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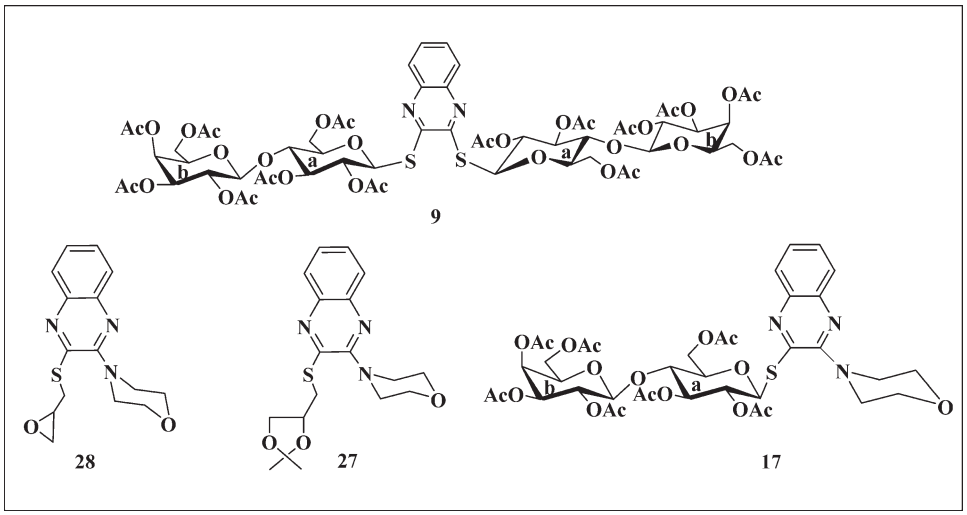

Sulfanyl-glycosides have been synthesized by reaction of 2,3-dimercaptoquinoxaline (**1**) with aceto-halo sugars in presence of base to give the thioglycosides-derived quinoxalines **5**–**7** and **9**. Similarly, the acyclic analogs **23**–**26** were prepared by coupling of **1** with different acyclo-alkylating agents. The preparation of 3-morpholinyl-quinoxalines **10** and **11** allowed the synthesis of 3-glycosylsulfanyl-2-morpholinyl-quinoxalines **12**–**14** and **17** as well as the acyclic analogs **27**–**29**. Microwave irradiation of the reactants turned out to be preferred over the conventional method for achieving the synthetic goals. This study made an available venue to the synthesis of diverse quinoxaline derivatives.

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INTRODUCTION

The wide use of sulfanyl(thio)-glycosides as biological inhibitors [1], inducers, and ligands for affinity chromatography of carbohydrate processing enzymes and proteins has attracted much attention toward their synthesis [2–4]. Recently, glycosylthio heterocycles have proved their success as glycosyl donors as well as glycosyl acceptors as a result of their variable stability under variety of conditions. Moreover, their use as acceptors and subsequently as donors increased their value in the field of oligosaccharide synthesis [2].

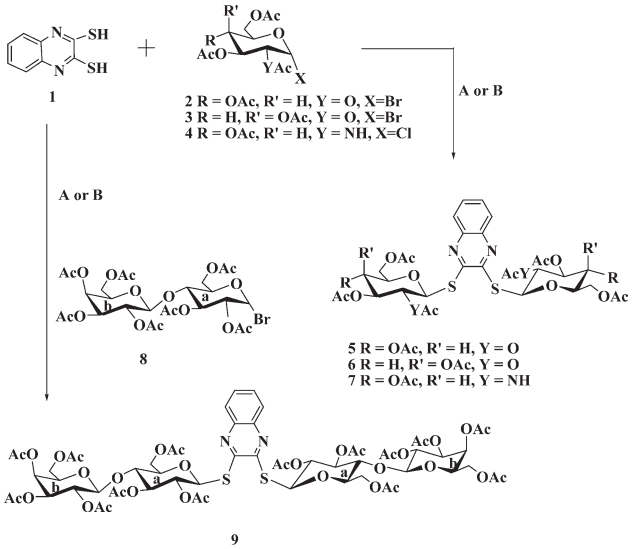
Functionalized quinoxaline systems are an important class of nitrogen-containing heterocycles possessing a broad spectrum of biological activities [5]. Benefits from the emerging technology of microwave (MW)-assisted organic synthesis (MAOS) has had a profound impact on the synthesis of organic compounds [6,7] and on developing the combinatorial chemistry to exploit a high degree of molecular diversity.

Efforts in our laboratory has been devoted to develop efficient protocols for the preparation of a diverse collection of substituted heterocyclic scaffolds [8,9]. Continuing our interest in the chemistry of quinoxalines [10] and thioglycosides [1–4,11], as well as MAOS, we report herein the synthesis of divalent sulfanyl-glycosides–derived quinoxaline and their acyclic analogs. Selective monomorpholinylation of 2,3-dimercapto-quinoxaline allowed diverse reactions on the other thiol group whereby glycosylation and acyclo-alkylation reactions have been investigated, which have represented an efficient protocol for developing a library of compounds having the quinoxaline ring.

RESULT AND DISCUSSION

The 2,3-dimercaptoquinoxalinedithiol [12] (**1**) has served as a key starting material. It was prepared from the condensation of oxalic acid and *o*-phenylenediamine

Scheme 1. Reagents and conditions: (A) NaOH, DMF, and MWI. (B) K_2CO_3, DMF, and MWI.



and the product was converted to 2,3-dichloroquinoxaline whose reaction with thiourea gave the isothiouronium salt whose treatment with alka1i gave **1**. Reaction of **1** with 2,3,4,6-tetra-*O*-acetyl-α-D-glucopyranosyl bromide (**2**) in presence of aqueous sodium hydroxide or potassium carbonate gave 2,3-bis(2′,3′,4′,6′-tetra-*O*-acetyl-β-D-glucopyranosyl-thio)quinoxaline (**5**) [13]. Alternatively, **5** was recently prepared from the reaction of 2,3,4,6-tetra-*O*-acetyl-β-D-glucopyranosyl isothiouronium salt [14,15] with 2,3-dichloroquinoxaline in presence of triethylamine in acetonitrile. Similarly, 2,3-bis(glycosylthio)quinoxaline **6** and **7** were prepared from the reaction of the sodium salt of **1** with 2,3,4,6-tetra-*O*-acetyl-α-D-galactopyranosyl bromide (**3**) and 2-acetamido-3,4,6-tri-*O*-acetyl-2-deoxy-α-D-glucopyranosyl chloride (**4**), respectively (Scheme 1).

