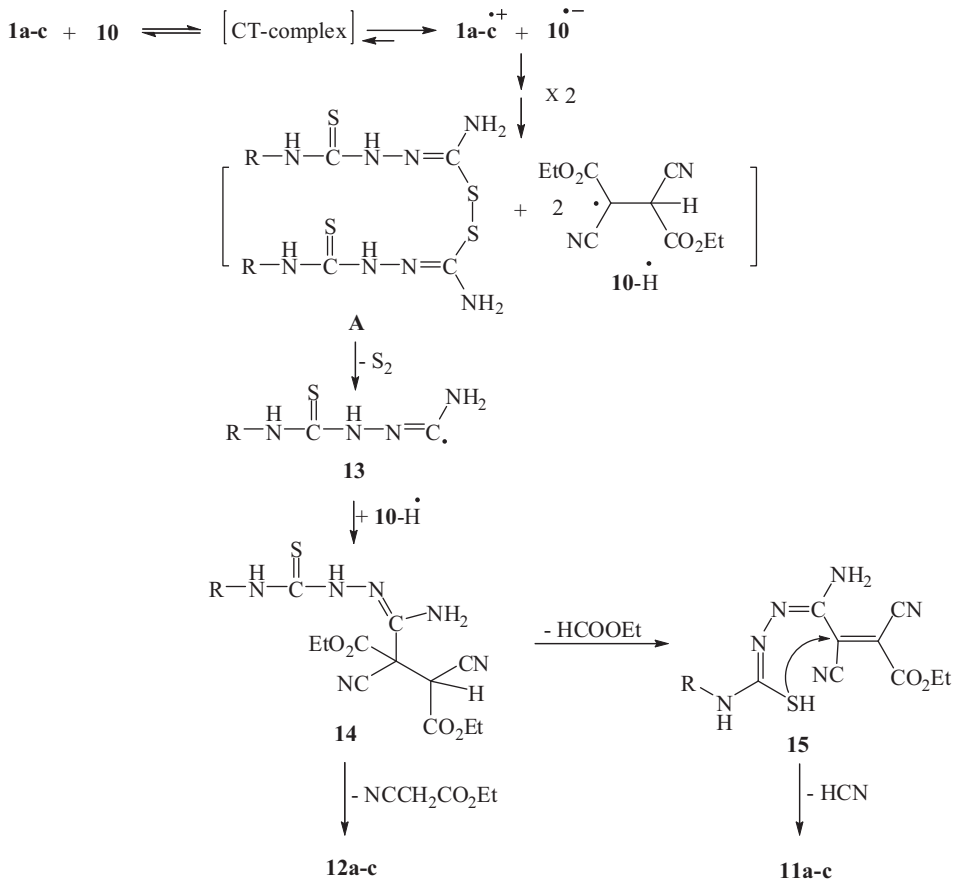
d_6, revealed signals at 4.62 due to benzylic-CH_2, 1.25 and 4.16 for ethoxy group (J = 7.10), two broad signals with the ratio 2:1 centred at 6.34 and 8.89 ppm, due to exocyclic NH_2 and benzylic-NH, respectively. Signals around 52.64 (CH_2), 118.19 (CN), 155.92, 161.44 (C-5, C-2) and 168.81 (COO) in the ^{13}C NMR spectrum further support structure **11b**. The molecular formula of compounds **11a–c** were obtained and confirmed by elemental analysis and mass data. The presence of ethoxy and benzylic groups are also evident from the ^{13}C-DEPT NMR spectrum exhibiting positive signals at 14.26 and negative signals at 52.64 and 60.79 ppm.

For the formation of thiadiazines **12a–c**, the IR spectrum of **12c** shows characteristic bands at ν = 3360, 3270 (NH_2 and NH), 2220 (CN) and 1685 (COO) as well as C=N at 1610 cm^{-1}. The ^1H NMR spectrum of **12c** shows two broad signals at δ_H = 6.35 and 7.55 ppm, due to NH_2 as well as allyl-NH. Also, the ^1H NMR spectrum of **12c** shows one singlet and two multiplets at δ_H = 4.09, 5.18–5.26 and 5.90–5.94 ppm, due to allyl group. The decoupled carbon spectra of **12c** showed signals at δ_C = 14.19 (CH_3), 42.88 (allyl-CH_2N), 60.63 (CH_2O), 116.06 (allyl-CH_2=), 118.16 (CN), and 134.22 ppm, (allyl-CH=). Also, the ^{13}C NMR of **12c** shows another signals at δ_C = 158.93, 159.67 and 166.12 ppm, due to (C-2, C-5) and (COO), respectively. The gross formula $C_{10}H_{13}N_5O_2S$ represents a product from one molecule of **1c** and one of **10** with loss of sulfur and ethyl cyanoacetate.

