The Synthesis of 2-Cyano-cyanothioformanilides from 2-(4-Chloro-5*H*-1,2,3-dithiazol-5-ylideneamino)benzonitriles Using DBU

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Abstract: A series of 2-(4-chloro-5*H*-1,2,3-dithiazol-5-ylideneamino)benzonitriles were prepared from the reaction of 4,5-dichloro-1,2,3-dithiazolium chloride (Appel salt) and the corresponding anthranilonitriles. Reaction of the 1,2,3-dithiazolimines with DBU (3 equiv) at –5 °C gave the corresponding 2-cyano-cyanothioformanilides in near quantitative yields. Treatment of 2-(4-chloro-5*H*-1,2,3-dithiazol-5-ylideneamino)benzonitrile with DBU (4 equiv) at –5 to +20 °C gave 2-isothiocyanatobenzonitrile in 96% yield. The latter compound was also formed directly from 2-cyano-cyanothioformanilide on treatment with DBU (1 equiv) in 95% yield. A tentative mechanism for the DBU-mediated dithiazole to cyanothioformanilide transformation is proposed and all compounds were fully characterized.

Key words: Appel salt, DBU, Cyanothioformanilide, isothiocyanate

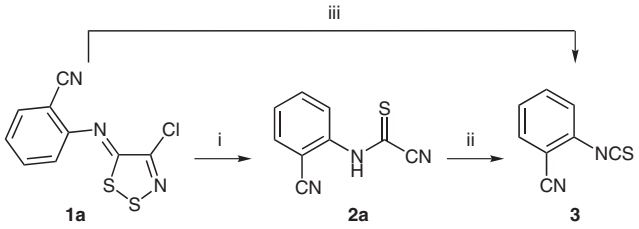
Cyanothioformanilides (thiooxanilonitriles) demonstrate herbicidal activity,[1] and have been used extensively for the preparation of various heterocycles including pyrroles,[2a,b] imidazoles,[3] oxazoles,[4] 1,3,4-thiadiazoles,[5] quinazolines,[6] and other fused heterocycles.[7] Furthermore, cyanothioformanilides participate in Diels–Alder[8] and ene-reactions,[9] they can be N-aroylated[10] and, upon addition of water, hydrogen sulfide or hydroxylamine to the nitrile, afford aminooxothioacetylanilines, aminothioxothioacetylanilines (*N*-aryldithioxamides)[3d,11] or amidinothioformylanilines,[4c,12] respectively.

Cyanothioformanilides are traditionally prepared by the reaction of *N*-aryl isothiocyanates with cyanide,[3j,4c,6a,7f,g,8c,13] or bis(dialkylamino)acetonitriles[14] and also via dethiohydration of *N*-aryldithiooxamides,[13d,15] thionation–dethiohydration of *N*-arylthiooxalamides,[15] and thionation–dehydration of aryloxalamides.[15] More recent methods involve treating 2-(4-chloro-5*H*-1,2,3-dithiazol-5-ylideneamino)benzenes with either the oxidizing agent *m*-chloroperoxybenzoic acid (MCPBA),[16] the reducing agent sodium cyanoborohydride ($NaBH_3CN$),[17] or with nucleophilic (thiophilic) reagents such as aqueous sodium hydroxide,[18] hydroxylamine,[19] *tert*-butylamine,[20] tryptamine,[21] *o*-aminophenethylamine and *o*-phenylenediamine,[22] triphenylphosphoraneylidenes,[23] triphenylphosphine in moist dichloromethane,[24] and through the use of ethylmagnesium bromide (1 equiv).[24h,25]

While the use of triphenylphosphine (2 equiv) was reported to give good yields of the cyanothioformanilides, it was not possible to obtain 2-cyano-cyanothioformanilide (**2a**) from the reaction of 2-(4-chloro-5*H*-1,2,3-dithiazol-5-ylideneamino)benzonitrile (**1a**) despite the preparation of the 4,5-dimethoxy analogue in high yield.[24c] Nevertheless Kim et al. successfully isolated 2-cyano-cyanothioformanilide (**2a**) from the reaction of the dithiazolimine **1a** with either $NH_2OH{\cdot}HCl$ (4 equiv) in pyridine at ~20 °C for 4 h (27%)[19] or as a by-product from reaction with phosphoraneylidenes in low yield (8%).[23] As part of our ongoing investigations of 4,5-dichloro-1,2,3-dithiazolium chloride (Appel salt)[26] and our desire to study the chemistry of 2-cyano-cyanothioformanilides **2**, we required an efficient synthesis that tolerated a range of aryl substituents. Here, we describe the reaction of 2-(4-chloro-5*H*-1,2,3-dithiazol-5-ylideneamino)benzonitriles **1** with 1,8-diazabicyclo[5.4.0]undec-7-ene (DBU), which affords the desired 2-cyano-cyanothioformanilides **2** in near quantitative yields.

Treatment of 2-(4-chloro-5*H*-1,2,3-dithiazol-5-ylideneamino)benzonitrile (**1a**) with only DBU (3 equiv) in dichloromethane at ca. –5 °C gave near quantitative conversion of dithiazolimine **1a** into 2-cyano-cyanothioformanilide (**2a**) and no sulfur formation could be observed by TLC. The use of an additional equivalent of DBU led to the clean formation of 2-isothiocyanatobenzonitrile (**3**), which could also be formed directly from a pure sample of 2-cyano-cyanothioformanilide (**1a**; Scheme 1). No reaction occurred between the dithiazolimine **1a** and three equivalents of either pyridine, 1,4-diazabicyclo[2.2.2]octane (DABCO), 4-(*N*,*N*-dimethylamino)pyridine (DMAP) or triethylamine in dichloromethane at ~20 °C.

The high-yielding formation of the isothiocyanate **3** is worthy of note; since 1995, only four reports have appeared on the conversion of 2-(4-chloro-5*H*-1,2,3-dithia-



Scheme 1 *Reagents and conditions*: (i) DBU (3 equiv), CH_2Cl_2, –5 °C, 5 min, 93%; (ii) DBU (1 equiv), 20 °C, 0.5 h, 95%; (iii) DBU (4 equiv), CH_2Cl_2, –5 to +20 °C, 0.5 h, 96%.

