Significantly Fast Synthesis of *S*-Glycosyl N-Substituted Dithiocarbamate and *S*-Glycosyl S′-Substituted Trithiocarbonate Derivatives under Solvent-Free Conditions

Manas Jana, Anup Kumar Misra*

Division of Molecular Medicine, Bose Institute, P-1/12, C. I. T. Scheme VII M, Kolkata 700054, India
Fax +91(33)23553886; E-mail: akmisra69@gmail.com

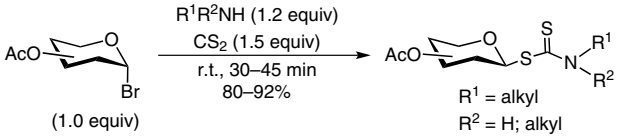
Received: 17.08.2012; Accepted after revision: 08.10.2012

Abstract: A series of *S*-glycosyl N-substituted dithiocarbamate and *S*-glycosyl S′-substituted trithiocarbonate derivatives have been synthesized under solvent-free conditions. Three-component reaction of glycosyl bromides with carbon disulfide and thiols or amines in the presence or absence of triethylamine furnished excellent yields of the target compounds in a short reaction time.

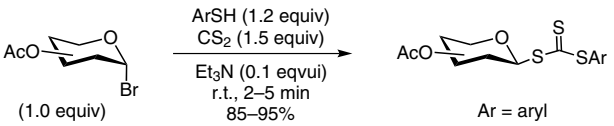
Key words: dithiocarbamate, trithiocarbonate, carbohydrates, carbon disulfide, three-component reaction, solvent-free

Dithiocarbamate derivatives are an important class of molecules having wide applications as pharmaceuticals[1] and agrochemicals.[2] They have been used as intermediates in the synthesis of different classes of organic molecules.[3] Several reports can be found in the literature for the synthesis of dithiocarbamate derivatives in organic[4–6] and aqueous media[7] as well as under solvent-free conditions.[8] Similar to dithiocarbamate derivatives, organic trithiocarbonate derivatives have significant applications in organic synthesis,[9] pharmaceutics,[10] and materials science.[11] Numbers of reports are also available for the synthesis of trithiocarbonate derivatives in organic solvents.[12–15] However, most of the reported methods for the synthesis of these compounds suffer from serious shortcomings, such as use of toxic and sensitive reagents, use of organic solvents, extended reaction times, tedious workup, or unsatisfactory yield.

We required *S*-glycosyl N-substituted dithiocarbamate and *S*-glycosyl S′-substituted trithiocarbonate derivatives as synthetic precursors. Syntheses of *S*-glycosyl N-substituted dithiocarbamate derivatives[16] have been reported by the reaction of glycosyl halide derivatives with amine carbodithioate salts in organic solvents or under phase-transfer conditions or reaction of glycal derivatives[16h] with in situ generated amine carbodithioate salts. However, reports on the synthesis of *S*-glycosyl S′-substituted trithiocarbonate derivatives are limited.[17] Previously, *S*-glycosyl N-substituted dithiocarbamate derivatives have been used as glycosyl donors in stereoselective glycosylations for the synthesis of oligosaccharides.[16g,h] We envisaged that a multicomponent one-pot reaction of glycosyl halides, carbon disulfide, and amines or thiols without organic solvent, and preferably, in the absence of a catalyst, could furnish the desired compounds. Herein, we report our findings on the solvent-free synthesis of *S*-glycosyl N-substituted dithiocarbamate and *S*-glycosyl S′-substituted trithiocarbonate derivatives by such three-component reactions (Scheme 1 and Scheme 2).



Scheme 1 Solvent-free and catalyst-free three-component reaction of glycosyl halide, carbon disulfide, and amine



Scheme 2 Triethylamine-catalyzed solvent-free three-component reaction of glycosyl halide, carbon disulfide, and thiol