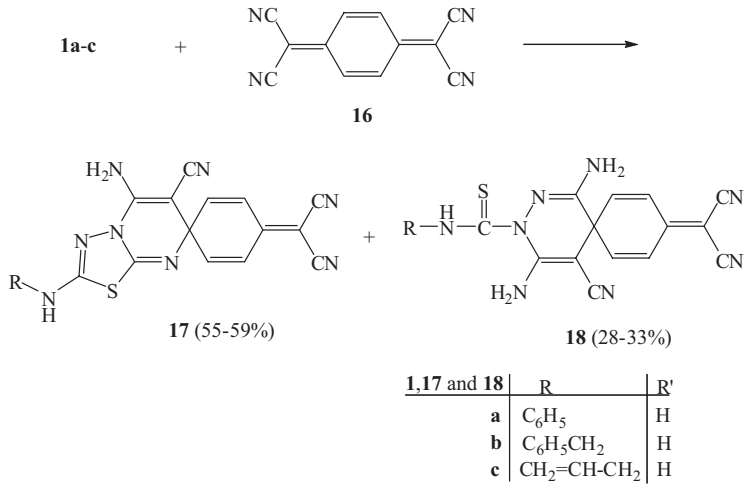
7,7',8,8'-Tetracyanoquinodimethane (TCNQ, **16**) is well known electron acceptor molecule,[21] which has been successfully used for the preparation of electrically conducting salts and CT-complexes.[22] The interest of TCNQ has focused on its potential applications on material rectifiers,[23] non-linear optical materials,[24] organoferromagnets[25] and organic chromophores.[26]

Recently, it has been reported that the addition of 1,8-diaminonaphthalene to TCNQ (**16**) afforded 2-(4-(1*H*,3*H*-pyrimidin-2-ylidene)cyclohexa-2,5-dienylidene)malononitrile.[27] Pyridine solution of TCNQ (**16**) and **1a–c** in a molar ratio of 2:1 were kept at 100°C for 2 h with admission of air. Chromatographic separation of the residue after concentration gave numerous coloured zones, from which products **17** and **18** could be isolated (Scheme 5).

Structural assignment of products **17a–c** is based on spectral data and on combustion analysis. The elemental analysis of **17b** supporting the gross formula $C_{21}H_{14}N_8S$, and the mass spectrum which gave a correct molecular ion at m/z = 410 (23%).



Scheme 4



1,17 and 18	R	R'
a	C_6H_5	H
b	$C_6H_5CH_2$	H
c	CH_2=CH-CH_2	H

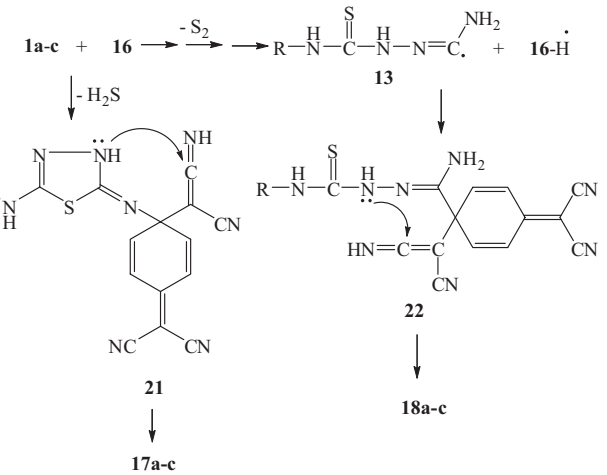
Scheme 5

The IR spectrum of **17b** showed NH_2 and NH absorption bands at ν = 3395 and 3315, cyano groups at 2220 and 2215 cm^{-1}. The ^1H NMR spectrum revealed two broad signals at δ = 6.70 and 8.91 ppm, related to NH_2 and benzyl-NH, respectively, besides the aromatic and cyclohexadiene protons. The ^{13}C NMR spectrum of **17b** confirmed its ^1H NMR spectral data by appearance of signals at 4.62, 6.30 and 6.58 due to benzylic-CH_2 and cyclohexadiene-CH. The ^{13}C NMR spectrum of **17b** revealed signals for pyrimidine (C-6, C-5) which resonate at δ = 60.45 and 160.91 ppm, respectively are accordance with the observed trends in the δ values for C-atoms in push-pull alkenes.[28,29]

The second zone characterised by a brown colour contains compounds spiropyridazine-cyclohexadiene derivatives **18a–c**. The IR spectrum of **18a** showed characteristic absorption to the NH_2 and NH groups at 3385, 3270, 1570 (NH def. and C-N str.) and 1358 as well as 998 cm^{-1}, to strong vibrational coupling of C=S and C-N entities. The ^1H NMR spectrum of **18a** showed three broad signals with the ratio 2:2:1 centred at 6.49, 6.62 and 9.84 due to two exocyclic-NH_2 and Ph-NH protons. The decoupled carbon spectrum of **18a** showed signals at δ = 180.19 (C=S), 60.71 (C-5), 156.67 (C-3), 160.83 (C-6) and 46.21 (q-C-4,1'). The analytical data of compound **18a** could also match for other isomers of products **19** and **20** (Fig. 2).

The alternative structures **19** and **20** could be ruled out on the bases of ^1H NMR, ^{13}C NMR and the fragment ions in the mass spectrum of **18a** at *m/z* 263, 207, 197, 135, 66 and 57.

As shown in Fig. 2, structure **18a** fits best to all the spectroscopic data (see experimental section).

