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## SYNTHESIS AND CHARACTERIZATION OF SOME NOVEL HETEROANNULATED CHROMENO[4,3-*b*]QUINOLINES

Najla A. Alshaye<sup>a</sup> and Magdy A. Ibrahim<sup>b\*</sup>

<sup>a</sup>Department of Chemistry, College of Science, Princess Nourah bint Abdulrahman University, P.O. Box 84428, Riyadh 11671, Saudi Arabia: naalshaye@pnu.edu.sa

<sup>b</sup>Department of Chemistry, Faculty of Education, Ain Shams University, Roxy, Heliopolis 11757, Cairo, Egypt

\*E-mail: magdy\_ahmed1977@yahoo.com

**Abstract** – The recently synthesized 1-chloro-11-oxo-3,4-dihydro-11*H*-chromeno[4,3-*b*]quinoline-2-carboxaldehyde (**1**) was efficiently utilized as a key precursor to construct a diversity of polyfused systems containing chromeno[4,3-*b*]quinoline. Reaction of compound **1** with some substituted hydrazines afforded pyrazoles annulated chromeno[4,3-*b*]quinoline. Treatment of compound **1** with a diversity of 1,3-*N,N*-binucleophiles led to pyrimidines annulated chromeno[4,3-*b*]quinoline. In addition, a diversity of fused pyridines annulated chromeno[4,3-*b*]quinoline were synthesized from condensation of compound **1** with a variety of 1,3-*C,N*-binucleophiles. Finally, the reactivity of compound **1** was tested towards a diversity of 1,4-binucleophilic reagents. Structures of the new compounds were established using spectral and analytical data.

## INTRODUCTION

Coumarins are widely dispersed in plants particularly in the roots, leaves, fruits, and seeds.<sup>1</sup> The effect of substituted coumarins in the inhibition of various cancer cells is significant.<sup>2</sup> The pharmacological properties as well as therapeutic uses of coumarins are well determined by governing the substituent in their nucleus.<sup>3</sup> An interesting framework for creating new anti-inflammatory medicines is widely provided by coumarin derivatives.<sup>4</sup> The biological uses of coumarins include antioxidant,<sup>5</sup> anti-HIV,<sup>6</sup> antiviral,<sup>7</sup> antibacterial,<sup>8</sup> antimalarial,<sup>9</sup> antifungal,<sup>10</sup> anti-influenza,<sup>11</sup> antimicrobial,<sup>12</sup> antiproliferative,<sup>13</sup> anticoagulant,<sup>14</sup> antileishmanial,<sup>15</sup> antiplatelet,<sup>16</sup> and antidepressant.<sup>17</sup> Computational studies are used to investigate and recognize the structural, vibrational and optical properties using DFT calculations.<sup>20</sup> The photoluminescence and fluorescence properties were examined for some coumarins.<sup>19</sup>

$\beta$ -Chloroaldehydes are well known as good precursors for construction of heterocyclic compounds.<sup>20</sup> The present work is directed to utilize the recently synthesized 1-chloro-11-oxo-3,4-dihydro-11*H*-chromeno[4,3-*b*]quinoline-2-carboxaldehyde (**1**)<sup>21</sup> to construct a novel series of heterocyclic compounds including chromeno[4,3-*b*]quinolines.

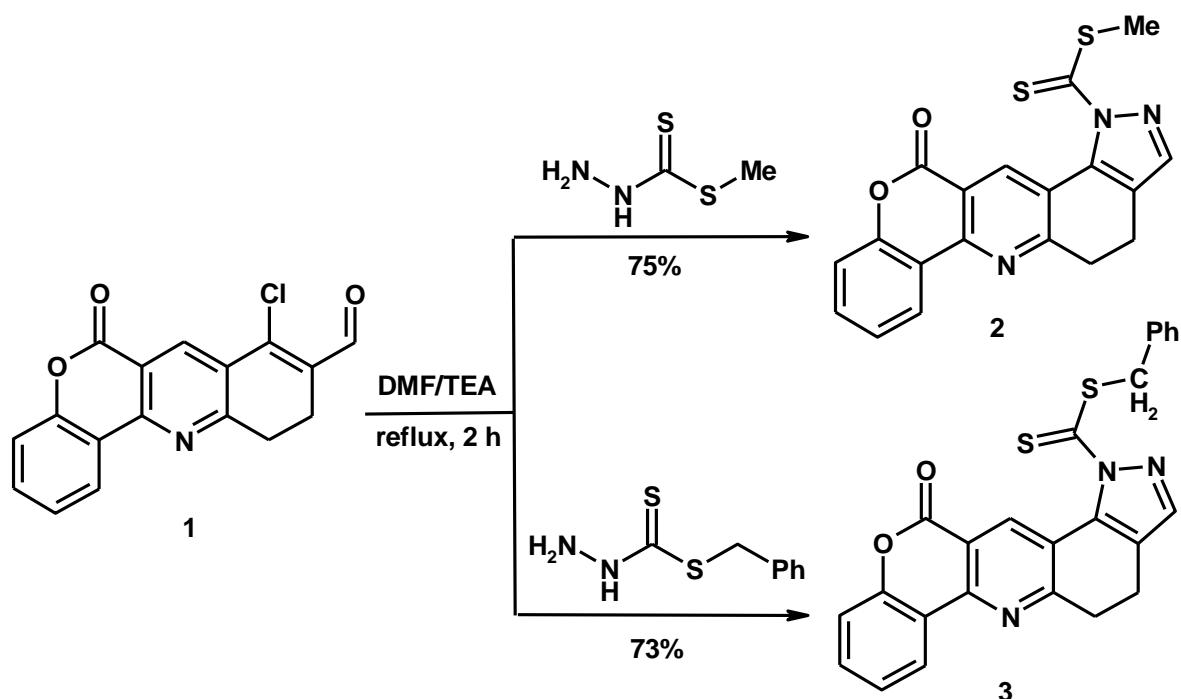
## RESULTS AND DISCUSSION

Recently, compound **1** was efficiently synthesized and characterized by different spectroscopic techniques.<sup>21</sup> Compound **1** represents a significant precursor for building a variety of angular annulated chromeno[4,3-*b*]quinolines due to the existence of aldehyde and chloro functions in the beta position to each other. The behavior of cyclic  $\beta$ -chloroaldehyde **1** was firstly examined towards some 1,2-binucleophilic reagents. So, condensation of compound **1** with *S*-methyl dithiocarbamate, and *S*-benzyl dithiocarbamate, in boiling DMF including triethylamine (TEA), furnished the novel chromeno[4,3-*b*]pyrazolo[3,4-*f*]quinoline-1-carbodithioate derivatives **2** and **3**, respectively (Scheme 1). These reactions proceed *via* condensation with loss of H<sub>2</sub>O and HCl molecules. In the IR spectra of compounds **2** and **3**, the aldehyde function that was presented at 1707 cm<sup>-1</sup> in the IR spectrum of compound **1** was vanished.<sup>21</sup> The molecular ion peaks at *m/z* 379 (C<sub>19</sub>H<sub>13</sub>N<sub>3</sub>O<sub>2</sub>S<sub>2</sub>) and 455 (C<sub>25</sub>H<sub>17</sub>N<sub>3</sub>O<sub>2</sub>S<sub>2</sub>) were shown by the mass spectra of compounds **2** and **3**, respectively, proving the suggested structures. In addition, the singlet signal of aldehyde proton, which was observed at  $\delta$  10.36 in the <sup>1</sup>H NMR spectrum of compound **1**, was vanished in the spectra of compounds **2** and **3**, and a new singlet due to H-3<sub>pyrazole</sub> was observed at  $\delta$  8.46 and 8.42. Also, singlet signals attributed to Me and CH<sub>2</sub> protons were seen in the <sup>1</sup>H NMR spectra of compounds **2** and **3** at  $\delta$  2.41 and 2.59, respectively. The <sup>13</sup>C NMR spectra of compounds **2** and **3** displayed specific signals due to C=S in the downfield region at  $\delta$  194.2 and 195.1, respectively.

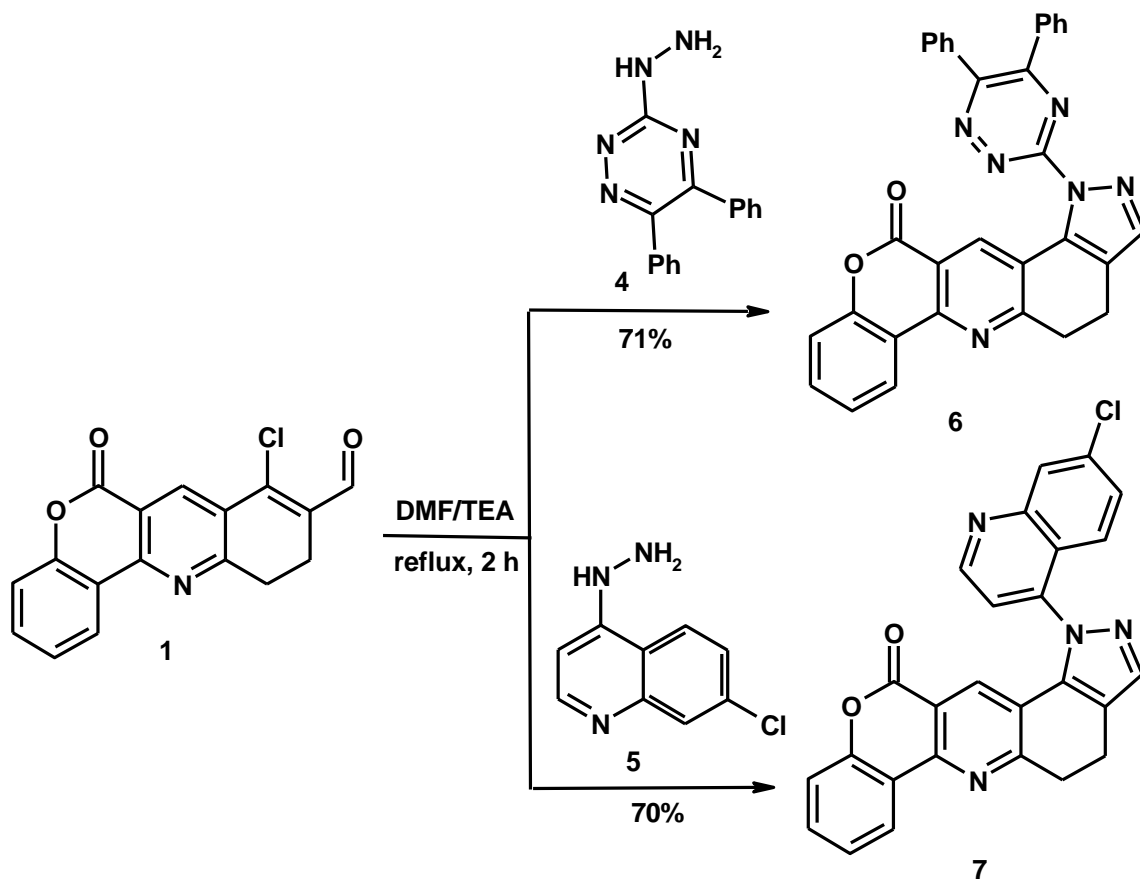
Similarly, treatment of compound **1** with 3-hydrazinyl-5,6-diphenyl-1,2,4-triazine (**4**),<sup>22</sup> and 7-chloro-4-hydrazinylquinoline (**5**),<sup>23</sup> in boiling DMF including TEA, afforded triazinyl/quinolinylchromeno[4,3-*b*]pyrazolo[3,4-*f*]quinolines **6** and **7**, respectively (Scheme 2). Their <sup>1</sup>H NMR spectra presented H-3<sub>pyrazole</sub> as typical signal at  $\delta$  8.49 and 8.47. The spectrum of compound **7** presented characteristic singlet signal assigned to H-8<sub>quinoline</sub> at  $\delta$  7.53. Structures **6** and **7** were further confirmed from their mass spectra that exhibited their parent ion peaks at *m/z* 520 (C<sub>32</sub>H<sub>20</sub>N<sub>6</sub>O<sub>2</sub>) and 450 (C<sub>26</sub>H<sub>15</sub>ClN<sub>4</sub>O<sub>2</sub>), respectively.