Initially, stirring equimolar mixture of piperidine, carbon disulfide, and 2,3,4,6-tetra-*O*-acetyl-α-D-glucopyranosyl bromide (**1**) at room temperature resulted in the exclusive formation of 2,3,4,6-tetra-*O*-acetyl-β-D-glucopyranosyl 1-piperidine carbodithioate (**4**) in 75% yield as a white solid in 30 minutes. After a series of experimentation it was observed that yield of compound **4** can be raised to 90% under optimized reaction conditions.[18] A scaled-up preparation of compound **4** was also carried out on a 5.0 gram scale, and the yield was comparable to the smaller scale (0.5 g) reaction. Previously, compound **4** has been prepared in 82% yield by the treatment of compound **1** with piperidine and carbon disulfide in the presence of sodium hydride in DMF at 0 °C to room temperature for one hour.[16g] In order to generalize the reaction conditions, a series of primary and secondary amines was allowed to react with a mixture of carbon disulfide and various glycopyranosyl bromides (mono- and disaccharides) at room temperature to give the corresponding *S*-glycosyl N-substituted dithiocarbamate derivatives (Table 1). Excellent yields of solid products were obtained in all reactions. Primary amines were also effective to furnish *S*-glycosyl N-substituted dithiocarbamate products (Table 1, entries 5 and 6).

SYNLETT 2012, 23, 2789–2794
Advanced online publication: 13.11.2012
DOI: 10.1055/s-0032-1317521; Art ID: ST-2012-D0694-L

Table 1 Solvent-Free Reaction of Glycosyl Bromides, Carbon Disulfide, and Amines at Room Temperature for the Synthesis of *S*-Glycosyl N-Substituted Dithiocarbamate Derivatives

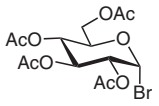
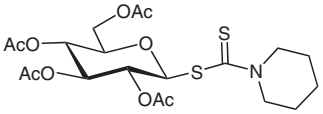
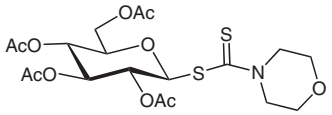
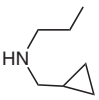
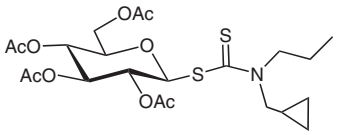
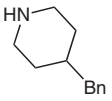
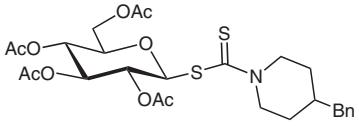
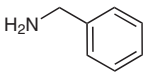
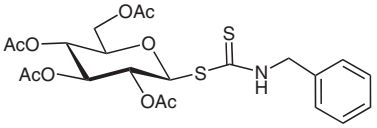
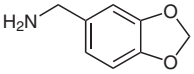
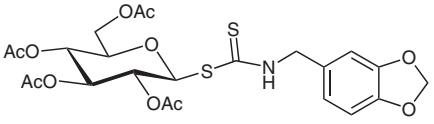
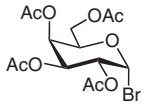
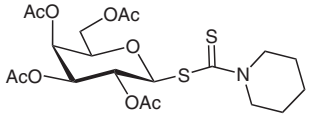
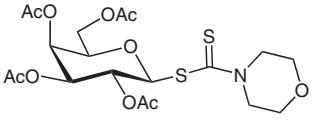
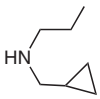
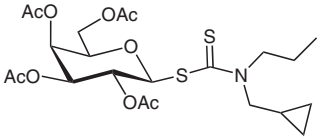
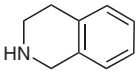
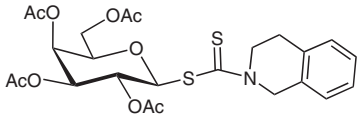
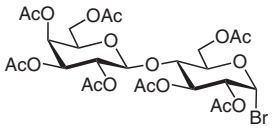
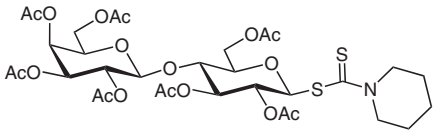
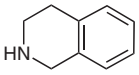
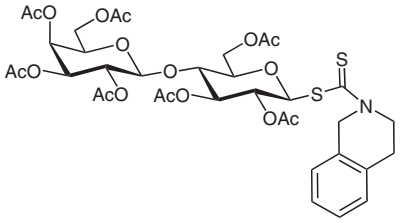
Entry	Glycosyl bromide	Amine	*S*-Glycosyl N-substituted dithiocarbamate	Time (min)	Yield (%)[a]
1	 **1**		 **4**[16g]	30 40[b]	90 88[b]
2	**1**		 **5**	30	92
3	**1**		 **6**	30	85
4	**1**		 **7**	30	86
5	**1**		 **8**	25	82
6	**1**		 **9**	25	85
7	 **2**		 **10**[16g]	30	92
8	**2**		 **11**	30	92
9	**2**		 **12**	30	82

Table 1 Solvent-Free Reaction of Glycosyl Bromides, Carbon Disulfide, and Amines at Room Temperature for the Synthesis of *S*-Glycosyl N-Substituted Dithiocarbamate Derivatives (continued)

Entry	Glycosyl bromide	Amine	*S*-Glycosyl N-substituted dithiocarbamate	Time (min)	Yield (%)[a]
10	**2**		 **13**	30	80
11	 **3**		 **14**	45	85
12	**3**		 **15**	45	80

[a] Isolated yield.
[b] Scale = 5.0 g.