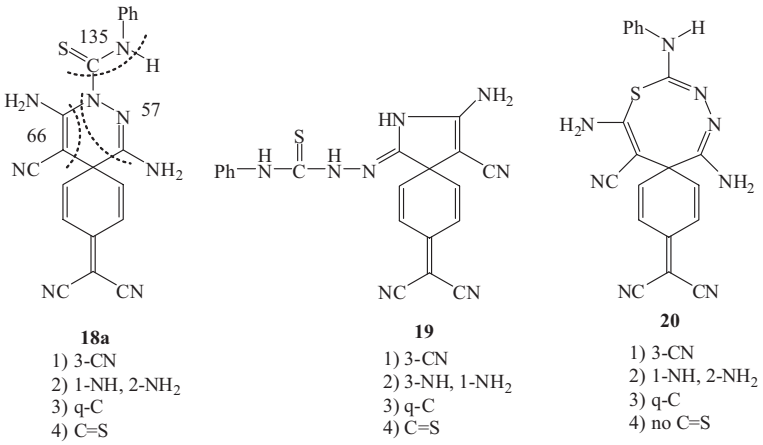


Scheme 6

Formation of spiro compounds **17** and **18** derivatives from TCNQ may be rationalised as outlined in (Scheme 6).

Experimental

Melting points have been determined using open capillaries on a Gallenkamp melting point apparatus and are uncorrected. Elemental analysis were determined by Microanalytical Centre, Cairo University, Egypt. The IR spetra were recorded with Shimadzue 408 instrument using potassium bromide. 500 MHz ^1H and 125 MHz ^{13}C



18a
1) 3-CN
2) 1-NH, 2-NH_2
3) q-C
4) C=S

19
1) 3-CN
2) 3-NH, 1-NH_2
3) q-C
4) C=S

20
1) 3-CN
2) 1-NH, 2-NH_2
3) q-C
4) no C=S

Fig. 2

NMR spectra on a Bruker DRX 500 spectrometer. Chemical shifts are expressed as δ [ppm] with reference to tetramethylsilane as an internal standard, s = singlet, d = doublet, dd = doublet of doublet, t = triplet, m = multiplet and br = broad. ^{13}C assignments (q C = sp^2 quaternary carbon atoms) were made with the aid of distortionless enhancement by polarisation transfer (DEPT) 135/90 spectra. Mass spectra were recorded on Varian MAT 311 instrument in EI Mode (70 eV) ionisation energy. Preparative layer chromatography (PLC) used air-dried 1.0 mm thick layers of slurry applied silica gel, Merck Pf_{254} on 48 cm wide and 20 cm high glass plates using the solvents listed. Zones were detected by quenching of indicator fluorescence upon exposure to 254 nm light and eluted with acetone.

Starting materials

1-Substituted-2,5-dithiobiureas **1a–c** were prepared according to published procedures, as were 1-phenyl-2,5-dithiobiurea (**1a**),[30] 1-benzyl-2,5-dithiobiurea (**1b**),[30,31] 1-allyl-2,5-dithiobiurea (**1c**).[30] Ethenetetracarbonitrile (**2**, Merck) was purified by crystallisation from chlorobenzene and sublimed. Diethyl (*E*)-2,3-dicyanobutenedioate (**10**) and 7,7',8,8'-tetracyanoquino-dimethane (**16**, **TCNQ**) were purchased from Aldrich and used as purchased.

Reactions of 1-substituted-2,5-dithiobiureas **1a–c** *with ethenetetracarbonitrile* **(2)**

To a chilled solution of 256 mg (2.0 mmol) of **2** in 10 ml of tetrahydrofuran (THF) a pre-cooled solution of **1a–c** in 15 ml of THF was added dropwise which caused a spontaneous change of colour from yellow to pink. The mixture was stirred for 3 h and allowed to warm up to room temperature. The stirring was continued for 48 h with admission of air to complete the reaction. After concentration, the reaction mixture to dryness, the residue sublimed at 80°C under vacuum to remove all unreacted **2**. The residue was then separated by PLC (100 mg per plate) using a suitable solvent mixture as aluent (cyclohexane/ethyl acetate 2:1 for the reaction of **2** with **1a** and **1b**; cyclohexane/ethyl acetate 3:1 for the reaction of **2** with **1c**) to give numerous coloured zones. The two most intense of which were removed and extracted. The fastest migrating one contained imidazothiazole derivatives **5a–c**, the second zone, which quenched all indicator fluorescence upon exposure to 254 nm UV-light, contained 1,2-bis[2-(substituted amino)-1,3,4-thiadiazol-2-yl]hydrazine **6a–c**. Extraction of the zones with acetone gave a residue, which was rechromatographed and recrystallised to separate the pure compounds.

2-(Phenylamino)imidazo[2,1-b][1,3,4]thiadiazole-5,6-dicarbonitrile **(5a):** Reddish brown crystals (0.149 g, 56%), m.p. 302–304°C (methanol). ^{1}H NMR (DMSO-d_6): δ = 9.76 (br, 1H, phenyl-NH), 7.11–7.66 (m, 5H, ArH). ^{13}C NMR: δ = 156.88 (*C*-2), 154.53 (*C*-4a), 143.33 (Ar*C*), 127.31, 128.82, 129.67 (Ar*C*H), 122.24, 122.26, (*C*-5, *C*-6), 118.11, 118.14 (*C*N). IR (KBr): 3380 (NH), 2215 (CN), 1635 (C=N), 1590 (ArC=C). MS (*m/z*,%): 266 (M$^+$, 22), 240 (14), 214 (3), 190 (8), 135 (44), 77 (100), 65 (42). $C_{12}H_6N_6S$ (266.28): Calcd; C, 54.13; H, 2.27; N, 31.56; S, 12.04. Found: C, 53.89; H, 2.41; N, 31.78; S, 11.81.