Examination of the ^{1}H NMR and ^{13}C NMR spectra of **6** indicated the chemical equivalence of protons and carbons of the two sugar moieties. The assignments were based on correlation experiments. Thus, the β-linkage of the thioglycosidic bond was confirmed from the value of coupling constant $J_{1',2'}$ (10.7 Hz) in the doublet of the anomeric proton at δ 6.03. The triplet of H-2′ at δ 5.52 can be correlated with the corresponding carbon at δ 67.5. The doublet of doublet of H-3′ resonated at δ 5.24 and correlated with H-4′ at δ 5.52 ($J_{3',4'} = 3.8$ Hz).The latter correlated with the multiplet of H-5′ and its carbon. Both of H-6′ and H-6″ were resonated as doublet of doublet at δ 4.05 and 4.14, respectively, whereas its carbon was assigned at δ 61.7.

Furthermore reaction of 2,3-dimercaptoquinoxaline (**1**) with 2,3,6-tri-*O*-acetyl-4-*O*-(2,3,4,6-tetra-*O*-acetyl-β-D-galactopyranosyl)-α-D-glucopyranosyl bromide (**8**) in presence of base gave the respective bisthioglycoside **9**. Alternatively, the sodium quinoxaline 2,3-thiolate from **1** can be reacted with the acetobromo sugars to give **9** in almost the same yield (Scheme 1).

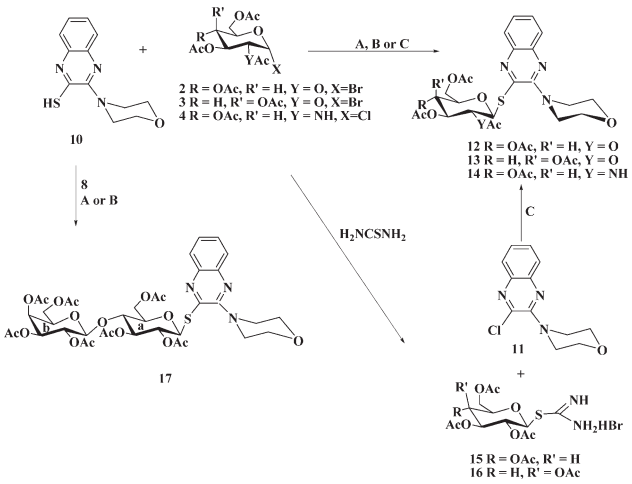
The ^{1}H and ^{13}C NMR spectra of compound **9** confirmed the assigned structure and showed also the equivalent nature of the two sugar moieties. The anomeric proton H-1′a was assigned to the doublet at δ 5.97 with $J_{1'a,2'a} = 10.7$ Hz indicating a biaxial orientation of H-1′a and H-2′a. H-1′a proton was correlated with the triplet of H-2′a at δ 5.20 and their respective carbons were assigned at δ 80.6 and 69.3, respectively. The H-2′b protons were resonated at δ 5.10 as doublet of doublet with $J_{2'b,1'b} = 7.6$ Hz and correlated with the doublet of H-1′b at δ 4.47 and the doublet of doublet of H-3′b at δ 4.92, respectively. The anomeric carbon C-1′b appeared at δ 101.2 confirmed that the anomeric proton is axial.

Morpholinylation of 2,3-dichloroquinoxaline gave 2-chloro-3-morpholinyl-quinoxaline (**11**) whose coupling with 2,3,4,6-tetra-*O*-acetyl-β-D-gluco- and β-D-galactopyranosyl isothiouronium bromide **15** and **16** [14,15], prepared from acetylated sugar bromide **2** and **3** and thiourea under MW [15], in presence of Et_3N in acetonitrile afforded the respective sulfanylglycosides 3-morpholinyl-2-(2′,3′,4′,6′-tetra-*O*-acetyl-1-β-sulfanyl-D-glucopyranosyl)quinoxaline (**12**) and 3-morpholinyl-2-(2′,3′,4′,6′-tetra-*O*-acetyl-1-β-sulfanyl-D-galactopyranosyl) quinoxaline (**13**). Alternatively, compounds **12** and **13** were obtained from the reaction of 2-mercapto-3-morpholinyl-quinoxaline (**10**) with the respective sugar bromide **2** and **3** in presence of potassium carbonate in DMF. Also **12–14** were synthesized from the coupling of the sodium salt of **10** with acetobromo sugars **2–4**. The ^{1}H NMR and ^{13}C NMR spectra confirmed the assigned structures. Thus, H-1′ in **12** appeared at δ 6.04 as a doublet with $J_{1',2'} = 10.7$ Hz, confirming the β-configuration. Further correlation of protons and carbons in a similar manner to that used above led to a complete assignment of protons and carbons.

Under the same reaction conditions, acetobromo lactose **8** was coupled with **10** to give the sulfanylglycoside **17**. The doublet corresponding to the anomeric protons H-1′a and H-1′b were resonated at δ 6.02 and 4.48, respectively, where $J_{1'a,2'a} = 10.7$ Hz that confirmed the β-configuration for the newly formed thioglycoside linkage. Both H-1′a and H-1′b were correlated with their carbons at δ 80.7 and 101.3, respectively (Scheme 2).

The acyclic analogs **23–26** were synthesized from the coupling of sodium salt of 2,3-quinoxalinedithiol (**1**), as nucleophilic source, with a number of acyclo-alkylating agents. Alternatively, the reaction of **1** with the alkylating agents has been done in presence of potassium carbonate. Thus, **1** was coupled with (±)epichlorohydrin to give 2,3-bis(2′,3′-epoxy-propyl-1′-thio)quinoxaline (**24**),

Scheme 2. Reagents and conditions: (A) NaOH, DMF, and MWI. (B) K_2CO_3, DMF, and MWI. (C) Et_3N, MeCN, and MWI.