After successful preparation of *S*-glycosyl N-substituted dithiocarbamate derivatives, the same solvent-free reaction conditions were applied to the preparation of *S*-glycosyl S′-substituted trithiocarbonate derivatives. A mixture of *p*-methylthiophenol (1.2 mmol), carbon disulfide (1.5 mmol), and compound **1** (1.0 mmol) was allowed to stir at room temperature. Unfortunately, the reaction did not proceed even after five hours at room temperature. In order to activate the reaction, a catalytic amount of triethylamine was added to the reaction mixture and, gratifyingly, the product, *S*-(2,3,4,6-tetra-*O*-acetyl-β-D-glucopyranosyl)-*S*′-(*p*-methylphenyl)trithio carbonate (**16**) was formed immediately (2 min) on addition of the base. After optimization, it was observed that the addition of 0.1 equivalent of triethylamine to the three-component solvent-free reaction with the above-mentioned ratio of the substrates furnished **16** in excellent yield (92%).[19] Use of other commonly used solid bases such as Na_2CO_3, $NaHCO_3$, K_2CO_3, NaOH, KOH, and Cs_2CO_3 was found to be ineffective to catalyze the reaction, maybe due to their insolubility in the reaction medium. However, a very low yield of product formation (ca. 15%) was observed using NaOH or KOH together with the formation of unwanted byproducts over a longer reaction time. The reaction conditions were further extended to the synthesis of a series of *S*-glycosyl S′-substituted trithiocarbonate derivatives by the reaction of a series of aryl and heteroaryl thiols with carbon disulfide and glycosyl halides (mono- and disaccharides; Table 2). Compound **16** was also prepared on a 5.0 gram scale, and its yield was similar to that obtained from smaller scale (0.5 g scale) synthesis. A noteworthy point of the two sets of reaction conditions is the exclusive formation of β-glycosidic products, with no trace of α-product being detected. It is also worth stressing that the reactions did not require any organic solvent. All products were unambiguously characterized by their melting point, NMR spectroscopic, and mass spectrometric analysis.

Table 2 Triethylamine-Catalyzed Solvent-Free Reaction of Glycosyl Bromides, Carbon Disulfide, and Thiols for the Preparation of *S*-Glycosyl S′-Substituted Trithiocarbonate Derivatives

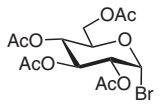
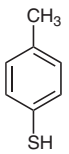
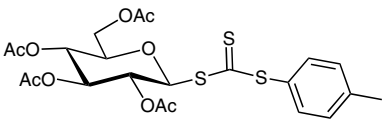
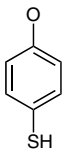
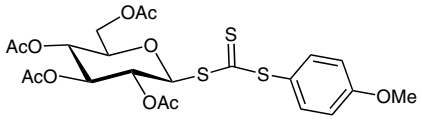
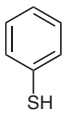
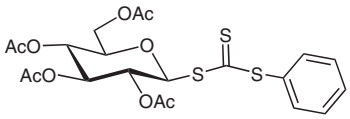
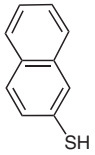
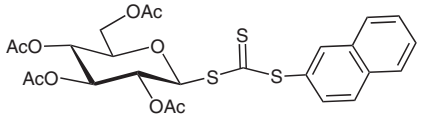
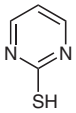
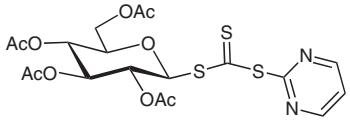
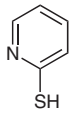
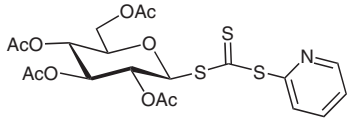
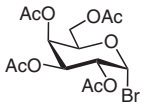
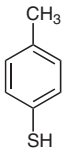
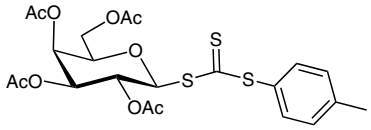
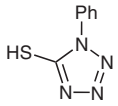
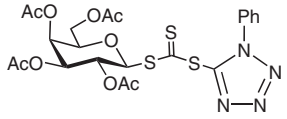
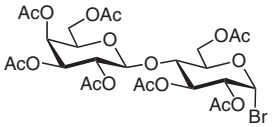
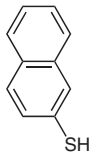
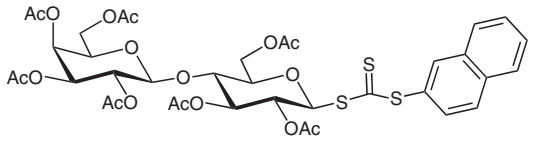
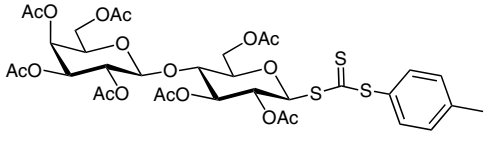
Entry	Glycosyl bromide	Thiol	*S*-Glycosyl S′-substituted trithiocarbonate	Time (min)	Yield (%)[a]
1	 **1**		 **16**	2 5[b]	92 90[b]