2-(Benzylamino)imidazo[2,1-b][1,3,4]thiadiazole-5,6-dicarbonitrile **(5b):** Reddish brown crystals (0.148 g, 53%), m.p. 325–327°C (acetonitrile). ^{1}H NMR (DMSO-d_6): δ = 8.85 (br, 1H, benzyl-NH), 7.06–7.58 (m, 5H, ArH), 4.62 (s, 2H, CH_2). ^{13}C NMR: δ = 156.66 (*C*-2), 154.31 (*C*-4a), 122.22, 122.25 (*C*-5, *C*-6), 118.10, 118.13 (*C*N), 52.41 (*C*H$_2$). IR (KBr): 3365 (NH), 2980 (Ali-CH), 2220 (CN), 1630 (C=N), 1600 (ArC=C). MS (*m/z*,%): 280 (M$^+$, 19), 204 (12), 149 (72), 91 (100), 65 (28). $C_{13}H_8N_6S$ (280.31): calcd; C, 55.70; H, 2.88; N, 29.98; S, 11.44. Found: C, 55.93; H, 2.65; N, 30.16; S, 11.67.

2-(Allylamino)imidazo[2,1-b][1,3,4]thiadiazole-5,6-dicarbonitrile **(5c):** Reddish brown crystals (0.117 g, 51%), m.p. 271–273°C (ethanol). ^{1}H NMR (DMSO-d_6): δ = 7.59 (br, 1H, allyl-NH), 5.90–5.93 (m, 1H, allyl-CH=), 5.01–5.18 (m, 2H, allyl-CH_2=), 4.05 (br, 2H, allyl-CH_2N). ^{13}C NMR: δ = 156.77 (*C*-2), 155.11 (*C*-4a), 134.21 (allyl-*CH*=), 122.15, 122.18 (*C*-5, *C*-6), 118.08, 118.10 (*C*N), 114.81 (allyl-*C*H$_2$=), 43.33 (allyl-*C*H$_2$N). IR (KBr): 3370 (NH), 2965 (Ali-CH), 2215 (CN), 1635 (C=N). MS (*m/z*,%): 230 (M$^+$, 36), 204 (6), 154 (44), 99 (82), 41 (100). $C_9H_6N_6S$ (230.25): Calcd; C, 46.95; H, 2.63; N, 36.50; S, 13.93. Found: C, 47.18; H, 2.81; N, 36.29; S, 14.16.

1,2-Bis[5-(phenylamino)-1,3,4-thiadiazol-2-yl]hydrazine **(6a)**: Yellow crystals (0.122 g, 32%), m.p. 240–242°C (acetonitrile). ^{1}H NMR (DMSO-d_6): δ = 9.81 (br, 2H, phenyl-NH), 7.06–7.49 (m, 10H, ArH), 6.61 (br, 2H, hydrazine-NH). ^{13}C NMR: δ = 155.76 (*C*-2), 154.33 (*C*-5), 143.12 (Ar*C*), 127.63, 128.81, 129.67 (Ar*C*H). IR (KBr): 3370–3340 (NH), 1620 (C=N), 1595 (ArC=C). MS (*m/z*,%): 382 (M$^+$, 21), 354 (11), 261 (34), 219 (100), 150 (92), 135 (33), 77 (62), 65 (21). $C_{16}H_{14}N_8S_2$ (382.47): Calcd; C, 50.25; H, 3.69; N, 29.30; S, 16.77. Found: C, 50.44; H, 3.52; N, 29.14; S, 16.96.

1,2-Bis[5-(benzylamino)-1,3,4-thiadiazol-2-yl]hydrazine **(6b):** Pale yellow crystals (0.148 g, 36%), m.p. 262–264°C (acetonitrile). ^{1}H NMR (DMSO-d_6): δ = 8.87 (br, 2H, benzyl-NH), 7.10–7.38 (m, 10H, ArH), 6.57 (br, 2H, hydrazine-NH), 4.61 (s, 2H, CH_2). ^{13}C NMR: δ = 155.48 (*C*-2), 154.21 (*C*-5), 141.63 (Ar*C*), 127.56, 128.82, 129.59 (Ar*C*H), 52.58 (*C*H$_2$). IR (KBr): 3385-3360 (NH), 1625 (C=N), 1600 (ArC=C). MS (*m/z*,%): 410 (M$^+$, 16), 382 (22), 261 (46), 164 (76), 149 (81), 91 (100), 65 (36). $C_{18}H_{18}N_8S_2$ (410.52): Calcd; C, 52.66; H, 4.42; N, 27.30; S, 15.62. Found: C, 52.43; H, 4.64; N, 27.53; S, 15.39.

1,2-Bis[5-(allylamino)-1,3,4-thiadiazol-2-yl]hydrazine **(6c):** Pale yellow crystals (0.105 g, 34%), m.p. 195–197°C (acetonitrile). ^{1}H NMR (DMSO-d_6): δ = 7.61 (br, 2H, allyl-NH), 5.88–5.94 (m, 2H, allyl-CH=), 5.08–5.16 (m, 4H, allyl-CH_2=), 4.08 (br, 4H, allyl-CH_2N),; ^{13}C NMR: δ = 155.83 (*C*-2), 154.71 (*C*-5), 134.28 (allyl-*CH*=), 115.08 (allyl-*C*H$_2$=), 43.28 (allyl-*C*H$_2$N). IR (KBr): 3365–3345 (NH), 1615 (C=N). MS (*m/z*,%): 310 (M$^+$, 23), 282 (14), 269 (27), 211 (16), 131 (89), 114 (46), 99 (62), 41 (100). $C_{10}H_{14}N_8S_2$ (310.41): Calcd; C, 38.69; H, 4.55; N, 36.10; S, 20.66. Found: C, 38.48; H, 4.71; N, 38.88; S, 20.89.