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zol-5-ylideneamino)benzenes into *N*-aryl isothiocyanates. These have involved the use of either MCPBA,[16] ethylmagnesium bromide (2 equiv) in hot anhydrous THF under an argon atmosphere,[24f,h,25] or sodium hydride (2.2 equiv) in anhydrous THF at 67 °C for 18 hours.[24h] Furthermore, only two methods have appeared on the conversion of cyanothiofomanilides into *N*-aryl isothiocyanates using either ethylmagnesium bromide (2 equiv) in hot, anhydrous THF under an argon atmosphere,[24h,25] or in neat 2,6-lutidine using microwave irradiation.[24h] Despite this, the conversion of the cyanothioformanilide **2a** into isothiocyanate **3** in the presence of DBU (1 equiv) was not surprising. A quick screen of alternative 3° amine bases (1 equiv) in dichloromethane at ~20 °C showed that pyridine was unreactive, whereas the use of DABCO or DMAP led to incomplete conversion after two days, and that triethylamine could effect the conversion slowly (10 h) to give the isothiocyanate **3** in 65% yield. The unusual reactivity of dithiazole towards DBU was, however, at first unclear. None of the alternative bases screened (pyridine, DABCO, DMAP, and Et_3N) under similar reaction conditions (3 equiv base at ~20 °C in CH_2Cl_2) showed any reactivity.

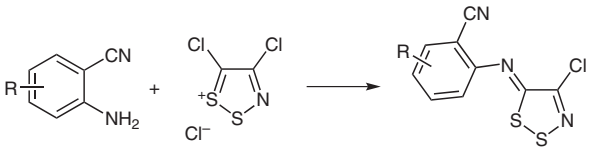
DBU and DBN are commonly used to effect base-induced dehydrohalogenations and other eliminations to produce carbon–carbon and carbon–heteroatom multiple bonds.[27] As such, these bicyclic amidines are often referred to as non-nucleophilic strong bases.[28] Nevertheless, a careful search of the literature revealed multiple reports of nucleophilic behavior for both DBU and DBN, notably in reactions with either phosphorus[29] or carbon[30] electrophiles to afford adducts sporting new nitrogen–phosphorus and nitrogen–carbon bonds, respectively. On the basis that, under identical conditions, DMAP failed to react with the 1,2,3-dithiazolimine **1a** it can be qualitatively said that DBU was a more powerful nucleophile, or at least more thiophilic towards the 1,2,3-dithiazolimine **1a**. Similar differences between the reactivity of DMAP and DBU have been reported.[31] The enhanced nucleophilicity was not altogether unsurprising considering the enamine-like character of the bicyclic amidine.[32]

The facile conversion of 1,2,3-dithiazolimine **1a** into 2-cyano-cyanothioformanilide (**2a**) was extended to a wider range of 2-(4-chloro-5*H*-1,2,3-dithiazol-5-ylideneamino)benzonitriles **1b**–**g**, which were readily prepared from the corresponding anthranilonitriles **4a**–**g** and 4,5-dichloro-1,2,3-dithiazolium chloride **5** (Table 1).

In general, the reaction of the dithiazolimines **1** with DBU (3 equiv) at ca. –5 °C rapidly gave the desired 2-cyano-cyanothioformanilides **2** in high yield (Table 2). In a couple of examples where the yield was significantly lower than 90%, the reactions could be initiated at ca. –78 °C and, under these conditions, the products were obtained in yields >90%.

A tentative mechanistic rationale for the reaction can be proposed as follows. Nucleophilic attack via the DBU amidine nitrogen at the dithiazole S(2) ring sulfur and subsequent ring-opening can afford the disulfide **6**. A second equivalent of DBU could then abstract HCl to give the neutral disulfide **7**. Further nucleophilic attack by a third equivalent of DBU could cleave the disulfide S–S bond to ultimately give the cyanothioformanilide and the neutral sulfane **8** (Scheme 2).

Table 1 Reaction of Anthranilonitriles **4** with 4,5-Dichloro-1,2,3-dithiazolium Chloride (**5**) Followed by Treatment with Pyridine[a]

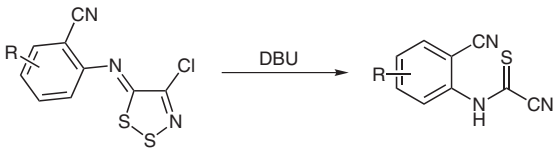


4a–g **5** **1a–g**

4	R	Product	Yield (%)
4a	H	**1a**	92
4b	6-Me	**1b**	91
4c	5-O_2N	**1c**	80
4d	4-Cl	**1d**	87
4e	5-Cl	**1e**	86
4f	4-MeO	**1f**	74
4g	4,5-$(MeO)_2$	**1g**	76

[a] Reaction conditions: **4** (0.65 mmol), **5** (1 equiv), CH_2Cl_2, ~20 °C, 1 h then pyridine (2 equiv), ~20 °C, 2 h.

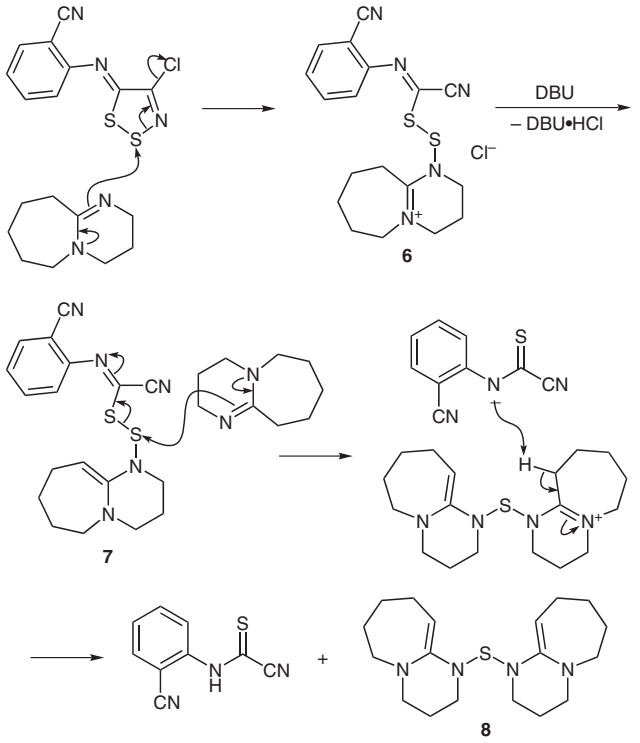
Table 2 Reaction of 2-(4-Chloro-5*H*-1,2,3-dithiazol-5-ylideneamino)benzonitriles **1** with DBU



1a–g **2a–g**

1	R	Temp (°C)	Time (min)	Product	Yield (%)
1a	H	– 5	5	**2a**	93
1b	6-Me	– 5	5	**2b**	94
1c	5-O_2N	– 5	10	**2c**	69
1c	5-O_2N	–78 to 20	45	**2c**	93
1d	4-Cl	– 5	15	**2d**	82
1d	4-Cl	–78 to 20	35	**2d**	91
1e	5-Cl	– 5	15	**2e**	87
1f	4-MeO	– 5	15	**2f**	95
1g	4,5-$(MeO)_2$	– 5	15	**2g**	88

[a] Reaction conditions: **1** (0.40 mmol), DBU (3 equiv), anhyd CH_2Cl_2 (2 mL).