Table 2 Triethylamine-Catalyzed Solvent-Free Reaction of Glycosyl Bromides, Carbon Disulfide, and Thiols for the Preparation of *S*-Glycosyl S′-Substituted Trithiocarbonate Derivatives (continued)

Entry	Glycosyl bromide	Thiol	*S*-Glycosyl S′-substituted trithiocarbonate	Time (min)	Yield (%)[a]
2	**1**		 **17**	5	90
3	**1**		 **18**	2	95
4	**1**		 **19**	5	92
5	**1**		 **20**	2	86
6	**1**		 **21**	2	88
7	 **2**		 **22**	2	95
8	**2**		 **23**	10	85
9	 **3**		 **24**	5	88
10	**3**		 **25**	2	

[a] Isolated yield.
[b] Scale = 5.0 g.

In summary, a three-component reaction of glycosyl halides, carbon disulfide, and amines or thiols has been carried out under solvent-free conditions to furnish *S*-glycosyl N-substituted dithiocarbamate or *S*-glycosyl S′-substituted trithiocarbonate derivatives in excellent yield. The preparation of dithiocarbamates was achieved without using any catalyst, while preparation of trithiocarbonate derivatives required triethylamine as the catalyst. The advantageous features of the present methodology over the earlier reported preparations of *S*-glycosyl N-substituted dithiocarbamate or *S*-glycosyl S′-substituted trithiocarbonate derivatives are that it is an operationally simple, exceptionally high-yielding, and highly stereoselective conversion with no requirement for organic solvents. Further utilization of these compounds in glycosylation reactions is in progress in our laboratory.

Acknowledgment

M.J. thanks CSIR, New Delhi for providing junior research fellowship. This work was supported by Department of Science and Technology (DST), New Delhi (Project No. SR/S1/OC-83/2010).

References and Notes

(1) (a) Ranise, A.; Spallarossa, A.; Schenone, S.; Burno, O.; Bondavalli, F.; Vargiu, L.; Marceddu, T.; Mura, M.; Colla, P. L.; Pani, A. *J. Med. Chem.* **2003**, *46*, 768. (b) Cao, S. L.; Feng, Y. P.; Jiang, Y. Y.; Liu, S. Y.; Ding, G. Y.; Li, R. T. *Bioorg. Med. Chem. Lett.* **2005**, *15*, 1915. (c) Chen, D.; Cui, Q. C.; Yang, H.; Dou, Q. P. *Cancer Res.* **2006**, *66*, 10425.

(2) (a) Len, C.; Postal, D.; Ronco, G.; Villa, P.; Goubert, C.; Jeufrault, E.; Mathon, B.; Simon, H. *J. Agric. Food Chem.* **1997**, *45*, 3. (b) Soloneski, S.; Gonzalez, M.; Piaggio, E.; Apezteguia, M.; Reigosa, A. A.; Larramendy, M. L. *Mutagenesis* **2001**, *16*, 487.