Reaction of 1-substituted-2,5-dithiobiureas **1a–c** *with diethyl (E)-2,3-dicyanobutenedioate* **(10):** A solution of 444 mg (2.0 mmol) of **10** in 30 ml THF was treated with **a**) 226 mg (1.0 mmol) of **1a**, **b**) 240 mg (1.0 mmol) of **1b**, **c**) 190 mg (1.0 mmol) of **1c** and stirred at 20°C for 48 h (**a**) and 96 h (**b, c**), respectively. During which time the colour of the solution changed from yellow to light red. Concentration of the reaction mixture to dryness, the residues was subjected to PLC using cyclohexane/ethyl acetate (5:1) as eluent. Chromatographic separation of the residue gave numerous coloured zones, two of which (with high intensity) were removed and extracted. The fastest move zone contained the thiadiazinylidene cyanoacetate derivatives **11a–c**, while the slowest moving zone contained the thiadiazine derivatives **12a–c**. Extraction of the zones with acetone and recrystallised gave the pure compounds.

Ethyl (Z)-2-[5-amino-2-(phenylamino)-6H-1,3,4-thiadiazin-6-ylidene]-2-cyanoacetate **(11a):** Orange crystals (0.154 g, 49%), m.p. 225–227°C (ethanol). ^{1}H NMR (DMSO-d_6): δ = 9.81 (br, 1H, Phenyl-NH), 6.98–7.46 (m, 5H, ArH), 6.37 (br, 2H, NH_2), 4.19 (q, 2H, *J* = 7.15, OCH_2), 1.27 (t, 3H, *J* = 7.15, CH_3). ^{13}C NMR: δ = 165.74 (*C*OO), 163.42 (*C*-5), 161.23 (*C*-2), 146.65 (*C*-6), 144.32 (Ar*C*), 127.63, 128.84, 129.61 (Ar*C*H), 118.24 (*C*N), 115.14 (ethylenic-*C*), 60.76 (*C*H$_2$O), 14.28 (*C*H$_3$). IR (KBr): 3360, 3280 (NH_2, NH), 2220 (CN), 1680 (CO), 1610 (C=N), 1580 (ArC=C). MS (*m/z*,%): 315 (M$^+$, 41), 299 (14), 204 (28), 180 (11), 150 (21), 135 (12), 77 (100). $C_{14}H_{13}N_5O_2S$ (315.35): Calcd; C, 53.32; H, 4.16; N, 22.21; S, 10.17. Found: C, 53.49; H, 3.98; N, 22.48; S, 10.36.

Ethyl (Z)- 2-[5-amino-2-(benzylamino)-6H-1,3,4-thiadiazin-6-ylidene]-2-cyanoacetate **(11b):** Orange crystals (0.151 g, 46%), m.p. 258–260°C (methanol). ^{1}H NMR (DMSO-d_6): δ = 8.89 (br, 1H, benzyl-NH), 7.05–7.44 (m, 5H, ArH), 6.34 (br, 2H, NH_2), 4.62 (s, 2H, PhCH_2), 4.16 (q, 2H, *J* = 7.10, OCH_2), 1.25 (t, 3H, *J* = 7.10, CH_3). ^{13}C NMR: δ = 165.56 (*C*OO), 163.12 (*C*-5), 161.44 (*C*-2), 146.65 (*C*-6), 143.61 (Ar*C*), 127.48, 128.68, 129.14 (Ar*C*H), 118.19 (*C*N), 114.99 (ethylenic-*C*), 60.79 (*C*H$_2$O), 52.64 (Ph-*C*H$_2$), 14.26 (*C*H$_3$). IR (KBr): 3350, 3225 (NH_2, NH), 2225 (CN), 1685 (CO), 1620 (C=N), 1590 (ArC=C). MS (*m/z*,%): 329 (M$^+$, 26), 313 (8), 303 (6), 218 (15), 180 (16), 149 (33), 91 (100), 77 (84). $C_{15}H_{15}N_5O_2S$ (329.38): Calcd; C, 54.70; H, 4.59; N, 21.26; S, 9.74. Found: C, 54.45; H, 4.80; N, 21.54; S, 10.02.

Ethyl(Z)-2-[5-amino-2-(allylamino)-6H-1,3,4-thiadiazin-6-ylidene]-2-cyanoacetate **(11c):** Orange crystals (0.126 g, 45%), m.p. 196–198°C (acetonitrile). ^{1}H NMR (DMSO-d_6): δ = 7.61 (br, 1H, allyl-NH), 6.40 (br, 2H, NH_2), 5.88–5.91 (m, 1H, allyl-CH=), 5.16–5.22 (m, 2H, allyl-CH_2=), 4.18 (q, 2H, *J* = 7.06, OCH_2), 4.05 (br, 2H, allyl-CH_2N), 1.26 (t, 3H, *J* = 7.06, CH_3). ^{13}C NMR: δ = 165.32 (*C*OO), 163.22 (*C*-2), 161.28 (*C*-2), 146.55 (*C*-6), 134.29 (allyl-*CH*=), 117.96 (*C*N), 115.88 (allyl-*C*H$_2$=), 114.15 (ethylenic-*C*), 60.93 (*C*H$_2$O), 43.12 (allyl-*C*H$_2$N), 14.26 (*C*H$_3$),. IR (KBr): 3370, 3290 (NH_2, NH), 2220 (CN), 1680 (CO), 1615 (C=N). MS (*m/z*,%): 279 (M$^+$, 16), 263 (9), 203 (13), 180 (23), 99 (91), 41 (100). $C_{11}H_{13}N_5O_2S$ (279.32): Calcd; C, 47.30; H, 4.69; N, 25.07; S, 11.48. Found: C, 47.49; H, 4.52; N, 24.87; S, 11.27.