After that, cyclic  $\beta$ -chloroaldehyde **1** was permitted to react with a diversity of 1,3-*N,N*-binucleophiles. Therefore, boiling compound **1** with cyanoguanidine, in boiling DMF/TEA, yielded chromeno[3',4':5,6]pyrido[2,3-*h*]quinazoline derivative **8** (Scheme 3). Its IR spectrum displayed definite absorption bands at 3241 (NH), 2201 (C $\equiv$ N) and 1722 cm<sup>-1</sup> (C=O <sub>$\alpha$ -pyrone</sub>). The <sup>1</sup>H NMR spectrum exhibited distinctive signals corresponding to H-4<sub>pyrimidine</sub> and H-4<sub>pyridine</sub> at  $\delta$  8.59 and 8.89, as well as D<sub>2</sub>O vanished signal at  $\delta$  11.35 assignable to NH proton. In the <sup>13</sup>C NMR spectrum, typical signals were

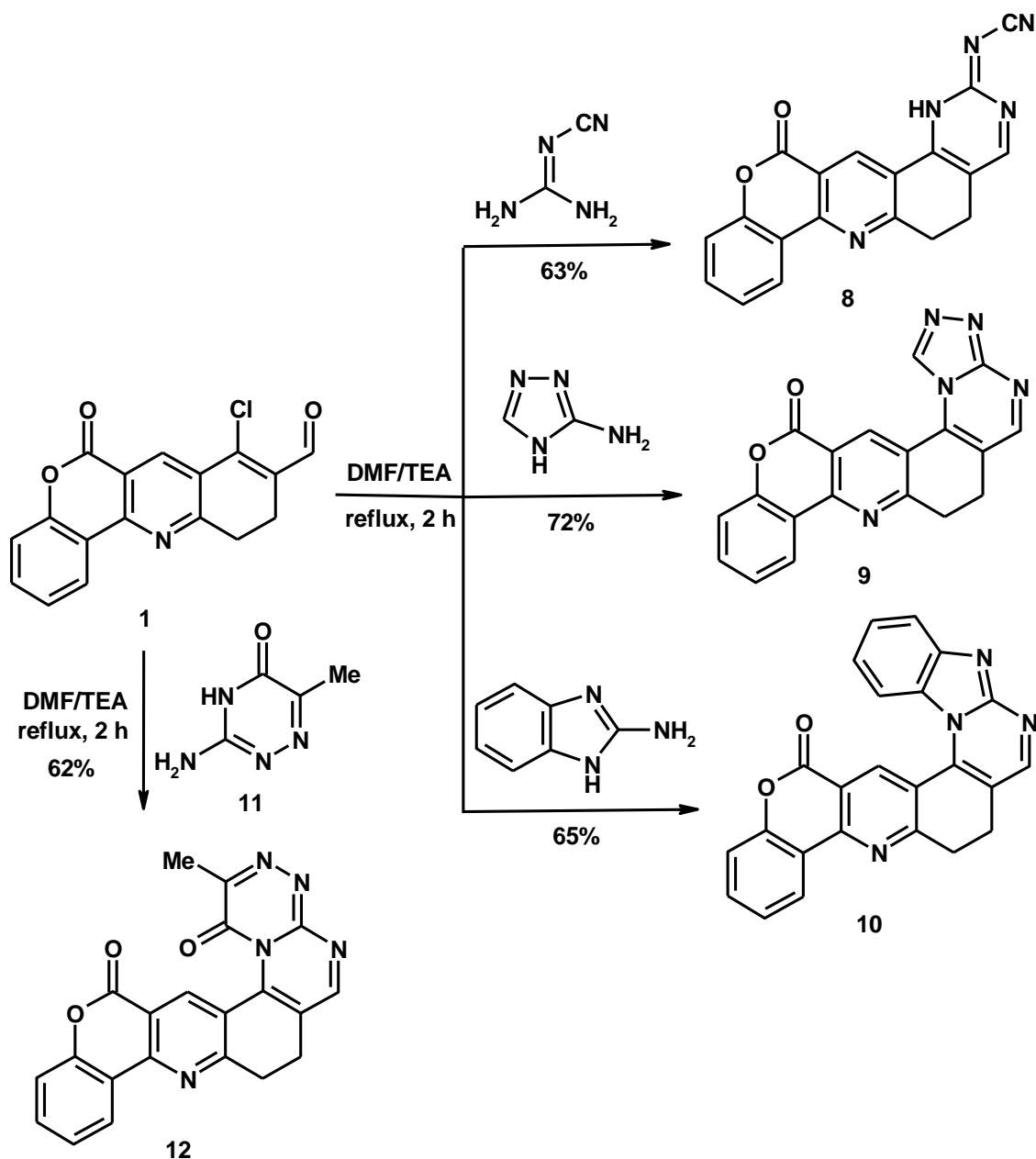
observed at  $\delta$  116.8 (C $\equiv$ N), 156.5 (C-2) and 171.2 (C=O $_{\alpha}$ -pyrone). The mass spectrum recorded the parent ion peak, as the base peak, at  $m/z$  341.



**Scheme 1.** Condensation of compound **1** with *S*-methyl/ *S*-benzyl dithiocarbazate



**Scheme 2.** Formation of poly fused chromeno[4,3-*b*]pyrazolo[3,4-*f*]quinolines **6** and **7**



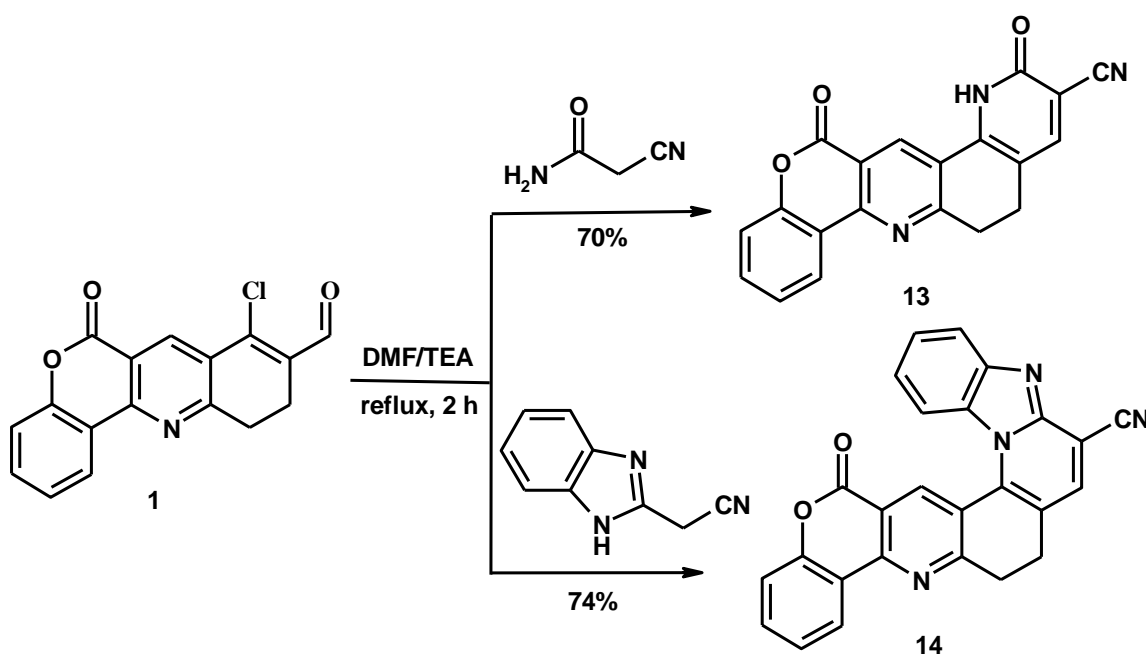
**Scheme 3.** Reaction of compound **1** with some 1,3-*N,N*-binucleophiles

Likewise, reaction of compound **1** with some heterocyclic binucleophiles namely 3-amino-1,2,4-triazole and 2-aminobenzimidazole led to chromeno[3',4':5,6]pyrido[2,3-*h*][1,2,4]triazolo[4,3-*a*]quinazoline **9** and chromeno[3',4':5,6]pyrido[2,3-*h*]benzimidazo[1,2-*a*]quinazoline **10**, respectively (Scheme 3). Their  $^1\text{H}$  NMR spectra displayed specific singlet due to H-4<sub>pyrimidine</sub> at  $\delta$  8.63 and 8.58, respectively. The spectrum of compound **9** showed typical singlet due to H-3<sub>triazole</sub> at  $\delta$  9.03. Structures **9** and **10** were also verified by the mass spectra that recorded the molecular ion peaks at  $m/z$  341 and 390 that agree well with the proposed molecular formulas  $\text{C}_{19}\text{H}_{11}\text{N}_5\text{O}_2$  and  $\text{C}_{24}\text{H}_{14}\text{N}_4\text{O}_2$ , respectively.

Also, reaction of compound **1** with 3-amino-6-methyl-1,2,4-triazin-5(4*H*)-one (**11**),<sup>24</sup> in DMF/TEA under reflux, produced chromeno[3',4':5,6]pyrido[2,3-*h*][1,2,4]triazino[4,3-*a*]quinazoline **12** (Scheme 3). Its IR

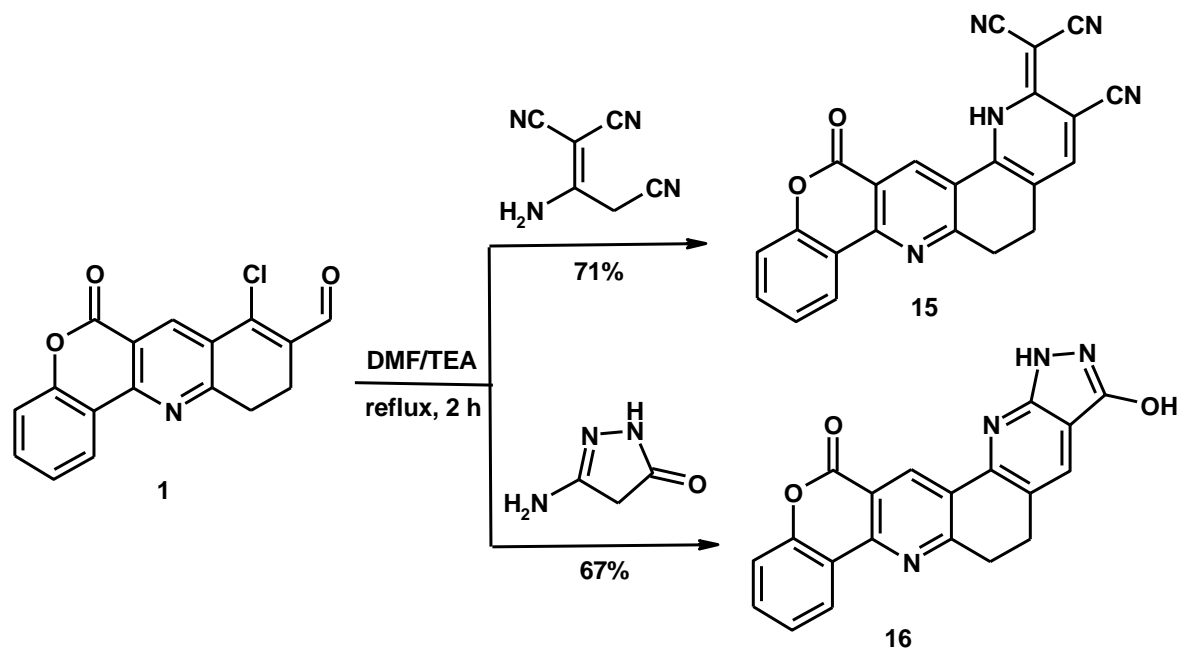
spectrum exhibited typical absorption bands at 1721 (C=O <sub>$\alpha$ -pyrone</sub>) and 1683 cm<sup>-1</sup> (C=O<sub>triazine</sub>). The <sup>1</sup>H NMR spectrum presented typical singlet signals at  $\delta$  2.86 (CH<sub>3</sub> triazine), 8.61 (H-4<sub>pyrimidine</sub>) and 8.89 (H-4<sub>pyridine</sub>). Structure **12** was also deduced from its mass spectrum which displayed the molecular ion peak at  $m/z$  383.