(3) (a) Greene, T. W.; Wuts, P. G. M. *Protecting Groups in Organic Synthesis*, 3rd ed.; Wiley Interscience: New York, **1999**, 484. (b) Barton, D. H. R. *Tetrahedron* **1992**, *48*, 2529. (c) Crich, D.; Quintero, L. *Chem. Rev.* **1989**, *89*, 1413. (d) Yu, T.; Yamada, T.; Weiss, R. G. *Chem. Mater.* **2010**, *22*, 5492. (e) Mukherjee, A. K.; Ashare, A. *Chem. Rev.* **1991**, *91*, 1.

(4) (a) Burke, J. T. R.; Bajwa, B. S.; Jacobsen, A. E.; Rice, K. C.; Streaty, R. A.; Klee, W. A. *J. Med. Chem.* **1984**, *27*, 1570. (b) Walter, W.; Bode, K. D. *Angew. Chem., Int. Ed. Engl.* **1967**, *6*, 281.

(5) Chaturvedi, D.; Ray, S. *Tetrahedron Lett.* **2006**, *47*, 1307.

(6) Ranu, B. C.; Saha, A.; Banerjee, S. *Eur. J. Org. Chem.* **2008**, 519.

(7) (a) Bhadra, S.; Saha, A.; Ranu, B. C. *Green Chem.* **2008**, *10*, 1224. (b) Azizi, N.; Aryanasab, F.; Torkiyan, L.; Ziyaei, A.; Saidi, M. R. *J. Org. Chem.* **2006**, *71*, 3634. (c) Azizi, N.; Aryanasab, F.; Tourkian, L.; Saidi, M. R. *Synth. Commun.* **2011**, *41*, 94.

(8) (a) Azizi, N.; Aryanasab, F.; Saidi, M. R. *Org. Lett.* **2006**, *8*, 5275. (b) Azizi, N.; Ebrahimi, F.; Aakbari, E.; Aryanasab, F.; Saidi, M. R. *Synlett* **2007**, 2797. (c) Azizi, N.; Pourhasan, B.; Aryanasab, F.; Saidi, M. R. *Synlett* **2007**, 1239. (d) Bardajee, G. R.; Afsari, H. S.; Sadraei, S.; Taimoory, S. *Phosphorus, Sulfur Silicon Relat. Elem.* **2012**, *187*, 871. (e) Bardajee, G. R.; Sadraei, S.; Taimoory, S.; Abtin, E. *Asian J. Biochem. Pharm. Res.* **2011**, *1*, 178. (f) Chaturvedi, D.; Mishra, N.; Mishra, V. *J. Sulfur Chem.* **2007**, *28*, 607.

(9) (a) Metzner, P. *Pure Appl. Chem.* **1996**, *68*, 863. (b) Quiclet-Sire, B.; Zard, S. Z. *Top. Curr. Chem.* **2006**, *252*, 201. (c) Martin, D. J.; Greco, C. C. *J. Org. Chem.* **1968**, *33*, 1275. (d) Jordis, U.; Rudolf, M. *Phosphorus Sulfur Relat. Elem.* **1984**, *19*, 279. (e) Corey, E. J.; Carey, F. A.; Winter, R. A. E. *J. Am. Chem. Soc.* **1965**, *87*, 934. (f) Leriverend, C.; Metzner, P.; Capperucci, A.; Degl'lnnocenti, A. *Tetrahedron* **1997**, *53*, 1323.

(10) (a) Johnson, D. J.; Amarnath, V.; Amarnath, K.; Valentine, H.; Valentine, W. M. *Toxicol. Sci.* **2003**, *76*, 65. (b) Godt, H. C.; Wann, R. E. *J. Org. Chem.* **1961**, *26*, 4047. (c) Burkhardt, C.; Dehmel, F.; Weinbrenner, S.; Julius, H.; Ciossek, T.; Maier, T.; Stengel, T.; Fettis, K.; Wieland, H.; Beckers, T. *J. Med. Chem.* **2008**, *51*, 3985. (d) Wegener, D.; Wirsching, F.; Riester, D.; Schwienhorst, A. *Chem. Biol.* **2003**, *10*, 61. (e) Dehmel, F.; Weinbrenner, S.; Julius, H.; Ciossek, T.; Maier, T.; Stengel, T.; Fettis, K.; Burkhardt, C.; Wieland, H.; Beckers, T. *J. Med. Chem.* **2008**, *51*, 3985.

(11) (a) Anand, O. N.; Kumar, V.; Singh, A. K.; Bist, R. P. S. *Lubrication Sci.* **2007**, *19*, 159. (b) El-khateeb, M.; Roller, A. *Polyhedron* **2007**, *26*, 3920. (c) Efrima, S.; Pradhan, N. *C. R. Chim.* **2003**, *6*, 1035.