Ethyl 5-amino-6-cyano-2-(phenylamino)-6(H)-1,2,4-thiadiazine-6-carboxylate **(12a):** Reddish brown crystals (0.124 g, 41%), m.p. 205–207°C (acetonitrile). ^{1}H NMR (DMSO-d_6): δ = 9.84 (br, 1H,

phenyl-NH), 7.09–7.46 (m, 5H, ArH), 6.39 (br, 2H, NH_2), 4.16 (q, 2H, J = 7.03, OCH_2), 1.25 (t, 3H, J = 7.03, CH_3). ^{13}C NMR: δ = 166.14 (*C*OO), 159.11 (*C*-5), 158.77 (*C*-2), 144.53 (Ar*C*), 127.38, 128.82, 129.69 (Ar*C*H), 117.97 (*C*N), 60.76 (*C*H_2O), 45.18 (*C*-6), 14.17 (*C*H_3). IR (KBr): 3350, 3260 (NH_2, NH), 2210 (CN), 1685 (CO), 1610 (C=N). MS (*m/z*,%): 303 (M^+, 34), 287 (8), 259 (11), 229 (9), 168 (26), 135 (74), 77 (100). $C_{13}H_{13}N_5O_2S$ (303.34): Calcd; C, 51.47; H, 4.32; N, 23.09; S, 10.57. Found: C, 51.69; H, 4.11; N, 22.85; S, 10.81.

Ethyl 5-amino-6-cyano-2-(benzylamino)-6(H)-1,2,4-thiadiazine-6-carboxylate **(12b):** Reddish brown crystals (0.124 g, 39%), m.p. 237–239°C (acetonitrile). ^{1}H NMR (DMSO-d_6): δ = 8.91 (br, 1H, benzyl-NH), 7.22–7.39 (m, 5H, ArH), 6.43 (br, 2H, NH_2), 4.64 (s, 2H, PhCH_2), 4.18 (q, 2H, J = 7.12, OCH_2), 1.23 (t, 3H, J = 7.12, CH_3). ^{13}C NMR: δ = 165.76 (*C*OO), 159.26 (*C*-5), 158.69 (*C*-2), 127.82, 127.96, 128.84 (Ar*C*H), 118.14 (*C*N), 141.12 (Ar*C*), 60.71 (*C*H_2O), 52.61 (Ph-*C*H_2), 44.96 (*C*-6), 14.22 (*C*H_3). IR (KBr): 3365, 3280 (NH_2, NH), 2220 (CN), 1690 (CO), 1620 (C=N). MS (*m/z*,%): 317 (M^+, 29), 290 (6), 243 (16), 168 (33), 149 (52), 91 (100), 77 (62). $C_{14}H_{15}N_5O_2S$ (317.37): Calcd; C, 52.98; H, 4.76; N, 22.07; S, 10.10. Found: C, 53.22; H, 4.59; N, 21.86; S, 10.36.

Ethyl 5-amino-6-cyano-2-(allylamino)-6(H)-1,2,4-thiadiazine-6-carboxylate **(12c):** Reddish brown crystals (0.96 g, 36%), m.p. 181–183°C (ethanol). ^{1}H NMR (DMSO-d_6): δ = 7.55 (br, 1H, allyl-NH), 6.35 (br, 2H, NH_2), 5.90–5.94 (m, 1H, allyl-CH=), 5.18–5.26 (m, 2H, allyl-CH_2=), 4.18 (q, 2H, J = 6.97, OCH_2), 4.09 (br, 2H, allyl-NH_2), 1.22 (t, 3H, J = 6.97, CH_3). ^{13}C NMR: δ = 166.12 (*C*OO), 159.67 (*C*-5), 158.93 (*C*-2), 134.22 (allyl-*CH*=), 118.16 (*C*N), 116.06 (allyl-*C*H_2=), 60.63 (*C*H_2O), 45.03 (*C*-6), 42.88 (allyl-*C*H_2N), 14.19 (*C*H_3). IR (KBr): 3360, 3270 (NH_2, NH), 2960 (Ali-H), 2220 (CN), 1685 (CO), 1610 (C=N). MS (*m/z*,%): 267 (M^+, 26), 193 (19), 168 (33), 165 (5), 99 (67), 41 (100). $C_{10}H_{13}N_5O_2S$ (267.31): Calcd; C, 44.93; H, 4.90; N, 26.20; S, 12.00. Found: C, 45.21; H, 4.72; N, 25.97; S, 11.97.