Scheme 2

It is worthy of note that the sulfane sulfur could migrate from N to C(6) and similar N–P to C(6)–P migrations have been reported with DBU adducts.[29i] While isolation of the anticipated sulfane **8** was not successful, the need for three equivalents of DBU was confirmed, since the use of less than this amount gave incomplete conversion of the starting dithiazolimine. The absence of elemental sulfur from the reaction mixture tentatively added support to the entrapment of the sulfur, possibly as the sulfane.

Treatment of 2-(4-chloro-5*H*-1,2,3-dithiazol-5-ylideneamino)benzonitriles **1a–g** with DBU (3 equiv) in dichloromethane at ambient or sub-ambient temperatures provides a simple and high-yielding protocol for the preparation of 2-cyano-cyanothioformamides **2a–g**. In one case, 2-(4-chloro-5*H*-1,2,3-dithiazol-5-ylideneamino)benzonitrile (**1a**) was reacted with DBU (4 equiv) to afford 2-isothiocyanatobenzonitrile (**3**) in high yield. These conditions provide the most efficient route to this class of cyanothioformanilides found to date.

CH_2Cl_2 was freshly distilled from CaH_2 under argon. Reactions were protected from atmospheric moisture by $CaCl_2$ drying tubes. Anhydrous Na_2SO_4 was used for drying organic extracts, and all volatiles were removed under reduced pressure. All reaction mixtures and column eluents were monitored by thin-layer chromatography using commercial glass-backed TLC plates (Merck Kieselgel 60 F_{254}); the plates were observed under UV light at 254 and 365 nm. The technique of dry flash chromatography was used throughout for all non-TLC-scale chromatographic separations using Merck Silica Gel 60 (<0.063 mm). Melting points were determined using a PolyTherm-A, Wagner & Munz, Koefler-Hotstage Microscope apparatus. Solvents used for recrystallization are indicated after the melting point. UV spectra were obtained using a Perkin–Elmer Lambda-25 UV/Vis spectrophotometer; inflections are identified by the abbreviation 'inf'. IR spectra were recorded on a Shimadzu FTIR-NIR Prestige-21 spectrometer with a Pike Miracle Ge ATR accessory; strong (s), medium (m) and weak (w) peaks are abbreviated. ^{1}H and ^{13}C NMR spectra were recorded on a Bruker Avance 300 instrument (300 and 75 MHz, respectively). Deuterated solvents were used for homonuclear lock and the signals are referenced to the deuterated solvent peaks. Low resolution (EI) mass spectra were recorded on a Shimadzu Q2010 GCMS with direct inlet probe. 4,5-Dichloro-1,2,3-dithiazolium chloride **1** was prepared according to the literature procedure.[33]

2-(4-Chloro-5*H*-1,2,3-dithiazol-5-ylideneamino)benzonitrile (1a); Typical Procedure

To a stirred solution of 4,5-dichloro-1,2,3-dithiazolium chloride (**5**; 352.4 mg, 1.69 mmol) in CH_2Cl_2 (4 mL) at ~20 °C and protected with $CaCl_2$ drying tube, was added 2-aminobenzonitrile (**4a**; 200 mg, 1.69 mmol). After 1 h, pyridine (273.4 μL, 3.38 mmol, 2 equiv) was added dropwise, and the reaction mixture was stirred at ~20 °C for an additional 2 h. The reaction mixture was adsorbed onto silica and chromatography (hexane) gave S_8 (traces). Further elution (hexane–CH_2Cl_2, 8:2) gave 4-chloro-5*H*-1,2,3-dithiazole-5-thione (**9**; 10 mg, 6%) and (hexane–CH_2Cl_2, 2:8) gave the title compound **1a**.

Yield: 395 mg (92%); yellow crystals; mp 125–126 °C (Lit.[21] 128 °C) (cyclohexane–CH_2Cl_2).

IR: 3088 (w), 3025 (w; ArCH), 2238 (m; C≡N), 1593 (s), 1562 (s), 1479 (s), 1145 (s), 857 (s), 771 (s) cm^{-1}.

^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.76–7.65 (m, 2 H, Ar*H*), 7.35–7.29 (m, 2 H, Ar*H*).

^{13}C NMR (75 MHz, $CDCl_3$): δ = 161.5, 153.2, 148.0, 134.4 (Ar*C*H), 134.0 (Ar*C*H), 126.3 (Ar*C*H), 117.4 (Ar*C*H), 116.3 (C≡N), 106.0 (*C*C≡N).

^{13}C NMR (75 MHz, DEPT-135, DMSO-d_6): δ = 134.4 (Ar*C*H), 134.0 (Ar*C*H), 125.3 (Ar*C*H), 117.4 (Ar*C*H).

MS (EI): *m*/*z* (%) = 255 (35) [M$^+$ + 2], 253 (84) [M$^+$], 192 (99), 160 (12), 154 (18), 128 (11), 125 (10), 116 (4), 102 (71), 93 (13), 75 (53), 64 (100), 51 (31).

UV/Vis (CH_2Cl_2): λ_{max} (log ε) = 231 (3.33), 268 (inf; 2.79), 302 (2.65), 379 (2.92), 398 (inf; 2.85), 423 nm (inf; 2.56); identical to an authentic sample.

2-(4-Chloro-5*H*-1,2,3-dithiazol-5-ylideneamino)-6-methylbenzonitrile (1b)

Similar treatment of 2-amino-6-methylbenzonitrile (**4b**; 200 mg, 1.52 mmol), 4,5-dichloro-1,2,3-dithiazolium chloride (**5**; 315.9 mg, 1.52 mmol) and pyridine (245.9 μL, 3.04 mmol, 2 equiv) in CH_2Cl_2 (4 mL) gave the title compound **1b**.

Yield: 369.3 mg (91%); yellow cotton fibers; mp 109–110 °C (cyclohexane–EtOH).

IR: 2232 (w; C≡N), 1601 (m), 1582 (s), 1461 (m), 1149 (s), 961 (s), 790 (s), 779 (s) cm^{-1}.