2,3-*O*-isopropylidene-1-*O*-(4-toluenesulfonyl)glycerol to give **25** and allyl bromide to give **26**. The spectral analysis confirmed the involvement of both of the two sulfur atoms in the alkylation.

The 3-morpholinyl-quinoxaline-2-thiol (**10**) has been utilized for the synthesis of the acyclic derivatives **27**–**29** by the alkylation with **19**, **20**, and **22** in the presence of base (Scheme 3). The S-alkylated derivatives **27** and **28** are potential precursors for modifications, via opening of the dioxalane or epoxide ring, thus provide acyclonucleoside analogs [15,16].

When the above reactions were done under MW conditions, the same products were obtained but in higher yield and in shorter reaction times; although a domestic MW oven was used, it indicated the successful approach for their synthesis (Table 1). Thus, mild conditions and relatively clean reactions indicating that the MW method has advantages over the conventional processes.

CONCLUSION

In conclusion, diversity of functionalized quinoxalines with glycosyl, morpholinyl, alkyl, and hydroxyalkyl moeties have been prepared. The synthesis of the sulfanylglycosides-derived quinoxalines was achieved by the reaction of 2,3-dimercaptoquinoxaline with acetohalogeno sugars. The 2-mercapto-3-morpholinyl-quinoxaline became readily available from 2,3-dichloroquinoxaline, served as a good precursor for providing various S-alkylated and glycosylated products, which are of potential biological activity.

EXPERIMENTAL

Melting points were determined on a Mel-Temp apparatus and are uncorrected. ^{1}H NMR and ^{13}C NMR spectra were recorded on Jeol spectrometer (500 MHz). The chemical shifts are expressed on the δ-scale using Me_4Si as a standard, and coupling-constant values are given in Hz. The assignments of ^{1}H NMR spectra were based on the chemical shift correlation DQFCOSY spectra, while the assignment of ^{13}C NMR spectra were based on heteronuclear multiple quantum coherence experiments. Glycosyl protons and carbons are identified by ''prime.'' TLC was performed on Merck Silica Gel 1B-F with detection by charring in sulfuric acid (5%) and by UV light. The MW irradiation was done in a closed Teflon cylindrical vessel that was placed at the center of rotating plate inside the oven EM-230 M (1200 watt output power). The vessels were supported in a frame for safety. Microanalyses were performed in the Microanalysis Unit at Cairo University.

2,3-Dimercaptoquinoxaline (1). A mixture of *o*-phenylenediamine (0.1 g, 0.92 mmol), oxalic acid (0.08 g, 0.92 mmol) in HCl (4*N*, 2 mL) was irradiated for 2 min. The product was dissolved in alkali solution (7 mL, 10%) followed by neutralization with dilute HCl to give quinoxaline-2,3-dione. A mixture of quinoxaline-2,3-dione (0.1 g, 0.5 mmol), bentonite (0.1 g), and phosphorus oxychloride (2 mL) was subjected to MW irradiation for 4 min. The reaction mixture was poured onto crushed ice. The precipitate was washed with water successively and recrystallized from ethanol to give 2,3-dichloroquinoxaline (90% yield). A solution of the later (0.2 g, 1 mmol) in ethanol (3 mL) was treated with thiourea (0.2 g, 2.6 mmol) and then irradiated for 4 min. The solvent was evaporated and

Scheme 3. Reagents and conditions: (A) NaOH, DMF, and MWI. (B) K_2CO_3, DMF, and MWI.

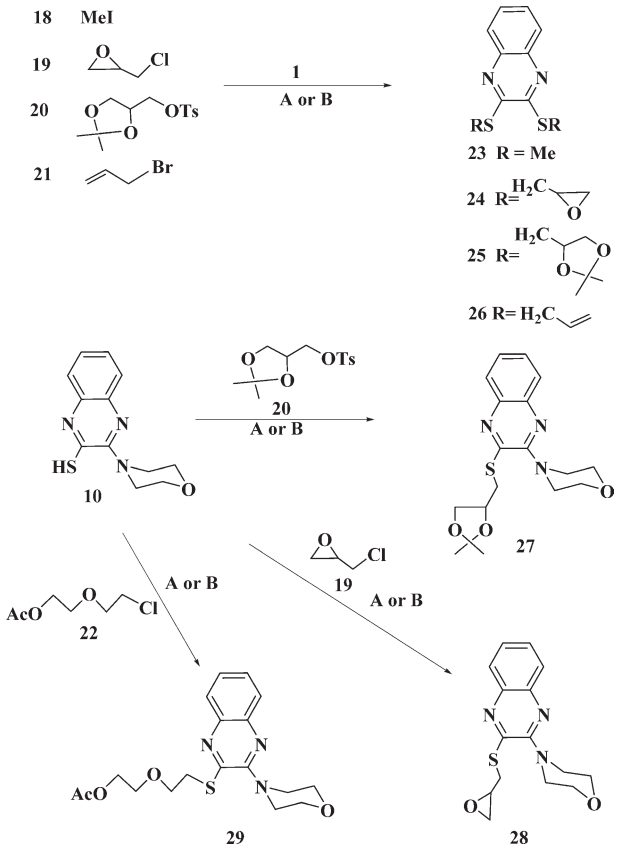


Table 1

Comparison of the results obtained from conventional method (CM) and microwave (MW) method.

Compound	Reagent	Time		Yield (%)		Mp (°C) found/literature
		CM (hr)	MW (min)	CM	MW	
5	A	3	4	60	82	172, 169–170 [13]
	B	4	4	70	82	
6	A	6	4	69	81	196–198
	B	6	5	60	70	
7	A	3	4	50	69	189–190, 192–194 [14]
	B	5	4	44	59	
9	A	5	6	72	85	150–151
	B	7	6	64	84	
12	A	5	3	61	76	160–162
	B	8	4	73	85	
	C	5	4	57	70	
13	A	7	5	60	71	64–66
	B	7	6	75	84	
	C	8	4	53	64	
14	A	6	4	65	78	177–178
	B	8	6	57	74	
17	A	6	4	70	85	199–200
	B	7	5	63	79	
23	A	3	2	75	91	127–129, 134–135 [5]
	B	7	3	75	86	
24	A	4	3	56	65	Syrup
	B	4	3	46	63	
25	A	5	2	67	86	Syrup
	B	4	3	65	77	
26	A	4	2	50	63	82–83
	B	5	3	61	75	
27	A	6	4	69	77	Syrup
	B	7	4	63	80	
28	A	7	6	58	66	112–114
	B	8	6	47	58	
29	A	4	3	50	61	Syrup
	B	6	5	43	52	

the remaining solid was dissolved in aqueous sodium hydroxide, then precipitated with dilute HCl. The product was filtered off and dried to give **1** in 93% yield, mp 298–300°C, lit. mp 295–298°C [12].