Reaction of 1-substituted-2,5-dithiobiureas **1a–c** *with 7,7',8,8'-tetracyanoquinodimethane* **(16):** To a solution of **16** (416 mg, 2.0 mmol) in dry pyridine (15 ml) a solution of **1a–c** (1.0 mmol each) in (5 ml) of dry pyridine was added dropwise over 5 minutes at room temperature with stirring. The mixture was warmed gently to 50–60°C and kept at this temperature with stirring and admission of air for 3 h, then warmed to maximum 100°C for few minutes and concentrated to dryness at 50°C. The residue was taken up several times with cold ethanol (15 ml) and the slurry was concentrated again to remove any residual pyridine. This operation was repeated four times. The residue was dissolved in (5 ml) acetone. This solution in each case was applied to five PLC plates and developed with toluene/ethyl acetate (3:1) for the run with **1a**, toluene/ethyl acetate (4:1) for the run with **1b** and **1c**. Numerous zones were observed, two of which were extracted. The fastest migrating zone contained compound **17**, the second zone contained compound **18**. Extraction of the zones with acetone gave a residue, which was rechromatographed with the same eluent to enhance separation. Recrystallisation from suitable solvents afforded compounds **17a–c** and **18a–c**.

{5-Amino-6-cyano-2-(phenylamino)spiro[1,3,4]thiadiazolo[3,2-a]pyrimidine-7,1'-cyclohexa[2,5]dien-4'-ylidene}malononitrile **(17a):** Blue crystals (0.234 g, 59%), m.p. 246–248°C (methanol). ^{1}H NMR (DMSO-d_6): δ = 9.77 (br, 1H, phenyl-NH), 7.06–7.46 (m, 5H, ArH), 6.74 (br, 2H, NH_2), 6.32, 6.61 (dd, 4H, cyclohexadiene-H). ^{13}C NMR: δ = 166.32 (*C*-4'), 161.12 (*C*-5), 157.12 (*C*-8a), 155.72 (*C*-2), 144.61 (Ar*C*), 127.62, 128.83, 129.64 (Ar*C*H), 124.71, 126.82 (cyclohexadiene-*C*H), 118.66 (*C*N), 73.84 (malononitrile-*C*), 60.62 (*C*-6), 45.77 (q-*C*-7,1'). IR (KBr): 3410, 3310 (NH_2, NH), 2225, 2220 (CN), 1630 (C=N), 1595 (ArC=C). MS (*m/z*,%): 396 (M^+, 31), 330 (11), 190 (19), 135 (51), 77 (100). $C_{20}H_{12}N_8S$ (396.43): Calcd; C, 60.59; H, 3.05; N, 28.27; S, 8.09. Found: C, 60.37; H, 2.94; N, 28.51; S, 8.32.

{5-Amino-6-cyano-2-(benzylamino)spiro[1,3,4]thiadiazolo[3,2-a]pyrimidine-7,1'-cyclohexa[2,5]dien-4'-ylidene}malononitrile **(17b):** Blue crystals (0.226 g, 55%), m.p. 276–278°C (acetonitrile). ^{1}H NMR (DMSO-d_6): δ = 8.91 (br, 1H, benzyl-NH), 6.98–7.35 (m, 5H, ArH), 6.70 (br, 2H, NH_2), 6.30, 6.58 (dd, 4H, cyclohexadiene-H), 4.62 (s, 2H, CH_2). ^{13}C NMR: δ = 166.22 (*C*-4'), 160.91 (*C*-5), 156.88 (*C*-8a), 155.57 (*C*-2), 141.77 (Ar*C*), 127.83, 127.91, 128.68 (Ar*C*H), 124.79, 126.77 (cyclohexadiene-*C*H), 118.61 (*C*N), 73.69 (malononitrile-*C*), 60.45 (*C*-6), 52.61 (*C*H_2), 45.53 (q-*C*-7,1'). IR (KBr): 3395, 3315 (NH_2, NH), 2220, 2215 (CN), 1625 (C=N), 1595 (ArC=C). MS (*m/z*,%): 410 (M^+, 23), 344 (9), 204 (22), 149 (66), 91 (100), 77 (58). $C_{21}H_{14}N_8S$ (410.45): Calcd; C, 61.45; H, 3.44; N, 27.30; S, 7.81. Found: C, 61.68; H, 3.65; N, 27.57; S, 7.55.

{5-Amino-6-cyano-2-(allylamino)spiro[1,3,4]thiadiazolo[3,2-a]pyrimidine-7,1'-cyclohexa[2,5]dien-4'-ylidene}malononitrile **(17c):** Blue crystals (0.105 g, 57%), m.p. 216–218°C (acetonitrile). ^{1}H NMR (DMSO-d_6): δ = 7.61 (br, 1H, ally-NH), 6.65 (br, 2H, NH_2), 6.33, 6.61 (dd, 4H, cyclohexadiene-H), 5.88–5.92 (m, 1H, allyl-CH=), 5.20–5.24 (m, 2H, allyl-CH_2=), 4.05 (br, 2H, allyl-CH_2N). ^{13}C NMR: δ = 165.98 (*C*-4'), 160.87 (*C*-5), 156.75 (*C*-8a), 155.57 (*C*-2), 134.31 (allyl-*CH*=), 124.72, 126.64 (cyclohexadiene-*C*H), 118.61 (*C*N), 116.14 (allyl-*C*H_2=), 73.75 (malononitrile-*C*), 60.51 (*C*-6), 45.48 (q-*C*-7,1'), 42.85 (allyl-*C*H_2N). IR: 3400, 3320 (NH_2, NH), 2225, 2220 (CN), 1630 (C=N). MS (*m/z*,%): 360 (M^+, 22), 294 (9), 163 (26), 99 (57), 41 (100). $C_{17}H_{12}N_8S$ (360.40): Calcd; C, 56.65; H, 3.36; N, 31.09; S, 8.90. Found: C, 56.81; H, 3.22; N, 30.89; S, 9.14.