Next, cyclic  $\beta$ -chloroaldehyde **1** reacted with some 1,3-*C,N*-binucleophiles such as cyanoacetamide and 1*H*-benzimidazol-2-ylacetonitrile giving chromeno[4,3-*J*][1,7]phenanthroline **13** and chromeno[4,3-*J*]-benzoimidazo[1,2-*a*][1,7]phenanthroline **14** (Scheme 4). Their IR spectra showed typical absorption bands due to C $\equiv$ N functions at 2216 and 2219 cm<sup>-1</sup>, respectively. In the <sup>1</sup>H NMR spectra of compounds **13** and **14**, two singlet signals appeared in each spectrum due to 2H-4<sub>pyridine</sub> at  $\delta$  8.68/8.85 and 8.54/8.76, respectively. D<sub>2</sub>O-vanished signal (due to NH<sub>pyridine</sub>) was observed in the spectrum of compound **13** at  $\delta$  11.83. The <sup>13</sup>C NMR spectrum of compound **13** showed specific signals at  $\delta$  116.4 (C $\equiv$ N), 167.4 (C-2 as C=O) and 170.6 (C=O <sub>$\alpha$ -pyrone</sub>). The mass spectra of compounds **13** and **14** confirmed the assigned structures and presented the molecular ion peaks, as the base peaks, at  $m/z$  341 and 414, respectively.



**Scheme 4.** Reaction of compound **1** with some 1,3-*C,N* binucleophiles

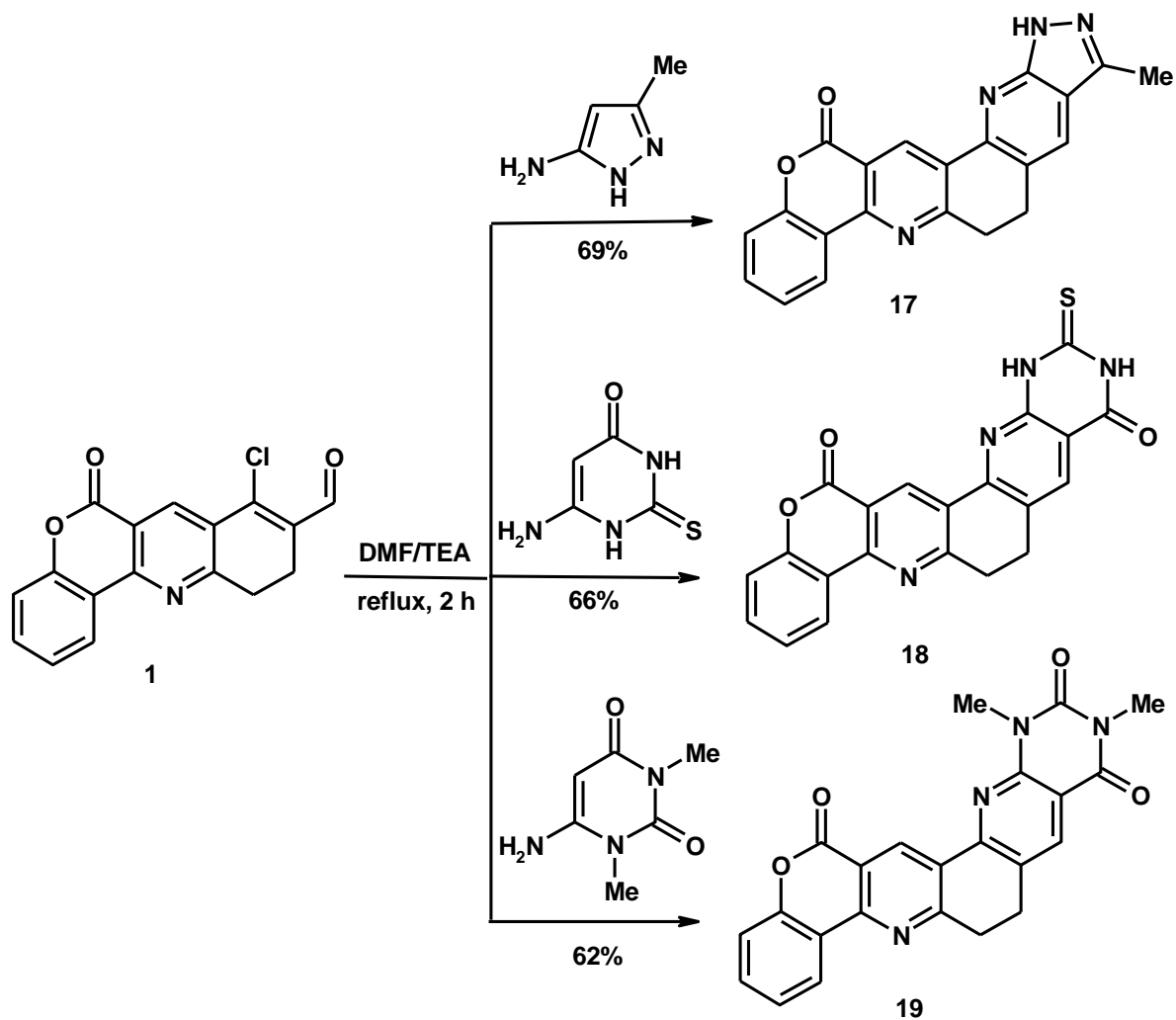
Moreover, treating compound **1** with 2-aminoprop-1-ene-1,1,3-tricarbonitrile and 5-amino-2,4-dihydro-3*H*-pyrazol-3-one, in DMF/TEA, gave chromeno[4,3-*J*][1,7]phenanthroline **15** and chromeno[4,3-*J*]-pyrazolo[3,4-*b*][1,7]phenanthroline **16**, respectively (Scheme 5).<sup>25</sup> The IR spectrum of compound **15** displayed characteristic absorption bands at 3286 (NH), 2223, 2204, 2196 (3C $\equiv$ N) and 1712 cm<sup>-1</sup> (C=O <sub>$\alpha$ -pyrone</sub>). Structures **15** and **16** were also confirmed from their mass spectra which showed the molecular ion peaks at  $m/z$  389 and 356.



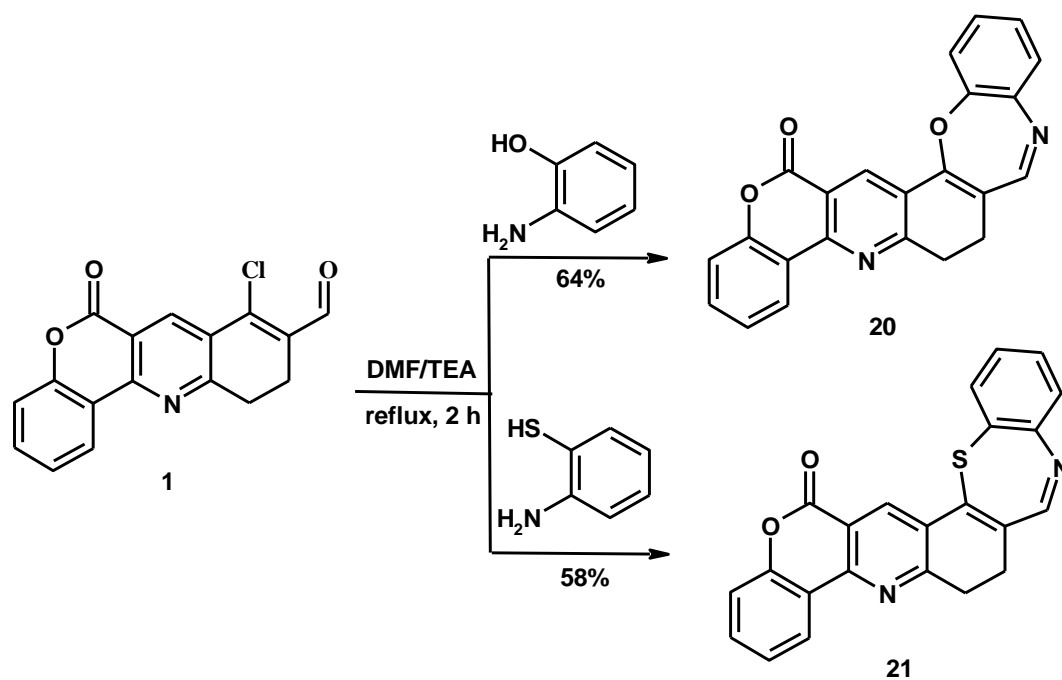
**Scheme 5.** Formation of heteroannulated compounds **15** and **16**

Further, cyclic  $\beta$ -chloroaldehyde **1** reacted with a diversity of cyclic enamines, as 1,3-*C,N*-binucleophiles. Thus, reaction of compound **1** with 5-amino-3-methyl-1*H*-pyrazole, 6-amino-2-thioxo-2,3-dihydropyrimidin-4(1*H*)-one and 6-amino-1,3-dimethylpyrimidine-2,4(1*H*,3*H*)-dione gave the angular annulated chromeno[4,3-*J*]pyrazolo[3,4-*b*][1,7]phenanthroline **17** and chromeno[4,3-*J*]pyrimido[4,5-*b*][1,7]phenanthrolines **18**, **19** (Scheme 6). Structures **17-19** were proved using the mass spectra which displayed their molecular ion peaks at  $m/z$  354, 400 and 412, respectively. The  $^1\text{H}$  NMR spectra for compounds **17-19** showed characteristic singlets due to 2H-4<sub>pyridine</sub> at  $\delta$  8.69/ 8.81, 8.54/ 8.78 and 8.61/ 8.83, respectively.