General procedure for the glycosylation or alkylation of 2,3-dimercaptoquinoxaline. ***Method A.*** A solution of **1** (0.2 g, 1 mmol) in aqueous sodium hydroxide (0.09 g in 4 mL) was evaporated to dryness. The resulting salt was dissolved in DMF (3 mL), treated with the glycosylating or alkylating agents and stirred. The mixture was poured onto ice water, then filtered off.

Method B. A mixture of **1** (0.2 g, 1 mmol) and potassium carbonate (0.3 g, 2.3 mmol) in DMF (4 mL) was stirred for 2 hr. The corresponding glycosylating or alkylating agents were added and the stirring was continued. The mixture was poured onto ice water, then filtered off. For more details, see Table 1.

2,3-Bis(2′,3′,4′,6′-tetra-O-Acetyl-β-D-glucopyranosyl-sulfanyl)quinoxaline (5). This compound was recrystallized from ethanol. ^{1}H NMR ($CDCl_3$): δ 1.84, 2.02, 2.03, 2.05 (4s, 24H, 8 × CH_3CO), 4.09 (d, 2H, $J_{6',6''}$ = 12.6 Hz, 2 × H-6′), 4.11–4.18 (m, 2H, 2 × H-5′), 4.26 (dd, 2H, $J_{6'',5'}$ = 5.7 Hz, $J_{6'',6'}$ = 12.6 Hz, 2 × H-6″), 5.15 (dd, 2H, $J_{4',3'}$ = 9.2 Hz, $J_{4',5'}$ = 9.8 Hz, 2 × H-4′), 5.32 (dd, 2H, $J_{2',1'}$ = 10.3 Hz, $J_{2',3'}$ = 9.2 Hz, 2 × H-2′), 5.50 (dd, 2H, $J_{3',4'}$ = 9.2 Hz, $J_{3',2'}$ = 9.2 Hz, 2 × H-3′), 6.09 (d, 2H, $J_{1',2'}$ = 10.3 Hz, 2 × H-1′), 7.45–7.67, 7.80–7.95 (2m, 4H, Ar-H).

2,3-Bis(2′,3′,4′,6′-tetra-O-Acetyl-β-D-galactopyranosyl-sulfanyl)quinoxaline (6). This compound was recrystallized from ethanol. ^{1}H NMR ($CDCl_3$): δ 1.87, 2.01, 2.03, 2.18 (4s, 24H, 8 × CH_3CO), 4.05 (dd, 1 H, $J_{6',5}$ = 6.8 Hz, $J_{6',6''}$ = 11.4 Hz, H-6′), 4.14 (dd, 2H, $J_{6'',5}$ = 6.1 Hz, $J_{6'',6'}$ = 11.4 Hz, 2 × H-6″), 4.20–4.22 (m, 2H, 2 × H-5′), 4.66 (dd, 2H, $J_{6',5'}$ = 6.1 Hz, $J_{6',6''}$ = 11.4 Hz, 2 × H-6′), 5.24 (dd, 2H, $J_{3',2'}$ = 9.9 Hz, $J_{4',3'}$ = 3.0 Hz, 2 × H-3′), 5.52 (2t, 4H, $J_{2',3'}$ = 9.9 Hz, $J_{4',3'}$ = 3.0 Hz, 2 × H-2′, 2 × H-4′), 6.03 (d, 2H, $J_{1',2'}$ = 10.7 Hz, 2 × H-1′), 7.65–7.67, 7.90–7.92 (2m, 4H, Ar-H); ^{13}C NMR ($CDCl_3$): δ 20.7, 20.9 (8 × CH_3CO), 61.7 (2 × C-6′), 66.4 (2 × C-4′), 67.5 (2 × C-2′), 72.2 (2 × C-3′), 75.1 (2 × C-5′), 81.3 (2 × C-1′), 127.8, 129.3 (C-Ar), 140.2 (2 × C=N), 151.0 (2 × C—S), 169.6, 170.2, 170.49, 170.5 (8 × CO). Anal. Calcd. for $C_{36}H_{42}N_2O_{18}S_2$ (854.85): C, 50.58; H, 4.95; N, 3.28; S, 7.50. Found: C, 50.64; H, 4.56; N, 3.24; S, 7.78.

2,3-Bis(2′-acetamido-2′-deoxy-3′,4′,6′-tri-O-acetyl-β-glucopyranosyl-sulfanyl)quinoxaline (7). This compound was recrystallized from ethanol. ^{1}H NMR ($CDCl_3$-D_2O): δ 1.80, 1.89, 2.01, 2.04 (4s, 24H, 6 × CH_3CO, 2 × NHAc), 4.04–4.06 (m, 4H, 2 × H-5′, 2 × H-6′), 4.22 (dd, 2H, $J_{6'',5'}$ = 3.5 Hz, $J_{6'',6'}$ = 9.2 Hz, 2 × H-6″), 4.31 (dd, 2H, $J_{2',1'}$ = 10.8 Hz,

$J_{2',3'}$ = 9.7 Hz, 2 × H-2′), 5.08 (dd, 2H, $J_{4',3'}$ = 9.2 Hz, $J_{4',5'}$ = 9.7 Hz, 2 × H-4′), 5.40 (dd, 2H, $J_{3',2'}$ = 9.7 Hz, $J_{3',4'}$ = 9.2 Hz, 2 × H-3′), 6.10 (d, 2H, $J_{1',2'}$ = 10.8 Hz, 2 × H-1′), 7.50–7.67, 7.90–7.95 (2m, 4H, Ar-H).