1,4-Diamino-5-cyano-9-(dicyanomethylene)-N-phenyl-2,3-diazospiro[5.5]undeca-1,4,7,10-tetraene-9-thioamide **(18a):** Violet crystals (0.111 g, 28%), m.p. 289–291°C (acetonitrile). ^{1}H NMR (DMSO-d_6): δ = 9.84 (br, 1H, phenyl-NH), 7.09–7.70 (m, 5H, ArH), 6.62 (br, 2H, NH_2), 6.49 (br, 2H, NH_2), 6.29, 6.58 (dd, 4H, cyclohexadiene-H). ^{13}C NMR: δ = 180.19 (*C*=*S*), 166.41 (*C*-9), 160.83 (*C*-4), 156.67 (*C*-1), 141.18 (Ar*C*), 127.86, 128.88, 129.51 (Ar*C*H), 125.13, 126.64 (cyclohexadiene-*C*H), 117.97, 118.31 (*C*N), 74.26 (malononitrile-*C*), 60.71 (*C*-5), 46.21 (q-*C*-6). IR (KBr): 3385, 3270 (NH_2, NH), 2225, 2215 (CN), 1610 (C=N), 1570 (NH def. and C-N str.), 1358, 998 (C=S, C-N). MS (*m/z*,%): 398 (M^+, 27), 263 (35), 207 (36), 197 (21), 169 (15), 150 (42), 135 (57), 77 (100), 66 (46), 57 (37). $C_{20}H_{14}N_8S$ (398.44): Calcd; C, 60.29; H, 3.54; N, 28.12; S, 8.05. Found: C, 60.51; H, 3.33; N, 27.89; S, 8.31.

1,4-Diamino-5-cyano-9-(dicyanomethylene)-N-benzyl-2,3-diazospiro[5.5]undeca-1,4,7,10-tetraene-9-thioamide **(18b):** Violet crystals (0.136 g, 33%), m.p. 324–326°C **(**acetonitrile). ^{1}H NMR (DMSO-d_6): δ = 8.91 (br, 1H, benzyl-NH), 7.16–7.53 (m, 5H, ArH), 6.54 (br, 2H, NH_2), 6.46 (br, 2H, NH_2), 6.25, 6.55 (dd, 4H, cyclohexadiene-H), 4.62 (CH_2). ^{13}C NMR: δ = 180.46 (*C*=*S*), 166.72 (*C*-9), 161.12 (*C*-4), 156.41 (*C*-1), 141.66 (Ar*C*), 127.84, 127.96, 128.62 (Ar*C*H), 125.06, 126.51 (cyclohexadiene-*C*H), 118.05, 118.27 (*C*N), 74.28 (malononitrile-*C*), 60.66 (*C*-5), 52.56 (*C*H_2), 45.96 (q-*C*-6). IR (KBr): 3370, 3280 (NH_2, NH), 2225, 2215 (CN), 1620 (C=N), 1565 (NH def. and C-N str.), 1355, 1005 (C=S, C-N). MS (*m/z*,%): 412 (M^+, 18), 263 (14), 207 (9), 169 (22), 164 (26), 149 (77), 91 (100), 77 (66), 66 (51), 57 (24). $C_{21}H_{16}N_8S$ (412.47): Calcd; C, 61.15; H, 3.91; N, 27.17; S, 7.77. Found: C, 60.92; H, 4.08; N, 27.41; S, 7.59.

1,4-Diamino-5-cyano-9-(dicyanomethylene)-N-allyl-2,3-diazospiro[5.5]undeca-1,4,7,10-tetraene-9-thioamide **(18c):** Violet crystals (0.101 g, 28%), m.p. 261–263°C **(**acetonitrile). ^{1}H NMR (DMSO-d_6): δ = 7.84 (br, 1H, allyl-NH), 6.57 (br, 2H, NH_2), 6.48 (br, 2H, NH_2), 6.28, 6.60 (dd, 4H, cyclohexadiene-H), 5.92–5.96 (m, 1H, allyl-CH=), 5.18–5.26 (m, 2H, allyl-CH_2=), 4.10 (br, 2H, allyl-CH_2N). ^{13}C NMR: δ = 180.52 (*C*=*S*), 166.12 (*C*-9), 160.88 (*C*-4), 156.36 (*C*-1), 134.38 (allyl-*CH*=), 125.11, 126.49 (cyclohexadiene-*C*H), 118.06, 118.26 (*C*N), 115.96 (allyl-*C*H_2=), 74.36 (malononitrile-*C*), 60.58 (*C*-5), 46.08 (q-*C*-6), 42.78 (allyl-*C*H_2N). IR (KBr): 3345, 3270 (NH_2, NH), 2220, 2210 (CN), 1560 (NH def. and C-N str.), 1355, 1015 (C=S, C–N). MS (*m/z*,%): 362 (M^+, 14), 263 (26), 207 (14), 197 (16), 181 (8), 169 (19), 99 (46), 66 (58), 57 (45), 41 (100). $C_{17}H_{14}N_8S$ (362.41): Calcd; C, 56.34; H, 3.89; N, 30.92; S, 8.85. Found: C, 56.11; H, 4.11; N, 31.14; S, 8.63.

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