Then, compound **1** reacted with some 1,4-binucleophiles such as *o*-aminophenol and *o*-aminothiophenol, in DMF/TEA, producing chromenobenzoxazepinoquinoline **20** and chromenobenzothiazepinoquinoline **21** (Scheme 7). Structures **20** and **21** were confirmed by the mass spectra which presented the molecular ion peaks at  $m/z$  366 and 382, corresponding to the suggested formula weights of  $\text{C}_{23}\text{H}_{14}\text{N}_2\text{O}_3$  and  $\text{C}_{23}\text{H}_{14}\text{N}_2\text{O}_2\text{S}$ , respectively. In the  $^1\text{H}$  NMR spectrum of each compound, two characteristic singlet signals attributed to H-6 and H-4<sub>pyridine</sub> were seen at  $\delta$  8.37/8.76 and 8.41/8.83, respectively.



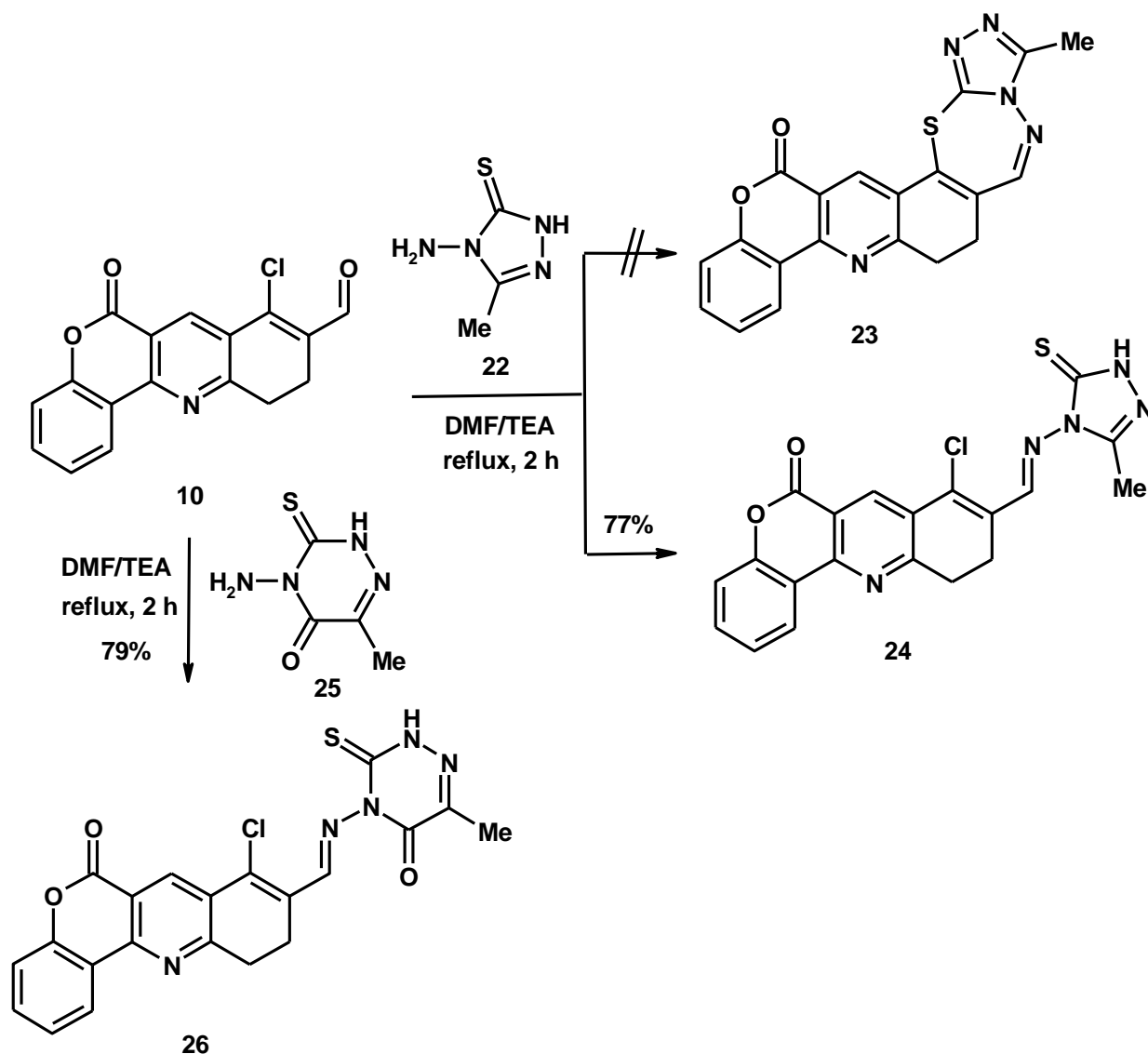
**Scheme 6.** Reaction of compound **1** with some cyclic 1,3-*C,N* binucleophiles



**Scheme 7.** Reaction of compound **1** with *o*-aminophenol and *o*-aminothiophenol

Meanwhile, boiling compound **1** with 4-amino-5-methyl-2,4-dihydro-3*H*-1,2,4-triazole-3-thione (**22**) did not afford the cyclized product **23**, but the reaction stops at the stage of the condensation process giving the condensation product **24** (Scheme 8). Its mass spectrum considered as excellent evidence for the structure **24** and presented the parent ion peak with its isotopic peak ( $M^+/M+2$ ) at  $m/z$  423/425 (relative abundance  $I$  %; 15/5); the base peak was seen at  $m/z$  309/311 ( $I$  %; 100/34). The  $^1\text{H}$  NMR spectrum displayed characteristic singlet signals at  $\delta$  2.46 ( $\text{Me}_{\text{triazole}}$ ), 8.35 ( $\text{CH}_{\text{azomethine}}$ ) and 8.85 ( $\text{H-4}_{\text{pyridine}}$ ), as well as  $\text{D}_2\text{O}$ -vanished signal due to NH proton at  $\delta$  11.64. The  $^{13}\text{C}$  NMR spectrum showed definite signals at  $\delta$  18.2 (Me), 141.6 ( $\text{C-5}_{\text{triazole}}$ ), 171.3 ( $\text{C=O}_{\alpha\text{-pyrone}}$ ) and 189.6 ( $\text{C=S}$ ).

Finally, reaction of compound **1** with 4-amino-6-methyl-3-thioxo-3,4-dihydro-1,2,4-triazin-5(2*H*)-one (**25**) yielded the Schiff base **26** (Scheme 8). Its  $^1\text{H}$  NMR spectrum showed characteristic singlet signals at  $\delta$  2.39 ( $\text{Me}_{\text{triazine}}$ ), 8.32 ( $\text{CH}_{\text{azomethine}}$ ) and 8.88 ( $\text{H-4}_{\text{pyridine}}$ ), the spectrum also revealed  $\text{D}_2\text{O}$ -vanished signal due to NH proton at  $\delta$  12.54.



Scheme 8. Formation of Schiff bases **24** and **26**



## CONCLUSION

A novel series of angular polyfused systems containing chromeno[4,3-*b*]quinoline moiety were synthesized from condensation reactions of cyclic  $\beta$ -chloroaldehyde **1** with a diversity of binucleophilic reagents. Some novel chromeno[4,3-*b*]pyrazolo[3,4-*f*]quinolines **2**, **3**, **6** and **7** were prepared from reaction of compound **1** with some hydrazine derivatives. Reaction of compound **1** with cyanoguanidine, 3-amino-1,2,4-triazole, 2-aminobenzimidazole and 3-amino-6-methyl-1,2,4-triazin-5(4*H*)-one afforded a series of chromeno[3',4':5,6]pyrido[2,3-*h*]quinazolines **8-10** and **12**. A novel series of chromeno[4,3-*J*]-[1,7]phenanthrolines **13-15**, chromeno[4,3-*J*]pyrazolo[3,4-*b*][1,7]phenanthrolines **16**, **17** and chromeno[4,3-*J*]pyrimido[4,5-*b*][1,7]phenanthrolines **18**, **19** were efficiently synthesized from reaction of compound **1** with some acyclic and cyclic 1,3-*C,N*-binucleophiles. Treating compound **1** with *o*-aminophenol and *o*-aminothiophenol afforded chromenobenzoxazepinoquinoline **20** and chromenobenzothiazepinoquinoline **21**. Schiff bases **24** and **26** were obtained from reaction of compound **1** with 4-amino-5-methyl-2,4-dihydro-3*H*-1,2,4-triazole-3-thione (**22**) and 4-amino-6-methyl-3-thioxo-3,4-dihydro-1,2,4-triazin-5(2*H*)-one (**25**).

## EXPERIMENTAL

**General.** Melting points were determined on a digital Stuart SMP3 apparatus. Infrared spectra were measured on FTIR Nicolet IS10 spectrophotometer (cm<sup>-1</sup>), using KBr disks. <sup>1</sup>H NMR (300 MHz) and <sup>13</sup>C NMR (75 MHz) spectra were measured on Mercury-300BB, using DMSO-*d*<sub>6</sub> as a solvent and TMS ( $\delta$ , ppm) as the internal standard. Mass spectra were obtained using GC-2010 Shimadzu Gas chromatography instrument mass spectrometer (70 eV). Elemental microanalyses were performed on a PerkinElmer CHN-2400 analyzer. 1-Chloro-11-oxo-3,4-dihydro-11*H*-chromeno[3,4-*b*]quinoline-2-carboxaldehyde (**1**) was prepared according to the published method.<sup>21</sup>

### Methyl 4,5-dihydrochromeno[4,3-*b*]pyrazolo[3,4-*f*]quinoline-1-carbodithioate (**2**)

A mixture of compound **1** (0.62 g, 2 mmol) and *S*-methyl dithiocarbamate (0.23 g, 2 mmol), in DMF (10 mL) containing TEA (0.1 mL), was heated under reflux for 2 h. The yellow crystals deposited after cooling were filtered and crystallized from *n*-butanol, mp > 300 °C, yield (0.57 g, 75%). IR (KBr, cm<sup>-1</sup>): 3036 (CH<sub>arom.</sub>), 2958, 2922 (CH<sub>aliph.</sub>), 1716 (C=O <sub>$\alpha$ -pyrone</sub>), 1611 (C=N), 1601 (C=C), 1238 (C=S). <sup>1</sup>H NMR (300 MHz, DMSO-*d*<sub>6</sub>,  $\delta$ ): 2.03 (t, 2H, *J*= 6.3 Hz, CH<sub>2</sub>), 2.23 (t, 2H, *J*= 6.3 Hz, CH<sub>2</sub>), 2.41 (s, 3H, CH<sub>3</sub>), 7.06 (t, 1H, *J*= 7.2 Hz, H-8), 7.35 (d, 1H, *J*= 7.5 Hz, H-9), 7.68 (t, 1H, *J*= 7.2 Hz, H-7), 7.97 (d, 1H, *J*= 7.5 Hz, H-10), 8.46 (s, 1H, H-3<sub>pyrazole</sub>), 8.87 (s, 1H, H-4<sub>pyridine</sub>). <sup>13</sup>C NMR (75 MHz, DMSO-*d*<sub>6</sub>,  $\delta$ ): 20.6 (SCH<sub>3</sub>), 22.9 (CH<sub>2</sub>), 27.1 (CH<sub>2</sub>), 114.3 (C-12a), 115.6 (C-3a), 119.8 (C-13a), 124.6 (C-9), 126.1 (C-7), 127.9 (C-8), 129.2 (C-10), 130.4 (C-6b), 132.8 (C-13b), 137.6 (C-3), 140.1 (C-13), 143.5 (C-6a), 146.2

(C-5a), 149.6 (C-10a), 171.3 (C=O $_{\alpha}$ -pyrone), 194.2 (C=S). Mass spectrum,  $m/z$  ( $I_r$  %): 379 (21), 364 (19), 288 (23), 260 (16), 233 (12), 195 (31), 145 (20), 120 (100), 93 (52), 77 (43), 64 (16). Anal. Calcd for C<sub>19</sub>H<sub>13</sub>N<sub>3</sub>O<sub>2</sub>S<sub>2</sub> (379.45): C, 60.14; H, 3.45; N, 11.07; S, 16.90%. Found: C, 59.86; H, 3.32; N, 10.93; S, 16.73%.