^{1}H NMR (300 MHz, CD_2Cl_2): δ = 7.56 (dd, *J* = 7.8, 7.8 Hz, 1 H, Ar*H*-4), 7.20 (d, *J* = 7.8 Hz, 1 H, Ar*H*-3 or 5), 7.16 (d, *J* = 8.1 Hz, 1 H, Ar*H*-3 or 5), 2.57 (s, 3 H, CH_3).

^{13}C NMR (75 MHz, CD_2Cl_2): δ = 161.6, 153.8, 148.35, 144.55, 134.1 (Ar*C*H), 127.85 (Ar*C*H), 115.75 (*C*≡N), 114.5 (Ar*C*H), 107.1 (*C*C≡N), 20.8 (*C*H$_3$).

^{13}C NMR (75 MHz, DEPT-135, CD_2Cl_2): δ = 134.1 (Ar*C*H), 127.85 (Ar*C*H), 114.5 (Ar*C*H), 20.8 (*C*H$_3$).

MS (EI): *m*/*z* (%) = 269 (27) [M$^+$ + 2], 267 (65) [M$^+$], 206 (87), 174 (5), 168 (13), 142 (12), 116 (22), 115 (21), 102 (4), 89 (28), 76 (6), 70 (6), 64 (100), 51 (5).

UV/Vis (CH_2Cl_2): λ_{max} (log ε) = 232 (3.04), 271 (inf; 2.47), 378 nm (2.63).

Anal. Calcd for $C_{10}H_6ClN_3S_2$: C, 44.9; H, 2.3; N, 15.7. Found: C, 44.9; H, 2.3; N, 15.7.

2-(4-Chloro-5*H*-1,2,3-dithiazol-5-ylideneamino)-5-nitrobenzonitrile (1c)

Similar treatment of 2-amino-5-nitrobenzonitrile (**4c**; 200 mg, 1.36 mmol), 4,5-dichloro-1,2,3-dithiazolium chloride (**5**; 283.6 mg, 1.36 mmol) and pyridine (220 μL, 2.72 mmol, 2 equiv) in CH_2Cl_2 (4 mL) gave the title compound **1c**.

Yield: 324.2 mg (80%); red powder; mp 181–182 °C (EtOH).

IR: 3099 (w) and 3077 (w; ArCH), 2234 (w; C≡N), 1586 (m), 1569 (s), 1515 (s), 1345 (s), 914 (s), 873 (s), 796 (s) cm^{-1}.

^{1}H NMR (300 MHz, DMSO-d_6): δ = 8.83 (d, *J* = 2.5 Hz, 1 H, Ar*H*-6), 8.59 (dd, *J* = 9.0, 2.6 Hz, 1 H, Ar*H*-4), 7.72 (d, *J* = 9.0 Hz, 1 H, Ar*H*-3).

^{13}C NMR (75 MHz, DMSO-d_6): δ = 165.1, 158.2, 146.7, 144.1, 130.6 (Ar*C*H), 130.1 (Ar*C*H), 119.2 (Ar*C*H), 115.0 (C≡N), 106.0 (*C*C≡N).

^{13}C NMR (75 MHz, DEPT-135, DMSO-d_6): δ = 130.6 (Ar*C*H), 130.1 (Ar*C*H), 119.2 (Ar*C*H).

MS (EI): *m*/*z* (%) = 300 (6) [M$^+$ + 2], 298 (14) [M$^+$], 237 (15), 205 (1), 175 (3), 157 (6), 127 (8), 125 (8), 115 (6), 100 (13), 93 (10), 88 (7), 75 (15), 70 (8), 64 (100), 50 (13).

UV/Vis (CH_2Cl_2): λ_{max} (log ε) = 490 (2.83), 305 (2.77), 265 (2.81), 231 nm (3.07).

Anal. Calcd for $C_9H_3Cl_2N_4O_2S_2$: C, 36.2; H, 1.0; N, 18.8. Found: C, 36.2; H, 1.0; N, 18.6.

4-Chloro-2-(4-chloro-5*H*-1,2,3-dithiazol-5-ylideneamino)benzonitrile (1d)

Similar treatment of 2-amino-4-chlorobenzonitrile (**4d**; 200 mg, 1.31 mmol), 4,5-dichloro-1,2,3-dithiazolium chloride (**5**; 273.1 mg, 1.31 mmol) and pyridine (212 μL, 2.62 mmol, 2 equiv) in CH_2Cl_2 (4 mL) gave the title compound **1d**.

Yield: 327.1 mg (87%); yellow powder; mp 177–178 °C (cyclohexane–CH_2Cl_2).

IR: 3069 (w; ArCH), 2237 (m; C≡N), 1587 (s), 1552 (s), 1148 (s), 919 (s), 875 (s), 858 (s), 832 (s), 799 (s), 753 (s) cm^{-1}.

^{1}H NMR (300 MHz, DMSO-d_6): δ = 7.98 (d, *J* = 8.4 Hz, 1 H, Ar*H*-6), 7.60 (d, *J* = 1.9 Hz, 1 H, Ar*H*-3), 7.47 (dd, *J* = 8.4, 2.0 Hz, 1 H, Ar*H*-5).

^{13}C NMR (75 MHz, DMSO-d_6): δ = 164.7, 155.0, 146.3, 139.8, 135.8 (Ar*C*H), 126.3 (Ar*C*H), 118.3 (Ar*C*H), 115.9 (C≡N), 103.3 (*C*C≡N).

^{13}C NMR (75 MHz, DEPT-135, DMSO-d_6): δ = 135.8 (Ar*C*H), 126.3 (Ar*C*H), 118.3 (Ar*C*H).

MS (EI): *m*/*z* (%) = 291 (5) [M$^+$ + 4], 289 (26) [M$^+$ + 2], 287 (35) [M$^+$], 228 (36), 226 (76), 194 (5), 188 (6), 162 (6), 136 (10), 127 (9), 125 (7), 100 (30), 93 (10), 84 (8), 75 (13), 64 (100), 50 (9).

UV/Vis (CH_2Cl_2): λ_{max} (log ε) = 233 (3.25), 272 (inf; 2.76), 337 nm (2.78).

Anal. Calcd for $C_9H_3Cl_2N_3S_2$: C, 37.5; H, 1.05; N, 14.6. Found: C, 37.6; H, 1.1; N, 14.7.

5-Chloro-2-(4-chloro-5*H*-1,2,3-dithiazol-5-ylideneamino)benzonitrile (1e)

Similar treatment of 2-amino-5-chlorobenzonitrile (**4e**; 200 mg, 1.31 mmol), 4,5-dichloro-1,2,3-dithiazolium chloride (**5**; 273.1 mg, 1.31 mmol) and pyridine (212 μL, 2.62 mmol, 2 equiv) in CH_2Cl_2 (4 mL) gave the title compound **1e**.