2,3-Bis(2′,3′,4′,6′-tetra-O-acetyl-β-D-galactopyranosyl-(1 → 4)-(2′,3′,6′-tri-O-acetyl-β-D-glucopyranosyl-sulfanyl)-quinoxaline (9). This compound was recrystallized from ethanol. ^{1}H NMR ($CDCl_3$): δ 1.88, 1.96, 2.01, 2.05, 2.05, 2.06, 2.15 (6s, 42H, 14 × CH_3CO), 3.85–3.89 (m, 6H, 2 × H-4′a, 2 × H-5′b, H-6″b, H-6′b), 4.02–4,07, 4.11–4.15 (2m, 6H, 2 × H-6′b, 2 × H-6′a, 2 × H-6″a), 4.47 (2d, 4H, $J_{1'b,2'b}$ = 10.6 Hz, 2 × H-1′b, 2 × H-5′a), 4.92 (dd, 2H, $J_{3'b,2'b}$ = 8.7 Hz, $J_{3'b,4'b}$ = 3.0 Hz, 2 × H-3′b), 5.10 (dd, 2H, $J_{2'b,1'b}$ = 10.7 Hz, $J_{2'b,3'b}$ = 8.4 Hz, 2 × H-2′b), 5.20 (t, 2H, $J_{2'a,3'a}$ = 9.9 Hz, 2 × H-2′a), 5.34–5.39 (m, 4H, 2 × H-3′a, 2 × H-4′b), 5.97 (d, 2H, $J_{1'a,2'a}$ = 10.7 Hz, 2 × H-1′a), 7.63–7.65, 7.86–7.88 (2m, 4H, Ar-H); ^{13}C NMR ($CDCl_3$): δ 20.8, 20.9 (14 × CH_3), 60.9 (2 × C-6′b), 62.3 (2 × C-6′a), 66.6 (2 × C-4′b), 69.1 (2 × C-2′b), 69.3 (2 × C-2′a), 70.8 (2 × C-5′b), 71.1 (2 × C-3′b), 74.1 (2 × C-3′a), 76.4 (2 × C-4′a), 80.6 (2 × C-1′a), 101.2 (2 × C-1′b), 128.0, 129.3,140.1 (C-Ar), 140.1 (C=N), 150.9 (2 × C—S), 169.8, 167.9,170.3, 170.4, 170.5 (14 × CO). Anal. Calcd. for $C_{60}H_{74}N_2O_{34}S_2$ (1431.35): C, 50.35; H, 5.21; N, 1.96; S, 4.48. Found: C, 50.15; H, 5.54; N, 1.98; S, 4.70.

2-Mercapto-3-morpholin-1-yl-quinoxaline (10). *Conventional method.* A solution of 2,3-dichloroquinoxaline (0.1 g, 0.5 mmol) in DMF (2 mL) was treated with morpholine (0.05 mL, 0.6 mmol) and stirred for 2 hr. The mixture was poured onto ice water, filtered off, and recrystallized from ethanol to give 2-chloro-3-morpholinyl-quinoxaline (**11**). A mixture of **11** (0.5 g, 2 mmol), thiourea (0.18 g, 2.4 mmol) in ethanol (5 mL) was heated under reflux for 2 hr. The solvent was evaporated under reduced pressure. The residue was dissolved in sodium hydroxide solution (9 mL, 8%), then neutralized with dilute HCl. The solid that separated was recrystallized from ethanol.

MWI method. A solution of 2,3-dichloroquinoxaline (0.1 g, 0.5 mmol) in DMF (2 mL) was treated with morpholine (0.05 mL, 0.6 mmol) was irradiated for 2 min, then processed as above, it gave the same product **11**. ^{1}H NMR ($CDCl_3$): δ 3.58 (t, 4H, 2 × CH_2N), 3.92 (t, 4H, 2 × CH_2O), 7.51–7.83 (4H, Ar-H). A mixture of **11** (0.5 g, 2 mmol), thiourea (0.18 g, 2.4 mmol) in ethanol (5 mL) was irradiation with MW for 2 min, then processed as above to give the product **10** (88% yield), mp 180–182°C. ^{1}H NMR ($CDCl_3$): δ = 3.89 (d, 4H, 2 × CH_2N), 3.90 (d, 4H, 2 × CH_2O), 7.35–7.67 (m, 4H, Ar-H), 12.21 (s, 1H, SH).

General procedure for the alkylation of 2-mercapto-3-morpholin-1-yl-quinoxaline. ***Method A.*** 2-Mercapto-3-morpholinyl-quinoxaline (**10**) (0.1 g, 0.4 mmol) was dissolved in aqueous sodium hydroxide (0.018 g, 3 mL), then water was evaporated to dryness. The residue was dissolved in DMF (3 mL), then stirred with the appropriate alkylating agent **2**–**4**. The mixture was poured onto ice water and the product that separated out was purified.

Method B. A mixture of **10** (0.1 g, 0.4 mmol), potassium carbonate (0.07 g, 0.5 mmol) in DMF (3 mL) was stirred for 2 hr at room temperature, then treated with the appropriate alkylating agent **2**–**4**. Stirring was continued, then processed as above.

Method C. A mixture of 2-chloro-3-morpholinyl-quinoxaline (0.2 g, 0.8 mmol), sugar isothiouronium salt **15** and **16** (1 mmol), and triethylamine (1 mmol) in acetonitrile (3 mL) was stirred, then the solvent was evaporated under reduced pressure to give the same products.