(12) (a) Duus, F. In *Comprehensive Organic Chemistry*; Vol. 3; Barton, D.; Ollis, W. D., Eds.; Pergamon: New York, **1979**, 432. (b) Goldt, H. C.; Wanns, A. E. *J. Org. Chem.* **1961**, *26*, 4047.

(13) Wood, M. R.; Duncalf, D. J.; Rannard, S. P.; Perrier, S. *Org. Lett.* **2006**, *8*, 553.

(14) (a) Degani, I.; Fochi, R.; Gatti, A.; Regondi, V. *Synthesis* **1986**, 894. (b) Aoyagi, N.; Ochiai, B.; Mori, H.; Endo, T. *Synlett* **2006**, 636.

(15) Chaturvedi, D.; Chaturvedi, A. K.; Mishra, N.; Mishra, V. *Tetrahedron Lett.* **2008**, *49*, 4886.

(16) (a) Horita, Y.; Takii, T.; Kuroishi, R.; Chiba, T.; Ogawa, K.; Kremer, L.; Sato, Y.; Lee, Y. S.; Hasegawa, T.; Onozaki, K. *Bioorg. Med. Chem. Lett.* **2011**, *21*, 899. (b) Horita, Y.; Takii, T.; Chiba, T.; Kuroishi, R.; Maeda, Y.; Kurono, Y.; Inagaki, E.; Nishimura, K.; Yamamoto, Y.; Abe, C.; Mori, M.; Onozaki, K. *Bioorg. Med. Chem. Lett.* **2009**, *19*, 6313. (c) Tejima, S.; Ishiguro, S. *Chem. Pharm. Bull.* **1967**, *15*, 255. (d) Szeja, W.; Bogusiak, J. *Synthesis* **1988**, 224. (e) Gabhe, B. S.; Deshmukh, S. P. *Int. J. Chem. Sci.* **2010**, *8*, 2083. (f) Ishiguru, S.; Tejima, S. *Chem. Pharm. Bull.* **1967**, *15*, 1478. (g) Fügedi, P.; Garegg, P. J.; Oscarson, S.; Rosen, G.; Silwanis, B. A. *Carbohydr. Res.* **1991**, *211*, 157. (h) Padungros, P.; Alberch, L.; Wei, A. *Org. Lett.* **2012**, *14*, 3380. (i) Mangte, D. V.; Deshmukh, S. P.; Bhokare, D. D.; Deshpande, A. R. *Ind. J. Pharm. Sci.* **2007**, *69*, 295. (j) Bhagat, S. K.; Fokmare, A. K.; Deshmukh, S. P. *Orient. J. Chem.* **2001**, *17*, 437. (k) Mangte, D. V.; Deshmukh, S. P. *Int. J. Chem. Sci.* **2004**, *2*, 159. (l) Mannerstedt, K.; Ekelof, K.; Oscarson, S. *Carbohydr. Res.* **2007**, *342*, 631. (m) Lichtenthaler, F. W.; Klares, U.; Lergenmuller, M.; Schwidetzky, S. *Synthesis* **1992**, 179. (n) Li, R.-T.; Ding, P.-Y.; Han, M.; Cai, M.-S. *Synth. Commun.* **1998**, *28*, 295. (o) Bogusiak, J.; Szeja, W. *Polish J. Chem.* **1993**, *67*, 2181. (p) Lee, B. H.; Bertram, B.; Schmezer, P.; Frank, N.; Wiessler, M. *J. Med. Chem.* **1994**, *37*, 3154. (q) Wei, A. US 20080124776 A1 20080529, **2008**.

(17) (a) Doane, W. M. *Methods Carbohydr. Chem.* **1972**, *6*, 413. (b) Narendra, N.; Lalithamba, H. S.; Sureshbabu, V. V. *Tetrahedron Lett.* **2010**, *51*, 6169. (c) Zhou, Y.; Beck, W. *J. Organomet. Chem.* **1994**, *479*, 217.

(18) **General Experimental Conditions for the Synthesis of *S*-Glycosyl N-Substituted Dithiocarbamate Derivatives**

A mixture of amine (1.2 mmol), CS_2 (1.5 mmol) was allowed to stir for 5 min at r.t. To the reaction mixture was

added glycosyl bromide (1.0 mmol), and the reaction mixture was allowed to stir at r.t. for the appropriate time as mentioned in Table 1. Excess reagents were removed under reduced pressure. H_2O was added to the crude product, and the mixture was stirred at r.t. The solid product, which precipitated out immediately, was filtered, washed with H_2O dried, and recrystallized from EtOH. Representative spectroscopic data of selected products are as follows.