Yield: 323.3 mg (86%); yellow cotton fibers; mp 147–148 °C (cyclohexane–CH_2Cl_2).

IR: 3071 (w; ArCH), 2237 (w; C≡N), 1568 (s), 1492 (s), 876 (s), 865 (s), 816 (s), 769 (s) cm^{-1}.

^{1}H NMR (300 MHz, DMSO-d_6): δ = 8.09 (d, *J* = 2.4 Hz, 1 H, Ar*H*-6), 7.85 (dd, *J* = 8.8, 2.4 Hz, 1 H, Ar*H*-4), 7.51 (d, *J* = 8.8 Hz, 1 H, Ar*H*-3).

^{13}C NMR (75 MHz, DMSO-d_6): δ = 163.5, 152.0, 146.7, 135.3 (Ar*C*H), 133.5 (Ar*C*H), 129.9, 119.7 (Ar*C*H), 115.4 (*C*≡N), 106.9 (*C*C≡N).

^{13}C NMR (75 MHz, DEPT-135, DMSO-d_6): δ = 135.3 (ArCH), 133.5 (ArCH), 119.7 (ArCH).

MS (EI): *m*/*z* (%) = 291 (8) [M$^+$ + 4], 289 (28) [M$^+$ + 2], 287 (37) [M$^+$], 228 (21), 226 (47), 194 (9), 188 (7), 162 (9), 136 (12), 127 (7), 125 (6), 109 (5), 100 (31), 93 (8), 75 (10), 70 (8), 64 (100), 50 (8).

UV/Vis (CH_2Cl_2): λ_{max} (log ε) = 430 (inf; 2.39), 383 (2.78), 313 (2.39), 247 (2.96), 229 nm (3.03).

Anal. Calcd for $C_9H_3Cl_2N_3S_2$: C, 37.5; H, 1.05; N, 14.6. Found: C, 37.6; H, 1.1; N, 14.7.

2-(4-Chloro-5*H*-1,2,3-dithiazol-5-ylideneamino)-4-methoxybenzonitrile (1f)

Similar treatment of 2-amino-4-methoxybenzonitrile (**4f**; 200 mg, 1.35 mmol), 4,5-dichloro-1,2,3-dithiazolium chloride (**5**; 281.8 mg, 1.35 mmol) and pyridine (218 μL, 2.70 mmol, 2 equiv) in CH_2Cl_2 (4 mL) gave the title compound **1f**.

Yield: 282.7 mg (74%); orange needles; mp 163–164 °C (cyclohexane–CH_2Cl_2).

IR: 2965 (w) and 2835 (w; CH_3), 2221 (s; C≡N), 1589 (s), 1495 (s), 1249 (s), 1095 (s), 1022 (s), 871 (s), 821 (s), 756 (s) cm^{-1}.

^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.66 (d, *J* = 8.7 Hz, 1 H, Ar*H*-6), 6.81 (dd, *J* = 8.7, 2.4 Hz, 1 H, Ar*H*-5), 6.75 (d, *J* = 2.4 Hz, 1 H, Ar*H*-3), 3.88 (s, 3 H, CH_3).

^{13}C NMR (75 MHz, DMSO-d_6): δ = 164.3, 163.6, 156.0, 146.3, 135.7 (Ar*C*H), 116.9 (C≡N), 112.4 (Ar*C*H), 103.4 (Ar*C*H), 95.7 (*C*C≡N), 56.1 (CH_3).

^{13}C NMR (75 MHz, DEPT-135, DMSO-d_6): δ = 135.7 (Ar*C*H), 112.4 (Ar*C*H), 103.3 (Ar*C*H), 56.1 (CH_3).

MS (EI): *m*/*z* (%) = 285 (19) [M$^+$ + 2], 283 (47) [M$^+$], 222 (42), 190 (4), 184 (7), 158 (100), 147 (11), 128 (24), 117 (15), 115 (19), 102 (15), 93 (8), 89 (18), 76 (11), 64 (55), 50 (7).

UV/Vis (CH_2Cl_2): λ_{max} (log ε) = 234 (3.30), 256 (inf; 3.17), 272 (inf; 2.88), 302 (2.53), 367 (2.75), 411 nm (inf; 2.51).

Anal. Calcd for $C_{10}H_5ClN_3OS_2$: C, 42.3; H, 2.1; N, 14.8. Found: C, 42.4; H, 2.0; N, 14.8.

2-(4-Chloro-5*H*-1,2,3-dithiazol-5-ylideneamino)-4,5-dimethoxybenzonitrile (1g)

Similar treatment of 2-amino-4,5-dimethoxybenzonitrile (**4g**; 200 mg, 1.12 mmol), 4,5-dichloro-1,2,3-dithiazolium chloride (**5**; 233.5 mg, 1.12 mmol) and pyridine (181 μL, 2.24 mmol, 2 equiv) in CH_2Cl_2 (4 mL) gave the title compound **1g**.

Yield: 266.4 mg (76%); orange crystals; mp 156–157 °C (cyclohexane–EtOH).

IR: 3002 (w; ArCH), 2961 (w), 2829 (w; CH_3), 2224 (m, C≡N), 1591 (s), 1498 (s), 1281 (s), 1222 (s), 1103 (s), 902 (s), 763 (s) cm^{-1}.

^1H NMR (300 MHz, $CDCl_3$): δ = 7.12 (s, 1 H, Ar*H*-6), 6.81 (s, 1 H, Ar*H*-3), 3.93 (s, 3 H, CH_3O), 3.93 (s, 3 H, CH_3O).

^{13}C NMR (75 MHz, DMSO-d_6): δ = 162.6, 153.9, 148.8, 146.6, 146.5, 117.0 (*C*≡N), 115.0 (Ar*C*H), 101.55 (Ar*C*H), 95.1 (*C*C≡N), 56.3 (CH_3O), 56.2 (CH_3O).

^{13}C NMR (75 MHz, DEPT-135, DMSO-d_6): δ = 115.0 (Ar*C*H), 101.6 (Ar*C*H), 56.3 (CH_3O), 56.2 (CH_3O).

MS (EI): *m*/*z* (%) = 315 (26) [M^+ + 2], 313 (63) [M^+], 300 (7), 298 (16), 220 (11), 214 (6), 205 (8), 188 (100), 177 (9), 173 (20), 162 (8), 145 (18), 134 (8), 119 (11), 117 (22), 104 (15), 102 (16), 90 (20), 83 (8), 76 (21), 70 (7), 64 (33), 51 (7).