### **Benzyl 4,5-dihydrochromeno[4,3-*b*]pyrazolo[3,4-*f*]quinoline-1-carbodithioate (3)**

A mixture of compound **1** (0.62 g, 2 mmol) and *S*-benzyl dithiocarbazate (0.39 g, 2 mmol), in DMF (10 mL) containing TEA (0.1 mL), was heated under reflux for 2 h. The yellow crystals deposited during heating were filtered and crystallized from *n*-butanol, mp > 300 °C, yield (0.66 g, 73%). IR (KBr, cm<sup>-1</sup>): 3069 (CH<sub>arom.</sub>), 2943, 2915 (CH<sub>aliph.</sub>), 1720 (C=O $_{\alpha}$ -pyrone), 1616 (C=N), 1600 (C=C), 1249 (C=S). <sup>1</sup>H NMR (300 MHz, DMSO-*d*<sub>6</sub>,  $\delta$ ): 2.05 (t, 2H,  $J$  = 6.6 Hz, CH<sub>2</sub>), 2.21 (t, 2H,  $J$  = 6.6 Hz, CH<sub>2</sub>), 2.59 (s, 2H, CH<sub>2</sub>), 6.92-7.14 (m, 5H, Ph-H), 7.21 (t, 1H,  $J$  = 7.5 Hz, H-8), 7.41 (d, 1H,  $J$  = 7.5 Hz, H-9), 7.71 (t, 1H,  $J$  = 7.5 Hz, H-7), 8.03 (d, 1H,  $J$  = 7.5 Hz, H-10), 8.42 (s, 1H, H-3<sub>pyrazole</sub>), 8.83 (s, 1H, H-4<sub>pyridine</sub>). <sup>13</sup>C NMR (75 MHz, DMSO-*d*<sub>6</sub>,  $\delta$ ): 22.3 (CH<sub>2</sub>), 27.8 (CH<sub>2</sub>), 35.2 (SCH<sub>2</sub>), 113.8 (C-12a), 115.9 (C-3a), 120.3 (C-13a), 122.1 (Ph-C), 124.8 (C-9), 126.3 (C-7), 126.8 (2Ph-C), 128.0 (C-8), 128.7 (2Ph-C), 129.7 (C-10), 130.9 (C-6b), 133.2 (C-13b), 134.5 (Ph-C), 137.4 (C-3), 139.9 (C-13), 143.7 (C-6a), 146.8 (C-5a), 149.3 (C-10a), 170.8 (C=O $_{\alpha}$ -pyrone), 195.1 (C=S). Mass spectrum,  $m/z$  ( $I_r$  %): 455 (24), 332 (18), 288 (31), 233 (17), 196 (25), 170 (11), 145 (14), 121 (26), 91 (100), 77 (63), 64 (13). Anal. Calcd for C<sub>25</sub>H<sub>17</sub>N<sub>3</sub>O<sub>2</sub>S<sub>2</sub> (455.55): C, 65.91; H, 3.76; N, 9.22; S, 14.08%. Found: C, 65.85; H, 3.57; N, 9.03; S, 13.86%.

### **4,5-Dihydro-1-(5,6-diphenyl-1,2,4-triazin-3-yl)-12*H*-chromeno[4,3-*b*]pyrazolo[3,4-*f*]quinolin-12-one (6)**

A mixture of compound **1** (0.62 g, 2 mmol) and 3-hydrazinyl-5,6-diphenyl-1,2,4-triazine (**4**) (0.58 g, 2 mmol), in DMF (10 mL) containing TEA (0.1 mL), was heated under reflux for 2 h. The yellow crystals deposited after cooling were filtered and crystallized from AcOH, mp > 300 °C, yield (0.74 g, 71%). IR (KBr, cm<sup>-1</sup>): 3046 (CH<sub>arom.</sub>), 2937, 2908 (CH<sub>aliph.</sub>), 1719 (C=O $_{\alpha}$ -pyrone), 1608 (C=N), 1593 (C=C). <sup>1</sup>H NMR (300 MHz, DMSO-*d*<sub>6</sub>,  $\delta$ ): 2.01 (t, 2H,  $J$  = 6.3 Hz, CH<sub>2</sub>), 2.22 (t, 2H,  $J$  = 6.3 Hz, CH<sub>2</sub>), 6.86-7.15 (m, 11H, 2Ph-H and H-8), 7.43 (d, 1H,  $J$  = 7.2 Hz, H-9), 7.67 (t, 1H,  $J$  = 7.5 Hz, H-7), 7.92 (d, 1H,  $J$  = 7.2 Hz, H-10), 8.49 (s, 1H, H-3<sub>pyrazole</sub>), 8.86 (s, 1H, H-4<sub>pyridine</sub>). Mass spectrum,  $m/z$  ( $I_r$  %): 520 (43), 342 (37), 314 (52), 261 (30), 233 (16), 196 (45), 178 (100), 145 (12), 120 (26), 93 (63), 77 (41), 64 (19). Anal. Calcd for C<sub>32</sub>H<sub>20</sub>N<sub>6</sub>O<sub>2</sub> (520.54): C, 73.84; H, 3.87; N, 16.14%. Found: C, 73.71; H, 3.66; N, 16.02%.

### **4,5-Dihydro-1-(7-chloroquinolinyl)-12*H*-chromeno[4,3-*b*]pyrazolo[3,4-*f*]quinolin-12-one (7)**

A mixture of compound **1** (0.62 g, 2 mmol) and 7-chloro-4-hydrazinylquinoline (**5**) (0.38 g, 2 mmol) in DMF (10 mL) containing TEA (0.1 mL), was heated under reflux for 2 h. The yellow crystals deposited during heating were filtered and crystallized from DMF/H<sub>2</sub>O, mp > 300 °C, yield (0.37 g, 70%). IR (KBr, cm<sup>-1</sup>): 3058 (CH<sub>arom.</sub>), 2927, 2886 (CH<sub>aliph.</sub>), 1715 (C=O $_{\alpha}$ -pyrone), 1613 (C=N), 1599 (C=C). <sup>1</sup>H NMR (300

MHz, DMSO-*d*<sub>6</sub>,  $\delta$ ): 2.05 (t, 2H,  $J$  = 6.0 Hz, CH<sub>2</sub>), 2.27 (t, 2H,  $J$  = 6.0 Hz, CH<sub>2</sub>), 6.98-7.17 (m, 2H, H-5<sub>quinoline</sub> and H-6<sub>quinoline</sub>), 7.26 (t, 1H,  $J$  = 7.2 Hz, H-9), 7.49 (d, 1H,  $J$  = 7.5 Hz, H-7), 7.53 (s, 1H, H-8<sub>quinoline</sub>), 7.64 (t, 1H,  $J$  = 7.5 Hz, H-8), 7.96 (d, 1H,  $J$  = 7.2 Hz, H-10), 8.04 (d, 1H,  $J$  = 8.1 Hz, H-3<sub>quinoline</sub>), 8.23 (d, 1H,  $J$  = 8.1 Hz, H-2<sub>quinoline</sub>), 8.47 (s, 1H, H-3<sub>pyrazole</sub>), 8.83 (s, 1H, H-4<sub>pyridine</sub>). <sup>13</sup>C NMR (75 MHz, DMSO-*d*<sub>6</sub>,  $\delta$ ): 21.7 (CH<sub>2</sub>), 26.5 (CH<sub>2</sub>), 111.9 (C-4<sub>quinoline</sub>), 114.6 (C-12a), 115.9 (C-3a), 118.3 (C-13a), 121.3 (C-3<sub>quinoline</sub>), 123.7 (C-5<sub>quinoline</sub>), 125.2 (C-9), 126.6 (C-7), 127.5 (C-8), 128.1 (C-6<sub>quinoline</sub>), 129.3 (C-10), 130.1 (C-6b), 131.6 (C-6<sub>quinoline</sub>), 133.5 (C-13b), 135.7 (C-7<sub>quinoline</sub>), 138.2 (C-3), 140.6 (C-13), 143.4 (C-6a), 145.3 (C-8a<sub>quinoline</sub>), 146.4 (C-5a), 147.5 (C-2<sub>quinoline</sub>), 148.9 (C-4<sub>quinoline</sub>), 150.3 (C-10a), 171.8 (C=O <sub>$\alpha$</sub> -pyrone). Mass spectrum,  $m/z$  ( $I_r$  %): 450/452 (100/33), 422/424 (58/19), 395/397 (45/15), 232 (17), 196 (34), 163/165 (67/22), 120 (57), 92 (49), 79 (19), 64 (10). Anal. Calcd for C<sub>26</sub>H<sub>15</sub>ClN<sub>4</sub>O<sub>2</sub> (450.88): C, 69.26; H, 3.35; N, 12.43%. Found: C, 68.96; H, 3.25; N, 12.31%.

**(5,6-Dihydro-13-oxo-13H-chromeno[3',4':5,6]pyrido[2,3-*h*]quinazolin-2(1H)-ylidene)cyanamide (8)**

A mixture of compound **1** (0.62 g, 2 mmol) and cyanoguanidine (0.16 g, 2 mmol), in DMF (10 mL) containing TEA (0.1 mL), was heated under reflux for 2 h. The yellow crystals deposited after cooling were filtered and crystallized from toluene, mp 268-269 °C, yield (0.43 g, 63%). IR (KBr, cm<sup>-1</sup>): 3241 (NH), 3029 (CH<sub>arom.</sub>), 2936, 2902 (CH<sub>aliph.</sub>), 2201 (C $\equiv$ N), 1722 (C=O <sub>$\alpha$</sub> -pyrone), 1617 (C=N), 1587 (C=C). <sup>1</sup>H NMR (300 MHz, DMSO-*d*<sub>6</sub>,  $\delta$ ): 1.98 (t, 2H,  $J$  = 6.6 Hz, CH<sub>2</sub>), 2.21 (t, 2H,  $J$  = 6.3 Hz, CH<sub>2</sub>), 7.22 (t, 1H,  $J$  = 7.2 Hz, H-10), 7.47 (d, 1H,  $J$  = 7.2 Hz, H-8), 7.69 (t, 1H,  $J$  = 7.2 Hz, H-9), 8.06 (d, 1H,  $J$  = 7.2 Hz, H-11), 8.59 (s, 1H, H-4<sub>pyrimidine</sub>), 8.89 (s, 1H, H-4<sub>pyridine</sub>), 11.35 (bs, 1H, NH exchangeable with D<sub>2</sub>O). <sup>13</sup>C NMR (75 MHz, DMSO-*d*<sub>6</sub>,  $\delta$ ): 22.3 (CH<sub>2</sub>), 26.7 (CH<sub>2</sub>), 113.9 (C-13a), 115.3 (C-4a), 116.8 (C $\equiv$ N), 120.3 (C-14a), 123.7 (C-10), 126.4 (C-8), 127.2 (C-9), 129.0 (C-11), 130.6 (C-7b), 132.4 (C-14b), 136.9 (C-4), 139.6 (C-14), 142.8 (C-7a), 145.7 (C-6a), 149.1 (C-11a), 156.5 (C-2), 171.2 (C=O <sub>$\alpha$</sub> -pyrone). Mass spectrum,  $m/z$  ( $I_r$  %): 341 (100), 290 (68), 261 (51), 233 (18), 195 (22), 144 (15), 120 (57), 105 (23), 93 (35), 77 (41), 64 (24). Anal. Calcd for C<sub>19</sub>H<sub>11</sub>N<sub>5</sub>O<sub>2</sub> (341.32): C, 66.86; H, 3.25; N, 20.52%. Found: C, 66.53; H, 3.08; N, 20.36%.