2,3,4,6-Tetra-*O*-acetyl-β-D-glucopyranosyl 4-Morpholine Carbodithioate (5)

White solid; mp 132–133 °C; $[\alpha]_D$ +26.3 (*c* 0.5, $CHCl_3$). IR (KBr): 2966, 1747, 1469, 1426, 1377, 1219, 1112, 1057, 1030, 996, 922, 825, 610 cm^{-1}. ^1H NMR (500 MHz, $CDCl_3$): δ = 5.86 (d, *J* = 10.5 Hz, 1 H, H-1), 5.34 (t, *J* = 9.5 Hz, 1 H, H-2), 5.29 (t, *J* = 9.5 Hz, 1 H, H-3), 5.11 (t, *J* = 10.0 Hz, 1 H, H-4), 4.28 (dd, *J* = 13.0, 5.0 Hz, 1 H, H-6_a), 4.12 (dd, 12,5, 2.0 Hz, 1 H, H-6_b), 3.89–3,85 (m, 1 H, H-5), 3.80–3.70 (m, 4 H, CH_2), 2.07, 2.04, 2.03, 2.01 (4 s, 12 H, 4 $COCH_3$). ^{13}C NMR (125 MHz, $CDCl_3$): δ = 192.4 (C=S), 170.4, 169.8, 169.4, 169.3 (4 *C*OCH_3), 86.7 (C-1), 76.3 (C-5), 74.3 (C-3), 68.5 (C-4), 68.0 (C-2), 66.2 (CH_2), 65.9 (CH_2), 61.6 (C-6), 51.6 (CH_2), 50.7 (CH_2), 20.8, 20.7, 20.6 (2 C, 4 CO*C*H_3). ESI-MS: *m/z* = 516.1 $[M + Na]^+$. Anal. Calcd for $C_{19}H_{27}NO_{10}S_2$ (493.10): C, 46.24; H, 5.51. Found: C, 46.10; H, 5.70.

(2,3,4,6-Tetra-*O*-acetyl-β-D-glucopyranosyl)-*N*-cyclopropylmethyl-*N*-propyl Dithiocarbamate (6)

White solid; mp 78–80 °C. $[\alpha]_D$ +12.5 (*c* 0.5, $CHCl_3$). IR (KBr): 2940, 1747, 1478, 1382, 1243, 1222, 1079, 1036, 913, 830, 606 cm^{-1}. ^1H NMR (500 MHz, $CDCl_3$): δ = 5.87 (d, *J* = 10.0 Hz, 1 H, H-1), 5.35 (t, *J* = 9.0 Hz, 1 H, H-3), 5.27 (t, *J* = 9.5 Hz, 1 H, H-2), 5.11 (t, *J* = 9.0 Hz, 1 H, H-4), 4.29 (dd, *J* = 12.5, 4.5 Hz, 1 H, H-6_a), 4.12 (d, *J* = 12.0 Hz, 1 H, H-6_b), 4.03–3.96 (m, 1 H), 3.92–3.87 (m, 2 H, H-5, CH_2), 3.86–3.72 (m, 1 H), 3.65–3.51 (m, 2 H), 2.07, 2.03, 2.01, (3 s, 12 H, 4 $COCH_3$), 1.80–1.65 (m, 2 H), 1.35–1.25 (m, 1 H), 0.98–0.90 (m, 3 H), 0.63–0.57 (m, 2 H), 0.35–0.32 (m, 2 H). ^{13}C NMR (125 MHz, $CDCl_3$): δ = 192.0 (C=S), 170.5, 169.8, 169.3, (2 C, 4 *C*OCH_3), 87.2 (C-1), 76.2 (C-5), 74.5 (C-3), 68.6 (C-4), 68.1 (C-2), 61.6 (C-6), 59.4 (CH_2), 57.0 (CH_2), 19.3 (CH_2), 20.8, 20.7, 20.6, 20.5 (4 CO*C*H_3), 11.3 (CH_3), 8.9 (CH), 4.3, 4.0 (CH_2). ESI-MS: *m/z* = 542.1 $[M + Na]^+$. Anal. Calcd for $C_{22}H_{33}NO_9S_2$ (519.16): C, 50.85; H, 6.40. Found: C, 50.70; H, 6.60.