UV/Vis (CH_2Cl_2): λ_{max} (log ε) = 350 (inf; 2.59), 379 (inf; 2.68), 398 (2.72), 418 (inf; 2.69), 443 nm (inf; 2.48).

Anal. Calcd for $C_{11}H_8ClN_3O_2S_2$: C, 42.1; H, 2.6; N, 13.4. Found: C, 42.3; H, 2.6; N, 13.3.

2-(Cyanothioformamido)benzonitrile (2a); Typical Procedure

To a stirred solution of 2-(4-chloro-5*H*-1,2,3-dithiazol-5-ylideneamino)benzonitrile (**1a**; 100 mg, 0.39 mmol) in distilled CH_2Cl_2 (2 mL) cooled to ca. –5 °C and protected with a $CaCl_2$ drying tube, was added in one portion, DBU (175 μL, 1.17 mmol, 3 equiv). After 5 min at ca. –5 °C, no starting material remained (TLC) and the reaction mixture was adsorbed onto silica. Chromatography (CH_2Cl_2) gave the title compound **2a**.

Yield: 67.8 mg (93%); orange powder; mp 100–101 °C (Lit.[19] 104–105 °C) (pentane–CH_2Cl_2).

IR: 3113 (w) and 3036 (w; ArCH), 2241 (m; C≡N), 1547 (m), 1477 (m), 1450 (m), 1364 (s), 1115 (m), 752 (s) cm^{-1}.

^1H NMR (300 MHz, $CDCl_3$): δ = 9.79 (br s, 1 H, NH), 8.23 (d, *J* = 7.8 Hz, 1 H, Ar*H*), 7.81 (d, *J* = 7.8 Hz, 1 H, Ar*H*), 7.73 (dd, *J* = 8.0, 7.95 Hz, 1 H, Ar*H*), 7.50 (dd, *J* = 7.1, 7.1 Hz, 1 H, Ar*H*).

^{13}C NMR (75 MHz, $CDCl_3$): δ = 164.6 (*C*=S), 138.3 (Ar*C*-2), 134.0 (Ar*C*H), 133.8 (Ar*C*H), 128.6 (Ar*C*H), 125.9 (Ar*C*H), 115.5 (C≡N), 113.0 (C≡N), 107.8 (Ar*C*-1, *C*C≡N).

^{13}C NMR (75 MHz, DEPT-135, $CDCl_3$): δ = 134.0 (Ar*C*H), 133.8 (Ar*C*H), 128.6 (Ar*C*H), 125.9 (Ar*C*H).

MS (EI): *m*/*z* (%) = 187 (100) [M^+], 186 (91), 160 (19), 135 (37), 117 (3), 108 (9), 102 (33), 70 (24), 61 (3), 51 (2).

UV/Vis (CH_2Cl_2): λ_{max} (log ε) = 228 (3.60), 250 (3.45), 333 nm (3.57); identical to an authentic sample.

2-(Cyanothioformamido)-6-methylbenzonitrile (2b)

Similarly, treatment of 2-(4-chloro-5*H*-1,2,3-dithiazol-5-ylideneamino)-6-methylbenzonitrile (**1b**; 100 mg, 0.37 mmol) cooled to ca. –5 °C with DBU gave, after chromatography (CH_2Cl_2) the title compound **2b**.

Yield: 71.4 mg (96%); yellow cotton fibers; mp 128–129 °C (cyclohexane–EtOH).

IR: 3229 (w), 3146 (w), 2986 (w), 2239 (m; C≡N), 1566 (m), 1474 (s), 1373 (s), 1179 (m), 1117 (m), 789 (s) cm^{-1}.

^1H NMR (300 MHz, CD_2Cl_2): δ = 9.75 (br s, 1 H, NH), 7.90 (d, *J* = 8.1 Hz, 1 H, Ar*H*-3 or 5), 7.63–7.55 (m, 1 H, Ar*H*-4), 7.43–7.36 (m, 1 H, Ar*H*-3 or 5), 2.61 (s, 3 H, CH_3).

^{13}C NMR (75 MHz, DMSO-d_6): δ = 165.4 (C=S), 143.5 (Ar*C*), 139.3 (Ar*C*), 133.9 (Ar*C*H), 130.0 (Ar*C*H), 124.6 (Ar*C*H), 114.8 (C≡N), 113.5 (C≡N), 109.7 (Ar*C*-1, *C*C≡N), 20.0 (*C*H_3).

^{13}C NMR (75 MHz, DEPT-135, DMSO-d_6): δ = 133.85 (Ar*C*H), 130.0 (Ar*C*H), 124.6 (Ar*C*H), 20.0 (CH_3).

MS (EI): *m*/*z* (%) = 201 (56) [M^+], 200 (31), 186 (14), 174 (100), 168 (15), 149 (14), 142 (17), 131 (6), 116 (87), 104 (16), 89 (43), 77 (25), 70 (24), 63 (25), 51 (15).

UV/Vis (CH_2Cl_2): λ_{max} (log ε) = 226 (3.71), 255 (inf; 3.38), 337 nm (3.65).

Anal. Calcd for $C_{10}H_7N_3S$: C, 59.7; H, 3.5; N, 20.9. Found: C, 59.7; H, 3.5; N, 20.9.

2-(Cyanothioformamido)-5-nitrobenzonitrile (2c)

Similarly, treatment of 2-(4-chloro-5*H*-1,2,3-dithiazol-5-ylideneamino)-5-nitrobenzo-nitrile (**1c**; 100 mg, 0.34 mmol) cooled to ca. –78 °C with DBU gave, after chromatography (CH_2Cl_2–*tert*-butyl methyl ether, 50:50), the title compound **2c**.

Yield: 74.9 mg (95%); red powder; mp >300 °C (pentane–CH_2Cl_2).

IR: 3611 (w), 3399 (w; NH), 3053 (w; ArCH), 2236 (w; C≡N), 1597 (m), 1483 (s), 1443 (s), 1346 (s), 1261 (m), 1177 (m), 843 (m), 733 (m) cm^{-1}.

^1H NMR (300 MHz, DMSO-d_6): δ = 8.58 (d, *J* = 2.7 Hz, 1 H, Ar*H*-6), 8.33 (dd, *J* = 2.7, 9.0 Hz, 1 H, Ar*H*-4), 7.64 (d, *J* = 9.0 Hz, 1 H, Ar*H*-3); NH missing.