3-Morpholinyl-2-(2′,3′,4′,6′-tetra-O-acetyl-β-D-glucopyranosyl-sulfanyl)quinoxaline (12). Crystallized from ethanol. ^{1}H NMR ($CDCl_3$): δ 1.88, 2.01, 2.03, 2.05 (4s, 12H, 4 × CH_3CO), 3.29–3.34 and 3.42–3.46 (2m, 4H, 2 × CH_2N), 3.86–3.88 (m, 4H, 2 × CH_2O), 3.99–4.01 (m, 1H, H-5′), 4.10 (dd, 1H, $J_{6',5'}$ = 2.2 Hz, $J_{6',6''}$ = 12.2 Hz, H-6′), 4.22 (dd, 1H, $J_{6'',5'}$ = 5.3 Hz, $J_{6'',6'}$ = 12.2 Hz, H-6″), 5.17 (t, 1H, $J_{4',3'}$ = 9.5 Hz, $J_{4',5'}$ = 9.5 Hz, H-4′), 5.33 (dd, 1H, $J_{2',3'}$ = 9.5 Hz, $J_{2',1'}$ = 10.7 Hz, H-2′), 5.43 (t, 1H, $J_{4',3'}$ = 9.5 Hz, $J_{3',2'}$ = 9.5 Hz, H-3′), 6.04 (d, 1H, $J_{1',2'}$ = 10.7 Hz, H-1′), 7.57 (2t, 2H, 2 × Ar-H), 7.84 (2d, 2H, 2 × Ar-H). ^{13}C NMR ($CDCl_3$): δ 20.7 and 20.8 (4 × CH_3CO), 49.9 (2 × CH_2N), 62.1 (C-6′), 66.7 (2 × CH_2O), 68.6 (C-4′), 69.2 (C-5′), 74.4 (C-2′), 76.3 (C-3′), 80.7 (C-1′), 127.5, 127.6, 128.9, 139.2, 139.2 (C-Ar), 148.2, 153.6 (2 × C=N), 169.6, 170.3, 170.7 (4 × CO). Anal. Calcd. for $C_{26}H_{31}N_3O_{10}S$ (577.60): C, 54.06; H, 5.40; N, 7.27; S, 5.5. Found: C, 54.30; H, 5.33; N, 6.91; S, 5.20.

3-Morpholinyl-2-(2′,3′,4′,6′-tetra-O-acetyl-β-1-sulfany-D-galactopyranosyl)quinoxaline (13). Purified by flash column chromatography using hexane–ethylacetate (H/E 4/1), ^{1}H NMR ($CDCl_3$): δ 1.86, 2.00, 2.01, 2.17 (4s, 12H, 4 × CH_3CO), 3.30–3.35 (m, 2H, CH_2N), 3.43–4.48 (m, 2H, CH_2N), 3.86–3.88 (m, 4H, 2 × CH_2O), 4.05–4.08 (m, 1H, H-5′), 4.15 (dd, 1H, $J_{2',1'}$ = 11.5 Hz, $J_{2',3'}$ = 10.7 Hz, H-2′), 4.23 (dd, 1H, $J_{6',5'}$ = 6.1 Hz, $J_{6',6''}$ = 12.2 Hz, H-6′), 5.27 (dd, 1H, $J_{6'',5'}$ = 6.1 Hz, $J_{6'',6'}$ = 12.2 Hz, H-6″), 5.54 (dd, 2H, $J_{3',2'}$ = 10.7 Hz, $J_{3',4'}$ = 3.8 Hz, H-3′, H-4′), 6.05 (d, 1H, $J_{1',2'}$ = 11.4 Hz, H-1′), 7.31, 7.82 (4H, Ar-H). ^{13}C NMR ($CDCl_3$): δ 20.7, 20.7, 20.8, 20.9 (4 × CH_3CO), 50.0 (CH_2N), 61.6 (C-6′), 66.7 (C-4′, CH_2O), 67.6 (C-2′), 72.4 (C-3′), 75.0 (C-5′), 81.0 (C-1′), 127.5, 127.6, 128.9, 139.2, 139.24 (C-Ar), 148.4 153.6 (2 × C=N), 169.8, 170.2, 170.4, 170.5 (4 × CO). Anal. Calcd. for $C_{26}H_{31}N_3O_{10}S$ (577.60): C, 54.06; H, 5.40; N, 7.27; S, 5.5. Found: C, 54.20; H, 5.41; N, 7.34; S, 5.30.

2-(2′-Acetamido-2′-deoxy-3′,4′,6′-tri-O-acetyl-β-1-sulfanyl-D-glucopyranosyl)-3-morpholin-1-yl-quinoxaline (14). Recrystallized from ethanol as yellow crystals. ^{1}H NMR ($CDCl_3$): δ 1.83, 1.93, 2.06, 2.07 (4s, 4H, 4 × CH_3CO), 3.31–3.36, 3.43–3.47 (2m, 4H, 2 × CH_2N), 3.88–3.89 (m, 5H, H-5′, 2 × CH_2O), 4.10 (bdd, 1H, $J_{6',6''}$ = 12.2 Hz, H-6′), 4.20 (dd, 1H, $J_{6'',6'}$ = 12.2 Hz, $J_{6'',5'}$ = 5.3 Hz, H-6″), 4.52 (dd, 1H, $J_{2',1'}$ = 10.7 Hz, $J_{2',3'}$ = 9.9 Hz, H-2′), 5.19 (dd, 1H, $J_{4',3'}$ = 10.7 Hz, $J_{4',5'}$ = 19.1 Hz, H-4′), 5.26 (dd, 1H, $J_{3',2'}$ = 9.9 Hz, $J_{3',4'}$ = 10.7 Hz, H-3′), 5.85 (d, 1H, J = 9.1 D_2O exchangeable, $J_{NH,2'}$ = 9.1 Hz, NH), 5.94 (d, 1H, $J_{1',2'}$ = 10.7 Hz, H-1′), 7.53–7.60, 7.81–7.83 (2m, 4H, Ar-H). ^{13}C NMR ($CDCl_3$): δ 20.7, 20.9 (4 × $OCOCH_3$), 22.8 ($NCOCH_3$), 50.0 (2 × CH_2N), 53.0 (C-2), 62.3 (C-6′), 66.7 (2 × CH_2), 68.5 (C-5), 72.1 (C-4), 77.9 (C-3), 81.4 (C-1′), 127.1, 127.7, 128.9, 138.9, 139.2 (6 × C-Ar), 149.5, 153.7, (2 × C=N), 169.4, 170.1, 170.9, 171.5 (4 × CO). Anal. Calcd. for $C_{26}H_{32}N_4O_9S$ (576.61): C, 54.16; H, 5.59; N, 9.72; S, 5.56. Found: C, 54.30; H, 5.41; N, 10.01; S, 5.30.