(19) **General Experimental Conditions for the Synthesis of *S*-Glycosyl S′-Substituted Trithiocarbonate Derivative**

To a mixture of thiol (1.2 mmol), CS_2 (1.5 mmol) and glycosyl bromide (1.0 mmol) was added Et_3N (0.1 mmol), and the reaction mixture was allowed to stir at r.t. for the appropriate time as mentioned in Table 2. Excess reagents were removed under reduced pressure. H_2O was added to the crude product, and the mixture was stirred at r.t. The solid product which precipitated out immediately was filtered, washed with H_2O, dried, and recrystallized from EtOH. Representative spectroscopic data of selected products are as follows.

***S*-(2,3,4,6-Tetra-*O*-acetyl-β-D-glucopyranosyl)-S′-(*p*-methylphenyl) Trithiocarbonate (16)**

White solid; mp 107–108 °C. $[\alpha]_D$ –17.2 (*c* 0.5, $CHCl_3$). IR (KBr): 2939, 1747, 1382, 1224, 1039, 918, 809, 604 cm^{-1}. ^1H NMR (500 MHz, $CDCl_3$): δ = 7.37 (d, *J* = 9.0 Hz, 2 H, ArH), 7.08 (d, *J* = 9.0 Hz, 2 H, ArH), 5.16 (t, *J* = 9.5 Hz, 1 H, H-3), 4.98 (t, *J* = 9.5 Hz, 1 H, H-2), 4.89 (t, *J* = 9.5 Hz, 1 H, H-4), 4.60 (d, *J* = 10.0 Hz, 1 H, H-1), 4.21–4.13 (m, 2 H, H-6_{ab}), 3.68–3.64 (m, 1 H, H-5), 2.34 (s, 3 H, CH_3), 2.09, 2.07, 2.02, 1.99 (4 s, 12 H, 4 $COCH_3$). ^{13}C NMR (125 MHz, $CDCl_3$): δ = 194.7 (C=S), 170.3, 170.0, 169.2, 169.0 (4 *C*OCH_3), 138.7–127.4 (ArC), 85.7 (C-1), 75.8 (C-5), 74.0 (C-3), 69.9 (C-2), 68.1 (C-4), 62.0 (C-6), 21.2 (CH_3), 20.7, 20.6 (2 C), 20.5 (4 CO*C*H_3). ESI-MS: *m/z* = 553.0 $[M + Na]^+$. Anal. Calcd for $C_{22}H_{26}O_9S_3$ (530.07): C, 49.80; H, 4.94. Found: C, 49.64; H, 5.14.

***S*-(2,3,4,6-Tetra-*O*-acetyl-β-D-glucopyranosyl)-S′-(*p*-methoxylphenyl) Trithiocarbonate (17)**

White solid; mp 88–90 °C. $[\alpha]_D$ –20.4 (*c* 0.5, $CHCl_3$). IR (KBr): 2940, 1747, 1494, 1383, 1226, 1038, 831 cm^{-1}. ^1H NMR (500 MHz, $CDCl_3$): δ = 7.45 (d, *J* = 9.0 Hz, 2 H, ArH), 6.84 (d, *J* = 9.0 Hz, 2 H, ArH), 5.19 (t, *J* = 9.5 Hz, 1 H, H-3), 4.99 (t, *J* = 9.5 Hz, 1 H, H-2), 4.88 (t, *J* = 9.5 Hz, 1 H, H-3), 4.56 (d, *J* = 10.0 Hz, 1 H, H-1), 4.22–4.16 (m, 2 H, H-6_{ab}), 3.81 (s, 3 H, OCH_3), 3.69–3.66 (m, 1 H, H-5), 2.10, 2.07, 2.01, 1.98 (4 s, 12 H, 4 $COCH_3$). ^{13}C NMR (125 MHz, $CDCl_3$): δ = 195.3 (C=S), 170.6, 170.2, 169.4, 169.2 (4 *C*OCH_3), 160.4–114.4 (ArC), 85.6 (C-1), 75.7 (C-5), 74.0 (C-3), 69.9 (C-2), 68.1 (C-4), 62.0 (C-6), 55.3 (OCH_3), 20.8, 20.7, 20.6, 20.5 (4 CO*C*H_3). ESI-MS: *m/z* = 569.0 $[M + Na]^+$. Anal. Calcd for $C_{22}H_{26}O_{10}S_3$ (546.06): C, 48.34; H, 4.79. Found: C, 48.17; H, 4.95.