**6,7-Dihydrochromeno[3',4':5,6]pyrido[2,3-*h*][1,2,4]triazolo[4,3-*a*]quinazolin-14(14H)-one (9)**

A mixture of compound **1** (0.62 g, 2 mmol) and 3-amino-1,2,4-triazole (0.16 g, 2 mmol), in DMF (10 mL) containing TEA (0.1 mL), was heated under reflux for 2 h. The pale-yellow crystals deposited after cooling were filtered and crystallized from AcOH/H<sub>2</sub>O, mp > 300 °C, yield (0.49 g, 72%). IR (KBr, cm<sup>-1</sup>): 3046 (CH<sub>arom.</sub>), 2953, 2921 (CH<sub>aliph.</sub>), 1716 (C=O <sub>$\alpha$</sub> -pyrone), 1608 (C=N), 1578 (C=C). <sup>1</sup>H NMR (300 MHz, DMSO-*d*<sub>6</sub>,  $\delta$ ): 2.03 (t, 2H,  $J$  = 6.0 Hz, CH<sub>2</sub>), 2.28 (t, 2H,  $J$  = 6.0 Hz, CH<sub>2</sub>), 7.25 (t, 1H,  $J$  = 7.8 Hz, H-10), 7.52 (d, 1H,  $J$  = 7.5 Hz, H-8), 7.71 (t, 1H,  $J$  = 7.5 Hz, H-9), 8.04 (d, 1H,  $J$  = 7.8 Hz, H-11), 8.63 (s, 1H, H-4<sub>pyrimidine</sub>), 8.87 (s, 1H, H-4<sub>pyridine</sub>), 9.03 (s, 1H, H-3<sub>triazole</sub>). <sup>13</sup>C NMR (75 MHz, DMSO-*d*<sub>6</sub>,  $\delta$ ): 21.7 (CH<sub>2</sub>), 26.4 (CH<sub>2</sub>), 113.6 (C-14a), 115.5 (C-5a), 118.7 (C-15a), 122.4 (C-11), 125.1 (C-9), 127.3 (C-10),

129.5 (C-12), 131.2 (C-8b), 132.8 (C-15b), 135.8 (C-5), 137.3 (C-15), 139.7 (C-1), 141.6 (C-8a), 145.9 (C-7a), 147.6 (C-12a), 150.2 (C-3a), 170.8 (C=O $_{\alpha}$ -pyrone). Mass spectrum,  $m/z$  ( $I_r$  %): 341 (100), 286 (75), 233 (52), 196 (32), 145 (20), 120 (42), 92 (29), 77 (23), 64 (9). Anal. Calcd for C<sub>19</sub>H<sub>11</sub>N<sub>5</sub>O<sub>2</sub> (341.32): C, 66.86; H, 3.25; N, 20.52%. Found: C, 66.82; H, 3.14; N, 20.29%.

### **8,9-Dihydrochromeno[3',4':5,6]pyrido[2,3-*h*]benzimidazo[1,2-*a*]quinazolin-16(16*H*)-one (10)**

A mixture of compound **1** (0.62 g, 2 mmol) and 2-aminobenzimidazole (0.27 g, 2 mmol), in DMF (10 mL) containing TEA (0.1 mL), was heated under reflux for 2 h. The pale-brown crystals deposited during heating were filtered and crystallized from DMF/H<sub>2</sub>O, mp > 300 °C, yield (0.51 g, 65%). IR (KBr, cm<sup>-1</sup>): 3062 (CH<sub>arom.</sub>), 1714 (C=O $_{\alpha}$ -pyrone), 1619 (C=N), 1602 (C=C). <sup>1</sup>H NMR (300 MHz, DMSO-*d*<sub>6</sub>,  $\delta$ ): 2.06 (t, 2H,  $J$  = 6.3 Hz, CH<sub>2</sub>), 2.29 (t, 2H,  $J$  = 6.3 Hz, CH<sub>2</sub>), 7.15-7.50 (m, 6H, Ar-H, H-13 and H-11), 7.73 (t, 1H,  $J$  = 7.5 Hz, H-12), 8.09 (d, 1H,  $J$  = 7.2 Hz, H-14), 8.58 (s, 1H, H-4<sub>pyrimidine</sub>), 8.82 (s, 1H, H-4<sub>pyridine</sub>). Mass spectrum,  $m/z$  ( $I_r$  %): 390 (100), 362 (46), 307 (31), 256 (43), 195 (17), 171 (12), 145 (16), 120 (56), 92 (33), 77 (24), 64 (13). Anal. Calcd for C<sub>24</sub>H<sub>14</sub>N<sub>4</sub>O<sub>2</sub> (390.39): C, 73.84; H, 3.61; N, 14.35%. Found: C, 73.59; H, 3.41; N, 14.20%.

### **2-Methyl-7,8-dihydrochromeno[3',4':5,6]pyrido[2,3-*h*][1,2,4]triazino[4,3-*a*]quinazoline-1,15-(1*H*,15*H*)-dione (12)**

A mixture of compound **1** (0.62 g, 2 mmol) and 3-amino-6-methyl-1,2,4-triazin-5(4*H*)-one (**11**) (0.25 g, 2 mmol), in DMF (10 mL) containing TEA (0.1 mL), was heated under reflux for 2 h. The pale-brown crystals deposited during heating were filtered and crystallized from AcOH, mp > 300 °C, yield (0.47 g, 62%). IR (KBr, cm<sup>-1</sup>): 3028 (CH<sub>arom.</sub>), 2944, 2917 (CH<sub>aliph.</sub>), 1721 (C=O $_{\alpha}$ -pyrone), 1683 (C=O<sub>triazine</sub>), 1613 (C=N), 1592 (C=C). <sup>1</sup>H NMR (300 MHz, DMSO-*d*<sub>6</sub>,  $\delta$ ): 1.95 (t, 2H,  $J$  = 6.0 Hz, CH<sub>2</sub>), 2.24 (t, 2H,  $J$  = 6.0 Hz, CH<sub>2</sub>), 2.86 (s, 3H, CH<sub>3</sub> triazine), 7.27 (t, 1H,  $J$  = 7.2 Hz, H-12), 7.55 (d, 1H,  $J$  = 7.2 Hz, H-10), 7.68 (t, 1H,  $J$  = 7.2 Hz, H-11), 8.05 (d, 1H,  $J$  = 7.2 Hz, H-13), 8.61 (s, 1H, H-4<sub>pyrimidine</sub>), 8.89 (s, 1H, H-4<sub>pyridine</sub>). Mass spectrum,  $m/z$  ( $I_r$  %): 383 (59), 355 (47), 300 (35), 257 (18), 171 (26), 146 (14), 120 (35), 93 (100), 77 (67), 64 (16). Anal. Calcd for C<sub>21</sub>H<sub>13</sub>N<sub>5</sub>O<sub>3</sub> (383.36): C, 65.79; H, 3.42; N, 18.27%. Found: C, 65.46; H, 3.32; N, 18.06%.

### **2,13-Dioxo-1,2,5,6-tetrahydro-13*H*-chromeno[4,3-*J*][1,7]phenanthroline-3-carbonitrile (13)**

A mixture of compound **1** (0.62 g, 2 mmol) and cyanoacetamide (0.16 g, 2 mmol) in DMF (10 mL) containing TEA (0.1 mL), was heated under reflux for 2 h. The pale-yellow crystals deposited after cooling were filtered and crystallized from DMF/H<sub>2</sub>O, mp > 300 °C, yield (0.48 g, 70%). IR (KBr, cm<sup>-1</sup>): 3315 (NH), 3036 (CH<sub>arom.</sub>), 2216 (C $\equiv$ N), 1713 (C=O $_{\alpha}$ -pyrone), 1618 (C=N), 1603 (C=C). <sup>1</sup>H NMR (300 MHz, DMSO-*d*<sub>6</sub>,  $\delta$ ): 2.01 (t, 2H,  $J$  = 6.3 Hz, CH<sub>2</sub>), 2.26 (t, 2H,  $J$  = 6.3 Hz, CH<sub>2</sub>), 7.28 (t, 1H,  $J$  = 7.8 Hz, H-10), 7.54 (d, 1H,  $J$  = 7.5 Hz, H-8), 7.78 (t, 1H,  $J$  = 7.5 Hz, H-9), 8.12 (d, 1H,  $J$  = 7.8 Hz, H-11), 8.68 (s, 1H, H-4<sub>pyridine</sub>), 8.85 (s, 1H, H-4<sub>pyridine</sub>), 11.83 (bs, 1H, NH exchangeable with D<sub>2</sub>O). <sup>13</sup>C NMR (75 MHz,

DMSO-*d*<sub>6</sub>,  $\delta$ ): 22.1 (CH<sub>2</sub>), 26.9 (CH<sub>2</sub>), 102.3 (C-3), 111.6 (C-13a), 114.2 (C-4a), 116.4 (C $\equiv$ N), 119.8 (C-14a), 122.9 (C-10), 125.7 (C-8), 127.4 (C-9), 129.3 (C-11), 130.4 (C-7b), 131.9 (C-14b), 135.8 (C-4), 139.1 (C-14), 142.6 (C-7a), 145.9 (C-6a), 149.3 (C-11a), 167.4 (C-2 as C=O), 170.6 (C=O <sub>$\alpha$</sub> -pyrone). Mass spectrum, *m/z* (*I*<sub>r</sub> %): 341 (100), 313 (63), 234 (39), 196 (18), 170 (23), 146 (16), 120 (31), 93 (51), 77 (33), 64 (16). Anal. Calcd for C<sub>20</sub>H<sub>11</sub>N<sub>3</sub>O<sub>3</sub> (341.32): C, 70.38; H, 3.25; N, 12.31%. Found: C, 70.25; H, 3.10; N, 12.15%.