3-Morpholinyl-2-(2′,3′,4′,6′-tetra-O-acetyl-β-D-galactopyranosyl-(1 → 4)-(2′,3′,4′,6′-tetra-O-acetyl-β-1-sulfanyl-D-glucopyranosyl)quinoxaline (17). Recrystallized from ethanol. ^{1}H NMR ($CDCl_3$): δ 1.86, 1.96, 2.00, 2.07, 2.07, 2.16 (6s, 21H, 7 × CH_3CO), 3.31–3.34 (m, 2H, CH_2N), 3.40–3.43 (m,

2H, CH_2N), 3.82–3.93 (m, 7H, 2 × CH_2O, H-2′b, H-6′a, H-6′b), 4.07 (dd, 1H, $J_{6''a,6'a}$ = 11.4 Hz, $J_{6''a,\ 5'a}$ = 5.3 Hz, H-6″a), 4.11 (t, 1H, $J_{5'b,4'b}$ = 3.8 Hz, $J_{5'b,6'b}$ = 6.8 Hz, H-5′b), 4.16 (dd, 1H, $J_{6''b,5'b}$ = 6.1 Hz, $J_{6''b,6'b}$ = 6.1 Hz, H-6″b), 4.43 (dd, 1H, $J_{5'a,4'a}$ = 9.9 Hz, $J_{5'a,6'a}$ = 1.5 Hz, H-5′a), 4.48 (d, 1H, $J_{1'b,2'b}$ = 7.6 Hz, H-1′b), 4.96 (dd, 1H, $J_{4'b,3'b}$ = 3.0 Hz, $J_{4'b,5'b}$ = 3.8 Hz, H-4′b), 5.16 (dd, 1H, $J_{2'a,1'a}$ = 10.7 Hz, $J_{2'a,3'a}$ = 8.4 Hz, H-2′a), 5.25 (dd, 1H, $J_{4'a,3'a}$ = 9.1 Hz, $J_{4'a,5'a}$ = 9.9 Hz, H-4′a), 5.37 (d, 1H, $J_{3'b,4'b}$ = 3.0 Hz, H-3′b), 5.40 (dd, 1H, $J_{3'a,2'a}$ = 8.4 Hz, $J_{3'a,4'a}$ = 9.1 Hz, H-3′a), 6.02 (d, 1H, $J_{1'a,2'a}$ = 10.7 Hz, H-1′a), 7.53–7.59, 7.81–7.85 (2m, 4H, Ar-H). ^{13}C NMR ($CDCl_3$): δ 20.7–20.8 (7 × CH_3CO), 49.9 (2 × CH_2 N), 60.9 (C-6′a), 62.4 (C-6′b), 66.7 (2 × CH_2O), 69.2 (C-3′a), 69.6 (C-2′b, C-2′a), 70.8 (C-3′b), 71.1 (C-4′a), 74.3 (C-4′b), 76.5 (C-5′b, C-5′a), 80.7 (C-1′a), 101.3 (C-1′b), 127.55, 127.57, 127.64, 128.94, 139.20 (C-Ar), 148.3 153.6 (2 × C=N), 169.3–170.5 (7 × CO). Anal. Calcd. for $C_{38}H_{47}N_3O_{18}S$ (865.85): C, 52.71, H, 5.47, N, 4.85, S, 3.70. Found: C, 52.45, H, 5.80, N, 4.75, S, 3.58.

2,3-Bis(±2′,3′-epoxypropyl-1′-sulfanyl)quinoxaline (24). The residue was purified by flash column chromatography using hexane–ethylacetate (H/E 6/1) to give **24** as a syrup. ^{1}H NMR ($CDCl_3$): δ 3.71 (dd, 4H, $J_{3',3''}$ = 6.1 Hz, $J_{3',2'}$ = 2.3 Hz, 2 × H-3′, 2 × H-3″), 4.28–4.29 (m, 4H, 2 × CH_2S), 4.78 (bd, 2H, 2 × H-2′), 7.60, 7.85 (4H, Ar-H). ^{13}C NMR ($CDCl_3$): δ 35.3 (2 × CH_2S), 47.4 (2 × C-3′), 71.1 (2 × C-2′), 127.6, 129.3, 139.2 (C-Ar), 154.6 (2 × C═S). Anal. Calcd. for $C_{14}H_{14}N_2O_2S_2$ (306.40): C, 54.88, H, 4.51, N, 9.14, S, 20.93. Found: C, 54.50, H, 4.30, N, 9.20, S, 20.50.

2,3-Bis[(±)-2′,3′-O-isopropylidene-2′,3′-dihydroxy-propyl-1′-sulfanyl]quinoxaline (25). The residue was purified by flash column chromatography using hexane–ethylacetate (H/E 5/1) to give **25**. ^{1}H NMR ($CDCl_3$): δ 1.36, 1.49 (2s, 12H, 4 × CH_3), 3.46–3.48 (m, 2H, 2 × H-2′), 3.70 (dd, 2H, $J_{3'',2'}$ = 5.3 Hz, $J_{3'',3'}$ = 13.0 Hz, 2 × H-3″), 3.84 (dd, 2H, $J_{1',2'}$ = 6.1 Hz, $J_{1',1''}$ = 8.4 Hz, 2 × H-1′), 4.14 (dd, 2H, $J_{1'',2'}$ = 6.1 Hz, $J_{1'',1'}$ = 8.4 Hz, 2 × H-1″), 4.45–4.49 (m, 2 × H-3′), 7.56, 7.87 (2 dd, 4H, Ar-H). ^{13}C NMR ($CDCl_3$): δ 25.7, 27.1 (4 × CH_3), 68.8 (2 × C-3′), 74.5 (2 × C-2′), 109.8 (CH_3CCH_3), 127.6, 128.4, 139.8 (C-Ar), 153.2 (2 × C=N). Anal. Calcd. for $C_{20}H_{26}N_2O_4S_2$ (422.55): C, 56.79, H, 6.20, N, 6.63, S, 15.14. Found: C, 56.51, H, 6.30, N, 6.89, S, 15.25.