^{13}C NMR (75 MHz, DMSO-d_6): δ = 162.7, 160.75, 141.5, 128.85 (Ar*C*H), 128.0 (Ar*C*H), 122.85 (Ar*C*H), 117.7 (C≡N), 116.1 (C≡N), 105.7 (*C*C≡N).

^{13}C NMR (75 MHz, DEPT-135, DMSO-d_6): δ = 128.9 (Ar*C*H), 128.0 (Ar*C*H), 122.85 (Ar*C*H).

MS (EI): *m*/*z* (%) = 232 (19) [M^+], 205 (100), 199 (8), 186 (6), 175 (36), 159 (37), 147 (24), 132 (14), 115 (26), 99 (7), 94 (14), 88 (17), 75 (21), 70 (16), 64 (21), 57 (14), 50 (13).

UV/Vis (CH_2Cl_2): λ_{max} (log ε) = 228 (3.10), 254 (2.97), 283 (2.75), 332 (2.79), 348 nm (2.85).

Anal. Calcd for $C_9H_4N_4O_2S$: C, 46.55; H, 1.7; N, 24.1. Found: C, 46.5; H, 1.8; N, 24.1.

4-Chloro-2-(cyanothioformamido)benzonitrile (2d)

Similarly, treatment of 4-chloro-2-(4-chloro-5*H*-1,2,3-dithiazol-5-ylideneamino)benzonitrile (**1d**; 100 mg, 0.35 mmol) cooled to ca. –78 °C with DBU gave, after chromatography (CH_2Cl_2) the title compound **2d**.

Yield: 69.6 mg (90%); yellow powder; mp 85–86 °C (pentane–CH_2Cl_2).

IR: 3568 (w), 3374 (m; NH), 3096 (w; ArCH), 2232 (m) and 2216 (w; C≡N), 1632 (m), 1580 (m), 1474 (s), 1456 (s), 1366 (m), 1059 (m), 812 (s) cm^{-1}.

^1H NMR (300 MHz, CD_2Cl_2): δ = 8.19 (br s, 1 H, NH), 7.75–7.72 (m, 2 H, Ar*H*-3 and 6), 7.59 (dd, *J* = 2.1, 8.7 Hz, 1 H, Ar*H*-5).

^{13}C NMR (75 MHz, DMSO-d_6): δ = 162.4 (C=S), 154.6 (Ar*C*), 137.4 (Ar*C*), 134.2 (Ar*C*H), 123.4 (Ar*C*H), 122.3 (Ar*C*H), 117.6 (C≡N), 117.1 (C≡N), 104.7 (*C*C≡N).

^{13}C NMR (75 MHz, DEPT-135, DMSO-d_6): δ = 134.2 (Ar*C*H), 123.4 (Ar*C*H), 122.3 (Ar*C*H).

MS (EI): *m*/*z* (%) = 223 (13) [M^+ + 2], 221 (34) [M^+], 196 (39), 194 (100), 190 (5), 188 (17), 186 (9), 169 (9), 159 (10), 136 (22), 124 (5), 100 (30), 88 (8), 75 (19), 70 (24), 63 (7), 50 (13).

UV/Vis (CH_2Cl_2): λ_{max} (log ε) = 230 (3.05), 259 (inf; 2.84), 264 (inf; 2.80), 327 (2.61), 340 (2.62), 380 nm (inf; 2.23).

Anal. Calcd for $C_9H_4ClN_3S$: C, 48.8; H, 1.8; N, 19.0. Found: C, 48.9; H, 1.9; N, 19.0.

5-Chloro-2-(cyanothioformamido)benzonitrile (2e)
Similarly, treatment of 2-(4-chloro-5*H*-1,2,3-dithiazol-5-ylideneamino)-5-chlorobenzonitrile (**1e**; 100 mg, 0.35 mmol) cooled to ca. –5 °C with DBU gave, after chromatography (CH_2Cl_2), the title compound **2e**.

Yield: 89.4 mg (89%); dark-red crystals; mp 131–132 °C (cyclohexane).

IR: 3271 (m; NH), 3082 (w; ArCH), 2228 (w; C≡N), 1587 (m), 1468 (m), 1406 (m), 1302 (s), 1236 (s), 1163 (s), 1076 (s), 841 (s) cm^{-1}.

^1H NMR (300 MHz, DMSO-d_6): δ = 8.18 (s, 1 H, Ar*H*-6), 7.90 (dd, *J* = 1.5, 7.5 Hz, 1 H, Ar*H*-4), 7.68 (d, *J* = 8.7 Hz, 1 H, Ar*H*-3); NH missing.

^{13}C NMR (75 MHz, DMSO-d_6): δ = 165.4 (C=S), 138.9 (Ar*C*), 134.6 (Ar*C*H), 133.3 (Ar*C*H), 132.9 (Ar*C*), 128.9 (Ar*C*H), 114.7 (C≡N), 113.7 (C≡N), 110.9 (*C*C≡N).

^{13}C NMR (75 MHz, DEPT-135, DMSO-d_6): δ = 134.6 (Ar*C*H), 133.3 (Ar*C*H), 128.9 (Ar*C*H).

MS (EI): *m*/*z* (%) = 223 (37) [M^+ + 2], 221 (82) [M^+], 196 (37), 194 (100), 190 (18), 188 (53), 171 (18), 169 (48), 151 (7), 136 (37), 124 (15), 100 (38), 84 (34), 75 (29), 70 (25), 56 (45).

UV/Vis (CH_2Cl_2): λ_{max} (log ε) = 232 (4.10), 274 (3.43), 346 nm (3.50).

Anal. Calcd for $C_9H_4ClN_3S$: C, 48.8; H, 1.8; N, 19.0. Found: C, 48.8; H, 1.8; N, 18.8.

2-(Cyanothioformamido)-4-methoxybenzonitrile (2f)
Similarly, treatment of 2-(4-chloro-5*H*-1,2,3-dithiazol-5-ylideneamino)-4-methoxybenzonitrile (**1f**; 100 mg, 0.35 mmol) cooled to ca. 0 °C with DBU gave, after chromatography (CH_2Cl_2), the title compound **2f**.

Yield: 73.7 mg (97%); yellow powder; mp 116–117 °C (cyclohexane).

IR: 3205 (w) and 3183 (w; NH), 3038 (w; ArCH), 2236 (m; C≡N), 1614 (s), 1549 (m), 1487 (m), 1449 (m), 1364 (s), 1252 (s), 817 (s) cm^{-1}.