**8,9-Dihydro-16-oxo-16*H*-chromeno[4,3-*J*]benzimidazo[1,2-*a*][1,7]phenanthroline-6-carbonitrile (14)**

A mixture of compound **1** (0.62 g, 2 mmol) and 1*H*-benzimidazol-2-ylacetonitrile (0.31 g, 2 mmol), in DMF (10 mL) containing TEA (0.1 mL), was heated under reflux for 2 h. The yellow crystals deposited during heating were filtered and crystallized from DMF, mp > 300 °C, yield (0.61 g, 74%). IR (KBr, cm<sup>-1</sup>): 3043 (CH<sub>arom.</sub>), 2219 (C $\equiv$ N), 1723 (C=O <sub>$\alpha$</sub> -pyrone), 1612 (C=N), 1593 (C=C). <sup>1</sup>H NMR (300 MHz, DMSO-*d*<sub>6</sub>,  $\delta$ ): 2.03 (t, 2H, *J* = 6.0 Hz, CH<sub>2</sub>), 2.25 (t, 2H, *J* = 6.0 Hz, CH<sub>2</sub>), 7.08-7.34 (m, 5H, Ar-H and H-13), 7.56 (d, 1H, *J* = 7.5 Hz, H-11), 7.70 (t, 1H, *J* = 7.5 Hz, H-12), 7.98 (d, 1H, *J* = 7.5 Hz, H-14), 8.54 (s, 1H, H-4<sub>pyridine</sub>), 8.76 (s, 1H, H-4<sub>pyridine</sub>). Mass spectrum, *m/z* (*I*<sub>r</sub> %): 414 (100), 386 (55), 335 (41), 309 (27), 219 (20), 196 (13), 120 (56), 93 (38), 77 (28), 64 (12). Anal. Calcd for C<sub>26</sub>H<sub>14</sub>N<sub>4</sub>O<sub>2</sub> (414.41): C, 75.35; H, 3.41; N, 13.52%. Found: C, 75.11; H, 3.26; N, 13.27%.

**(3-Cyano-5,6-dihydrochromeno[4,3-*J*][1,7]phenanthrolin-2(1*H*)-ylidene)propanedinitrile (15)**

A mixture of compound **1** (0.62 g, 2 mmol) and 2-aminoprop-1-ene-1,1,3-tricarbonitrile (0.26 g, 2 mmol), in DMF (10 mL) containing TEA (0.1 mL), was heated under reflux for 2 h. The orange crystals deposited during heating were filtered and crystallized from DMF/EtOH, mp > 300 °C, yield (0.55 g, 71%). IR (KBr, cm<sup>-1</sup>): 3286 (NH), 3021 (CH<sub>arom.</sub>), 2223, 2204, 2196 (3C $\equiv$ N), 1712 (C=O <sub>$\alpha$</sub> -pyrone), 1608 (C=N), 1594 (C=C). <sup>1</sup>H NMR (300 MHz, DMSO-*d*<sub>6</sub>,  $\delta$ ): 2.10 (t, 2H, *J* = 6.3 Hz, CH<sub>2</sub>), 2.31 (t, 2H, *J* = 6.3 Hz, CH<sub>2</sub>), 7.18 (t, 1H, *J* = 7.2 Hz, H-10), 7.44 (d, 1H, *J* = 7.2 Hz, H-8), 7.65 (t, 1H, *J* = 7.2 Hz, H-9), 8.02 (d, 1H, *J* = 7.2 Hz, H-11), 8.56 (s, 1H, H-4<sub>pyridine</sub>), 8.79 (s, 1H, H-4<sub>pyridine</sub>), 10.86 (bs, 1H, NH exchangeable with D<sub>2</sub>O). Mass spectrum, *m/z* (*I*<sub>r</sub> %): 389 (100), 361 (76), 335 (66), 285 (43), 259 (47), 196 (18), 171 (27), 145 (22), 120 (42), 93 (52), 77 (34), 64 (17). Anal. Calcd for C<sub>23</sub>H<sub>11</sub>N<sub>5</sub>O<sub>2</sub> (389.36): C, 70.95; H, 2.85; N, 17.99%. Found: C, 70.88; H, 2.65; N, 17.74%.

**5,6-Dihydro-3-hydroxy-1*H*-chromeno[4,3-*J*]pyrazolo[3,4-*b*][1,7]phenanthrolin-13(13*H*)-one (16)**

A mixture of compound **1** (0.62 g, 2 mmol) and 5-amino-2,4-dihydro-3*H*-pyrazol-3-one (0.20 g, 2 mmol) in DMF (10 mL) containing TEA (0.1 mL), was heated under reflux for 2 h. The brown crystals deposited during heating were filtered and crystallized from DMF/H<sub>2</sub>O, mp > 300 °C, yield (0.48 g, 67%). IR (KBr, cm<sup>-1</sup>): 3403 (OH), 3316 (NH), 3009 (CH<sub>arom.</sub>), 2926, 2905 (CH<sub>aliph.</sub>), 1715 (C=O <sub>$\alpha$</sub> -pyrone), 1616 (C=N), 1596 (C=C). <sup>1</sup>H NMR (300 MHz, DMSO-*d*<sub>6</sub>,  $\delta$ ): 2.06 (t, 2H, *J* = 6.0 Hz, CH<sub>2</sub>), 2.29 (t, 2H, *J* = 6.0 Hz,

CH<sub>2</sub>), 7.32-7.46 (m, 2H, H-10 and H-8), 7.72 (t, 1H, *J* = 7.2 Hz, H-9), 8.03 (d, 1H, *J* = 7.2 Hz, H-11), 8.73 (s, 1H, H-4<sub>pyridine</sub>), 8.83 (s, 1H, H-4<sub>pyridine</sub>), 11.43 (bs, 1H, NH exchangeable with D<sub>2</sub>O), 12.62 (bs, 1H, OH exchangeable with D<sub>2</sub>O). Mass spectrum, *m/z* (*I<sub>r</sub>* %): 356 (100), 331 (47), 285 (53), 245 (64), 195 (31), 170 (25), 120 (63), 93 (46), 77 (41), 64 (20). Anal. Calcd for C<sub>20</sub>H<sub>12</sub>N<sub>4</sub>O<sub>3</sub> (356.33): C, 67.41; H, 3.39; N, 15.72%. Found: C, 67.18; H, 3.21; N, 15.54%.

#### **5,6-Dihydro-3-methyl-1*H*-chromeno[4,3-*J*]pyrazolo[3,4-*b*][1,7]phenanthrolin-13(13*H*)-one (17)**

A mixture of compound **1** (0.62 g, 2 mmol) and 5-amino-3-methyl-1*H*-pyrazole (0.20 g, 2 mmol), in DMF (10 mL) containing TEA (0.1 mL), was heated under reflux for 2 h. The pale brown crystals deposited during heating were filtered and crystallized from DMF/H<sub>2</sub>O, mp > 300 °C, yield (0.49 g, 69%). IR (KBr, cm<sup>-1</sup>): 3315 (NH), 3016 (CH<sub>arom.</sub>), 2962, 2934 (CH<sub>aliph.</sub>), 1716 (C=O<sub>α-pyrone</sub>), 1613 (C=N), 1596 (C=C). <sup>1</sup>H NMR (300 MHz, DMSO-*d*<sub>6</sub>, δ): 1.96 (t, 2H, *J* = 6.3 Hz, CH<sub>2</sub>), 2.25 (t, 2H, *J* = 6.3 Hz, CH<sub>2</sub>), 2.42 (s, 3H, CH<sub>3</sub>), 7.26 (t, 1H, *J* = 7.5 Hz, H-10), 7.51 (d, 1H, *J* = 7.2 Hz, H-8), 7.68 (t, 1H, *J* = 7.2 Hz, H-9), 7.95 (d, 1H, *J* = 7.5 Hz, H-11), 8.69 (s, 1H, H-4<sub>pyridine</sub>), 8.81 (s, 1H, H-4<sub>pyridine</sub>), 11.57 (bs, 1H, NH exchangeable with D<sub>2</sub>O). <sup>13</sup>C NMR (75 MHz, DMSO-*d*<sub>6</sub>, δ): 16.7 (CH<sub>3</sub>), 21.8 (CH<sub>2</sub>), 26.5 (CH<sub>2</sub>), 110.4 (C-3a), 112.1 (C-13a), 114.6 (C-4a), 120.3 (C-14a), 122.5 (C-10), 125.2 (C-8), 127.9 (C-9), 129.7 (C-11), 130.3 (C-7b), 132.1 (C-14b), 135.6 (C-4), 137.9 (C-3), 139.8 (C-14), 142.3 (C-7a), 144.7 (C-6a), 148.4 (C-11a), 155.2 (C-15a), 171.5 (C=O<sub>α-pyrone</sub>). Mass spectrum, *m/z* (*I<sub>r</sub>* %): 354 (100), 326 (86), 285 (63), 244 (53), 195 (25), 146 (11), 120 (55), 93 (37), 77 (25), 64 (11). Anal. Calcd for C<sub>21</sub>H<sub>14</sub>N<sub>4</sub>O<sub>2</sub> (354.36): C, 71.18; H, 3.98; N, 15.81%. Found: C, 71.03; H, 3.86; N, 15.56%.

#### **6,7-Dihydro-2-thioxo-1*H*-chromeno[4,3-*J*]pyrimido[4,5-*b*][1,7]phenanthroline-4,14(3*H*,14*H*)-dione (18)**

A mixture of compound **1** (0.62 g, 2 mmol) and 6-amino-2-thioxo-2,3-dihydropyrimidin-4(1*H*)-one (0.29 g, 2 mmol), in DMF (10 mL) containing TEA (0.1 mL), was heated under reflux for 2 h. The pale brown crystals deposited during heating were filtered and crystallized from AcOH, mp > 300 °C, yield (0.53 g, 66%). IR (KBr, cm<sup>-1</sup>): 3356, 3279 (2NH), 3041 (CH<sub>arom.</sub>), 1712 (C=O<sub>α-pyrone</sub>), 1662 (C=O<sub>pyrimidine</sub>), 1615 (C=N), 1585 (C=C), 1244 (C=S). <sup>1</sup>H NMR (300 MHz, DMSO-*d*<sub>6</sub>, δ): 2.03 (t, 2H, *J* = 6.3 Hz, CH<sub>2</sub>), 2.28 (t, 2H, *J* = 6.3 Hz, CH<sub>2</sub>), 7.22 (t, 1H, *J* = 7.2 Hz, H-11), 7.57 (d, 1H, *J* = 7.2 Hz, H-9), 7.73 (t, 1H, *J* = 7.2 Hz, H-10), 7.98 (d, 1H, *J* = 7.2 Hz, H-12), 8.54 (s, 1H, H-4<sub>pyridine</sub>), 8.78 (s, 1H, H-4<sub>pyridine</sub>), 11.13 (bs, 2H, 2NH exchangeable with D<sub>2</sub>O). Mass spectrum, *m/z* (*I<sub>r</sub>* %): 400 (62), 357 (100), 329 (36), 285 (51), 244 (53), 195 (10), 170 (14), 145 (17), 120 (38), 92 (27), 77 (28), 64 (15). Anal. Calcd for C<sub>21</sub>H<sub>12</sub>N<sub>4</sub>O<sub>3</sub>S (400.41): C, 62.99; H, 3.02; N, 13.99%. Found: C, 62.84; H, 2.85; N, 13.72%.