2,3-Bis(allylsulfanyl)quinoxaline (26). Crystallized from ethanol. ^{1}H NMR ($CDCl_3$): δ 4.03 (d, 4H, J = 6.8 Hz, 2 × H-1′, 2 × H-1″), 5.17 (d, 2H, J = 9.9 Hz, 2 × H-3′), 5.40 (d, 2H, J = 16.8 Hz, 2 × H-3″), 5.98–6.05 (m, 2H, 2 × H-2′), 7.55, 7.85 (2dd, 4H, Ar-H). ^{13}C NMR ($CDCl_3$): δ 33.2 (2 × C-1′), 118.7 (2 × C-2′), 127.5, 128.1 (C-Ar), 133.0 (2 × C-3′), 139.9, 153.7 (2 × C=N). Anal. Calcd. for $C_{14}H_{14}N_2S_2$ (274.40): C, 61.28, H, 5.14, N, 10.21, S, 23.37. Found: C, 61.23, H, 5.00, N, 10.24, S, 23.10.

(±)-2-(2′,3′-O-Isopropylidene-2′,3′-dihydroxy-propyl-1′-sulfanyl)-3-morpholin-1-yl-quinoxaline (27). Purified by flash column chromatography using hexane–ethylacetate (H/E 6/1). ^{1}H NMR ($CDCl_3$): δ 1.36, 1.49 (2s, 6H, 2 × CH_3), 3.43–3.47 (m, 5H, 2 × CH_2N, H-1″), 3.57 (dd, 1H, $J_{3',2'}$ = 6.1 Hz, $J_{3',3''}$ = 8.4 Hz, H-3′), 3.82 (dd, 1H, $J_{1',1''}$ = 8.4 Hz, $J_{1',2'}$ = 6.1 Hz, H-1′), 3.90 (t, 4H, 2 × CH_2O), 4.12 (dd, 1H, $J_{3'',2'}$ = 6.1 Hz, $J_{3'',3'}$ = 8.4 Hz, H-3″), 4.45–4.50 (m, 1H, H-2′), 7.40–7.47 (m, 2H, 2 × Ar-H), 7.80–7.90 (m, 2H, 2 × Ar-H). ^{13}C NMR ($CDCl_3$): δ 25.7, 27.1 (2 × CH_3), 32.8 (C-1′), 49.8 (2 × CH_2N), 66.8 (2 × CH_2O), 68.9 (C-3′), 74.7 (C-2′), 109.7 (CH_3C), 127.20, 127.37, 127.47, 128.29, 138.72, 139.22 (C-Ar), 150, 153.67 (2 × C=N). Anal. Calcd. for $C_{18}H_{23}N_3O_3S$ (361.46): C, 59.81; H, 6.41; N, 11.62; S, 8.86. Found C, 59.58; H, 6.72; N, 11.41; S, 9.01.

2-(2′,3′-Epoxy-propyl-1′-sulfanyl)-3-morpholin-1-yl-quinoxaline (28). Purified by flash column chromatography using hexane–ethylacetate (H/E 4/1). ^{1}H NMR ($CDCl_3$): δ 2.51 (dd, 1H, $J_{3',2'}$ = 5.3 Hz, $J_{3',3''}$ = 6.1 Hz, H-3′), 2.58 (dd, 1H, $J_{3'',2'}$ = 1.5 Hz, $J_{3'',3'}$ = 6.1 Hz, H-3″), 3.24–3.29 (m, 1H, H-2′), 3.84–3.86 (m, 4H, 2 × CH_2N), 3.90–3.96 (m, 4H, 2 × CH_2O), 4.38 (dd, 1H, $J_{1',1''}$ = 13.7 Hz, $J_{1',2'}$ = 4.6 Hz, H-1′), 5.2 (dd, 1H, $J_{1'',1'}$ = 13.7 Hz, $J_{1'',2'}$ = 7.6 Hz, H-1″), 7.24–7.31 (m, 2H, 2 × Ar-H), 7.38, 7.57 (2dd, 2H, 2 × Ar-H). ^{13}C NMR ($CDCl_3$): δ 24.8 (C-1′), 30.6 (C-3′), 47.5 (2 × CH_2N), 47.6 (C-2′), 67.0 (2 × CH_2O), 113.5, 124.2, 125.6, 127.4, 123.0, 133.3 (C-Ar), 150.8, 152.2 (2 × C=N). Anal. Calcd. for $C_{15}H_{17}N_3O_2S$ (303.00): C, 59.38, H, 5.65, N, 13.85, S, 10.57. Found: C, 59.70, H, 5.91, N, 13.50, S, 10.57.

2-(5-Acetoxy-3-oxapent-1-yl-sulfanyl)-3-morpholin-1-yl-quinoxaline (29). The residue was purified by flash column chromatography using hexane–ethylacetate (H/E 6/1) to give **29** as a syrup. ^{1}H NMR ($CDCl_3$): δ 2.03 (s, 3H, CH_3CO), 3.45 (t, 2H, $J_{1',1''}$ = 9.2 Hz, H-1′, H-1″), 3.70–3.74 (m, 4H, 2 × CH_2N), 3.80–3.92 (m, 4H, 2 × CH_2O), 4.20 (dd, 2H, $J_{5',5''}$ = 13.7 Hz, $J_{5',4'}$ = 4.6 Hz, H-5′, H-5″), 4.74 and 5.66 (2d, 4H, H-2′, H-2″, H-4′, H-4″), 7.50–7.57, 7.80–7.87 (2m, 4H, Ar-H). ^{13}C NMR ($CDCl_3$): δ 21.0 (CH3), 38.7 (C-1′), 49.9 (2 × CH_2N), 63.6 (C-5′), 66.8 (2 × CH_2O), 68.9 (C-4′), 71.0 (C-2′), 127.3, 127.4, 128.5, 128.9, 139.0 (C-Ar), 149.9, 153.6 (2 × C=N), 171.1 (C=O). Anal. Calcd. for $C_{18}H_{23}N_3O_4S$ (377.47): C, 57.28; H, 6.14; N, 11.13; S, 8.49. Found C, 57.39; H, 6.45; N, 11.27; S, 8.11.

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