^1H NMR (300 MHz, CD_2Cl_2): δ = 9.80 (br s, 1 H, NH), 7.80 (br s, 1 H, Ar*H*-3), 7.71 (d, *J* = 8.7 Hz, 1 H, Ar *H*-6), 7.05–6.95 (m, 1 H, Ar*H*-5), 3.88 (s, 3 H, CH_3O).

^{13}C NMR (75 MHz, DMSO-d_6): δ = 164.9, 163.3, 142.2 (Ar*C*), 135.1 (Ar*C*H), 116.3 (C≡N), 114.3 (Ar*C*H), 113.9 (C≡N), 112.6 (Ar*C*H), 100.5 (*C*C≡N), 56.1 (*C*H_3O).

^{13}C NMR (75 MHz, DEPT-135, DMSO-d_6): δ = 135.1 (Ar*C*H), 114.3 (Ar*C*H), 112.6 (Ar*C*H), 56.1 (CH_3).

MS (EI): *m*/*z* (%) = 217 (100) [M^+], 201 (7), 190 (42), 186 (26), 184 (21), 175 (6), 165 (23), 160 (11), 147 (15), 132 (16), 120 (11), 117 (15), 102 (12), 89 (14), 77 (20), 70 (21), 63 (17), 50 (9).

UV/Vis (CH_2Cl_2): λ_{max} (log ε) = 217 (inf; 2.99), 229 (3.21), 250 (3.22), 272 (inf; 2.88), 337 nm (2.95).

Anal. Calcd for $C_{10}H_7N_3OS$: C, 55.3; H, 3.3; N, 19.3. Found: C, 55.3; H, 3.3; N, 19.3.

2-(Cyanothioformamido)-4,5-dimethoxybenzonitrile (2g)
Similarly, treatment of 2-(4-chloro-5*H*-1,2,3-dithiazol-5-ylideneamino)-4,5-dimethoxybenzonitrile (**1g**; 100 mg, 0.32 mmol) cooled to ca. –5 °C with DBU gave, after chromatography (CH_2Cl_2), the title compound **2g**.

Yield: 73.7 mg (88%); orange crystals; mp 145–146 °C (cyclohexane–EtOH).

IR: 3198 (w), 3103 (w; NH), 2230 (m; C≡N), 1516 (s), 1354 (s), 1271 (s), 1236 (s), 993 (s), 866 (s), 779 (s) cm^{-1}.

^1H NMR (300 MHz, CD_2Cl_2): δ = 7.83 (s, 1 H, Ar*H*-3), 7.16 (s, 1 H, Ar*H*-5), 3.97 (s, 3 H, CH_3O), 3.96 (3 H, CH_3O); NH missing.

^{13}C NMR (75 MHz, DMSO-d_6): δ = 165.3 (C=S), 153.0 (Ar*C*), 148.4 (Ar*C*), 133.5 (Ar*C*), 116.1 (C≡N), 114.6 (Ar*C*H), 113.5 (C≡N), 110.4 (Ar*C*H), 100.5 (*C*C≡N), 56.3 (CH_3O), 56.2 (CH_3O).

^{13}C NMR (75 MHz, DEPT-135, DMSO-d_6): δ = 114.65 (Ar*C*H), 110.4 (Ar*C*H), 56.3 (CH_3O), 56.2 (CH_3O).

MS (EI): *m*/*z* (%) = 247 (100) [M^+], 232 (7), 220 (50), 214 (15), 205 (27), 195 (35), 180 (21), 177 (28), 162 (13), 150 (10), 134 (13), 119 (17), 104 (13), 90 (7), 83 (7), 76 (15), 70 (23), 50 (11).

UV/Vis (CH_2Cl_2): λ_{max} (log ε) = 230 (3.56), 265 (3.48), 277 (inf; 3.51), 287 (3.56), 331 (inf; 3.07), 346 (3.11), 375 (3.16), 395 nm (inf; 3.07).

Anal. Calcd for $C_{11}H_9N_3O_2S$: C, 53.4; H, 3.7; N, 17.0. Found: C, 53.4; H, 3.8; N, 16.9.

2-Isothiocyanatobenzonitrile (3) from 2-(Cyanothioformamido)benzonitrile (2a)
To a stirred solution of 2-(cyanothioformamido)benzonitrile (**2a**; 100 mg, 0.53 mmol) in distilled CH_2Cl_2 (2 mL) at ~20 °C and protected with a $CaCl_2$ drying tube, was added dropwise, DBU (79.3 μL, 0.53 mmol, 1 equiv). The mixture was then allowed to stir at ~20 °C, until no starting material remained (TLC). The reaction mixture was adsorbed onto silica and purified by chromatography (CH_2Cl_2–*tert*-butyl methyl ether, 9:1) to give the title compound **3**.

Yield: 81.4 mg (96%); colorless needles; mp 66–67 °C (Lit.[24h] 64 °C) (cyclohexane).

IR: 2232m (C≡N), 1624 (m), 1597 (m), 1493 (s), 1377 (m), 1319 (s), 1099 (m), 752 (s).

^1H NMR (300 MHz, $CDCl_3$): δ = 8.26 (d, *J* = 7.8 Hz, 1 H, Ar*H*), 7.80 (d, *J* = 7.8 Hz, 1 H, Ar*H*), 7.73 (dd, *J* = 7.8, 7.8 Hz, 1 H, Ar*H*), 7.50 (dd, *J* = 7.35, 7.35 Hz, 1 H, Ar*H*).

MS (EI): *m*/*z* (%) = 161 (12) [M^+ + 1], 160 (100) [M^+], 133 (7), 116 (11), 102 (41), 91 (4), 76 (36) [C_6H_4], 75 (25), 70 (8), 64 (10), 51 (17), 50 (12), 44 (75), 43 (10); identical to an authentic sample.

2-Isothiocyanatobenzonitrile (3) from 2-(4-Chloro-5*H*-1,2,3-dithiazol-5-ylideneamino)benzonitrile (1a)
To a stirred solution of 2-(4-chloro-5*H*-1,2,3-dithiazol-5-ylideneamino)benzonitrile (**1a**; 100 mg, 0.39 mmol) in distilled CH_2Cl_2 (2 mL) cooled to ca. –5 °C and protected with a $CaCl_2$ drying tube, was added in one portion, DBU (233 μL, 1.56 mmol, 4 equiv). The mixture was then allowed to warm to ~20 °C, until no starting material remained (TLC). The reaction mixture was adsorbed onto silica and purified by chromatography (CH_2Cl_2–*tert*-butyl methyl ether, 9:1) gave the title compound **3**.

Yield: 59.3 mg (95%); colorless needles; mp 66–67 °C (Lit.[24h] 64 °C) (cyclohexane); identical to that described above.

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