#### **1,3-Dimethyl-6,7-Dihydro-1*H*-chromeno[4,3-*J*]pyrimido[4,5-*b*][1,7]phenanthroline-2,4,14(3*H*,14*H*)-trione (19)**

A mixture of compound **1** (0.62 g, 2 mmol) and 6-amino-1,3-dimethylpyrimidine-2,4(1*H*,3*H*)-dione (0.31 g, 2 mmol), in DMF (10 mL) containing TEA (0.1 mL), was heated under reflux for 2 h. The pale brown crystals deposited during heating were filtered and crystallized from AcOH/H<sub>2</sub>O, mp > 300 °C, yield (0.51 g, 62%). IR (KBr, cm<sup>-1</sup>): 3041 (CH<sub>arom.</sub>), 2963, 2941 (CH<sub>aliph.</sub>), 1718 (C=O<sub>α-pyrone</sub>), 1673, 1658 (2C=O<sub>pyrimidine</sub>), 1619 (C=N), 1582 (C=C). <sup>1</sup>H NMR (300 MHz, DMSO-*d*<sub>6</sub>, δ): 1.94 (t, 2H, *J*= 6.0 Hz, CH<sub>2</sub>), 2.23 (t, 2H, *J*= 6.0 Hz, CH<sub>2</sub>), 3.41 (s, 3H, NCH<sub>3</sub>), 3.63 (s, 3H, NCH<sub>3</sub>), 7.29 (t, 1H, *J*= 7.5 Hz, H-10), 7.53-7.65 (m, 2H, H-8 and H-9), 7.91 (d, 1H, *J*= 7.5 Hz, H-11), 8.61 (s, 1H, H-4<sub>pyridine</sub>), 8.83 (s, 1H, H-4<sub>pyridine</sub>). Mass spectrum, *m/z* (*I*<sub>r</sub> %): 412 (63), 356 (100), 342 (41), 300 (28), 285 (32), 246 (17), 195 (18), 170 (24), 120 (27), 92 (22), 77 (25), 64 (8). Anal. Calcd for C<sub>23</sub>H<sub>16</sub>N<sub>4</sub>O<sub>4</sub> (412.39): C, 66.99; H, 3.91; N, 13.59%. Found: C, 66.68; H, 3.74; N, 13.42%.

#### **7,8-Dihydrochromeno[4,3-*b*][1,4]benzoxazepino[2,3-*f*]quinolin-15(15*H*)-one (20)**

A mixture of compound **1** (0.62 g, 2 mmol) and *o*-aminophenol (0.22 g, 2 mmol) in DMF (10 mL) containing TEA (0.1 mL), was heated under reflux for 2 h. The brown crystals deposited during heating were filtered and crystallized from xylene, mp > 300 °C, yield (0.47 g, 64%). IR (KBr, cm<sup>-1</sup>): 3032 (CH<sub>arom.</sub>), 1719 (C=O<sub>α-pyrone</sub>), 1616 (C=N), 1586 (C=C). <sup>1</sup>H NMR (300 MHz, DMSO-*d*<sub>6</sub>, δ): 2.03 (t, 2H, *J*= 6.3 Hz, CH<sub>2</sub>), 2.28 (t, 2H, *J*= 6.3 Hz, CH<sub>2</sub>), 6.92-7.41 (m, 6H, Ar-H, H-12 and H-10), 7.62 (t, 1H, *J*= 7.2 Hz, H-11), 7.98 (d, 1H, *J*= 7.2 Hz, H-13), 8.37 (s, 1H, H-4<sub>oxazepine</sub>), 8.76 (s, 1H, H-4<sub>pyridine</sub>). Mass spectrum, *m/z* (*I*<sub>r</sub> %): 366 (49), 339 (43), 311 (35), 209 (29), 195 (16), 171 (37), 120 (47), 105 (26), 93 (100), 77 (53), 64 (23). Anal. Calcd for C<sub>23</sub>H<sub>14</sub>N<sub>2</sub>O<sub>3</sub> (366.37): C, 75.40; H, 3.85; N, 7.65%. Found: C, 75.21; H, 3.56; N, 7.43%.

#### **7,8-Dihydrochromeno[4,3-*b*][1,4]benzothiazepino[2,3-*f*]quinolin-15(15*H*)-one (21)**

A mixture of compound **1** (0.62 g, 2 mmol) and *o*-aminothiophenol (0.25 g, 2 mmol) in DMF (10 mL) containing TEA (0.1 mL), was heated under reflux for 2 h. The brown crystals deposited after cooling were filtered and crystallized from xylene, mp > 300 °C, yield (0.44 g, 58%). IR (KBr, cm<sup>-1</sup>): 3056 (CH<sub>arom.</sub>), 1701 (C=O<sub>α-pyrone</sub>), 1609 (C=N), 1596 (C=C). <sup>1</sup>H NMR (300 MHz, DMSO-*d*<sub>6</sub>, δ): 2.07 (t, 2H, *J*= 6.0 Hz, CH<sub>2</sub>), 2.24 (t, 2H, *J*= 6.0 Hz, CH<sub>2</sub>), 6.88-7.29 (m, 5H, Ar-H and H-12), 7.54 (d, 1H, *J*= 7.5 Hz, H-10), 7.68 (t, 1H, *J*= 7.5 Hz, H-11), 8.05 (d, 1H, *J*= 7.5 Hz, H-13), 8.41 (s, 1H, H-4<sub>thiazepine</sub>), 8.83 (s, 1H, H-4<sub>pyridine</sub>). Mass spectrum, *m/z* (*I*<sub>r</sub> %): 382 (58), 354 (63), 327 (31), 251 (40), 195 (10), 170 (12), 145 (14), 120 (100), 105 (21), 93 (39), 77 (34), 64 (10). Anal. Calcd for C<sub>23</sub>H<sub>14</sub>N<sub>2</sub>O<sub>2</sub>S (382.43): C, 72.23; H, 3.69; N, 7.33; S, 8.38%. Found: C, 72.00; H, 3.42; N, 7.26; S, 8.34%.

#### **1-Chloro-2-[(3-methyl-5-thioxo-1,5-dihydro-4*H*-1,2,4-triazol-4-yl)imino]methyl]-3,4-dihydrochromeno[4,3-*b*]quinolin-1(1*H*)-one (24)**

A mixture of compound **1** (0.62 g, 2 mmol) and 4-amino-5-methyl-2,4-dihydro-3*H*-1,2,4-triazole-3-thione (**22**) (0.26 g, 2 mmol), in DMF (10 mL) containing TEA (0.1 mL), was heated under reflux for 2 h.

The yellow crystals deposited during heating were filtered and crystallized from AcOH, mp > 300 °C, yield (0.65 g, 77%). IR (KBr, cm<sup>-1</sup>): 3268 (NH), 3047 (CH<sub>arom.</sub>), 2958, 2934 (CH<sub>aliph.</sub>), 1702 (C=O<sub>α-pyrone</sub>), 1613 (C=N), 1591 (C=C), 1248 (C=S). <sup>1</sup>H NMR (300 MHz, DMSO-*d*<sub>6</sub>, δ): 2.01 (t, 2H, *J* = 6.0 Hz, CH<sub>2</sub>), 2.24 (t, 2H, *J* = 6.0 Hz, CH<sub>2</sub>), 2.46 (s, 3H, CH<sub>3</sub> triazole), 7.28 (t, 1H, *J* = 7.8 Hz, H-8), 7.51 (d, 1H, *J* = 7.5 Hz, H-6), 7.72 (t, 1H, *J* = 7.5 Hz, H-7), 8.03 (d, 1H, *J* = 7.5 Hz, H-9), 8.35 (s, 1H, CH<sub>azomethine</sub>), 8.85 (s, 1H, H-4<sub>pyridine</sub>), 11.64 (bs, 1H, NH exchangeable with D<sub>2</sub>O). <sup>13</sup>C NMR (75 MHz, DMSO-*d*<sub>6</sub>, δ): 18.2 (CH<sub>3</sub>), 22.1 (CH<sub>2</sub>), 27.3 (CH<sub>2</sub>), 113.7 (C-11a), 121.4 (C-12a), 123.6 (C-8), 125.7 (C-6), 127.4 (C-7), 129.5 (C-9), 130.6 (C-5b), 131.9 (C-2), 135.3 (C-1), 137.6 (C=N), 139.7 (C-12), 141.6 (C-5<sub>triazole</sub>), 142.7 (C-5a), 146.1 (C-4a), 149.8 (C-9a), 171.3 (C=O<sub>α-pyrone</sub>), 189.6 (C=S). Mass spectrum, *m/z* (*I*<sub>r</sub> %): 423/425 (15/5), 309/311 (100/34), 281/283 (51/17), 254/254 (40/13), 194 (15), 120 (73), 105 (46), 93 (55), 77 (37), 64 (18). Anal. Calcd for C<sub>20</sub>H<sub>14</sub>ClN<sub>5</sub>O<sub>2</sub>S (423.88): C, 56.67; H, 3.33; N, 16.52; S, 7.56%. Found: C, 56.57; H, 3.12; N, 16.28; S, 7.46%.

**1-Chloro-2-[[6-methyl-5-oxo-3-thioxo-2,5-dihydro-1,2,4-triazin-4(3*H*)-yl]imino]methyl}-3,4-dihydrochromeno[4,3-*b*]quinolin-1(1*H*)-one (26)**

A mixture of compound **1** (0.62 g, 2 mmol) and 4-amino-6-methyl-3-thioxo-3,4-dihydro-1,2,4-triazin-5(2*H*)-one (**25**) (0.32 g, 2 mmol) in DMF (10 mL) containing TEA (0.1 mL), was heated under reflux for 2 h. The yellow crystals deposited during heating were filtered and crystallized from AcOH, mp > 300 °C, yield (0.71 g, 79%). IR (KBr, cm<sup>-1</sup>): 3325 (NH), 3063 (CH<sub>arom.</sub>), 2943, 2922 (CH<sub>aliph.</sub>), 1709 (C=O<sub>α-pyrone</sub>), 1617 (C=N), 1581 (C=C), 1239 (C=S). <sup>1</sup>H NMR (300 MHz, DMSO-*d*<sub>6</sub>, δ): 2.04 (t, 2H, *J* = 6.6 Hz, CH<sub>2</sub>), 2.23 (t, 2H, *J* = 6.6 Hz, CH<sub>2</sub>), 2.39 (s, 3H, CH<sub>3</sub> triazine), 7.31 (t, 1H, *J* = 7.2 Hz, H-8), 7.54 (d, 1H, *J* = 7.2 Hz, H-6), 7.75 (t, 1H, *J* = 7.2 Hz, H-7), 8.02 (d, 1H, *J* = 7.2 Hz, H-9), 8.32 (s, 1H, CH<sub>azomethine</sub>), 8.88 (s, 1H, H-4<sub>pyridine</sub>), 12.54 (bs, 1H, NH exchangeable with D<sub>2</sub>O). <sup>13</sup>C NMR (75 MHz, DMSO-*d*<sub>6</sub>, δ): 17.6 (CH<sub>3</sub>), 22.3 (CH<sub>2</sub>), 27.9 (CH<sub>2</sub>), 112.5 (C-11a), 120.3 (C-12a), 123.8 (C-8), 125.4 (C-6), 127.2 (C-7), 129.1 (C-9), 130.7 (C-5b), 132.3 (C-2), 134.6 (C-1), 136.9 (C=N), 138.5 (C-12), 140.9 (C-6<sub>triazine</sub>), 142.3 (C-5a), 145.6 (C-4a), 148.5 (C-9a), 168.7 (C=O<sub>triazine</sub>), 172.1 (C=O<sub>α-pyrone</sub>), 188.9 (C=S). Mass spectrum, *m/z* (*I*<sub>r</sub> %): 451/453 (13/4), 309/311 (100/33), 281/283 (35/12), 254/256 (24/8), 194 (19), 170 (15), 146 (11), 120 (66), 92 (30), 77 (23), 64 (10). Anal. Calcd for C<sub>21</sub>H<sub>14</sub>ClN<sub>5</sub>O<sub>3</sub>S (451.89): C, 55.82; H, 3.12; N, 15.50; S, 7.10%. Found: C, 55.56; H, 3.07; N, 15.35; S, 6.97%.

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