ISSN 1070-4280, Russian Journal of Organic Chemistry, 2012, Vol. 48, No. 9, pp. 1238–1244. © Pleiades Publishing, Ltd., 2012.
Original Russian Text © L.S. Khasanova, F.A. Gimalova, Z.R. Valiullina, N.K. Selezneva, R.M. Ganieva, L.V. Spirikhin, M.S. Miftakhov, 2012, published in Zhurnal Organicheskoi Khimii, 2012, Vol. 48, No. 9, pp. 1239–1245.

New Disaccharide Blocks for OSW-1 and Its Analogs

L. S. Khasanova, F. A. Gimalova, Z. R. Valiullina, N. K. Selezneva, R. M. Ganieva, L. V. Spirikhin, and M. S. Miftakhov

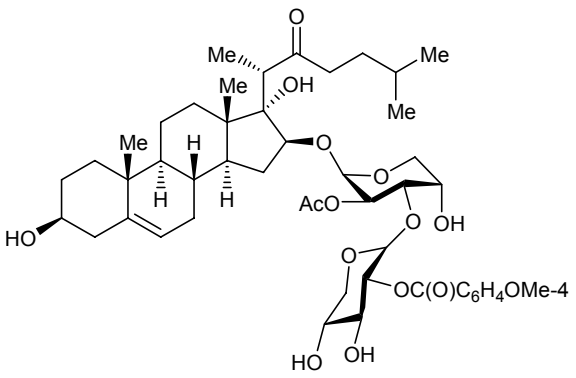
Institute of Organic Chemistry, Ufa Research Center, Russian Academy of Sciences, pr. Oktyabrya 71, Ufa, 450054 Bashkortostan, Russia
e-mail: bioreg@anrb.ru

Received December 30, 2011

Abstract—A new disaccharide block for OSW-1 natural steroidal antitumor agent was described. Regioisomeric 2- and 3-*O*-*p*-methoxybenzoyl derivatives of phenyl 1-thio-β-D-xylopyranoside and phenyl 2-*O*-acetyl-1-thio-β-L-arabinopyranoside derivatives blocked at positions *3* and *4* by R_3Si groups were synthesized with a view to use them in the preparation of OSW-1 analogs modified at the disaccharide fragment.

DOI: 10.1134/S1070428012090163

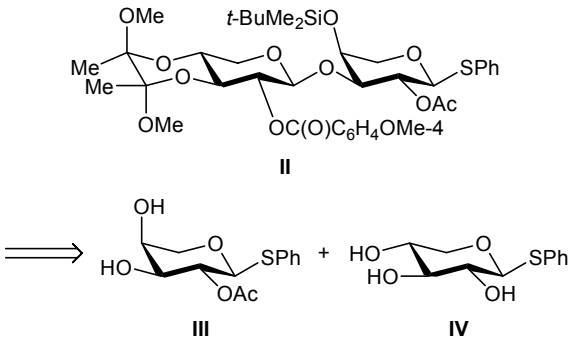
Cholestane glycoside OSW-1 (**I**) isolated from the bulbs of the South African plant *Ornithogalum saundersiae* possesses a very high cytotoxicity against a broad series of malignant tumor cells [1, 2]. The concentration of OSW-1 in the bulbs of *Ornithogalum saundersiae* is extremely low, so that required amounts of this steroidal glycoside can be obtained only by chemical synthesis [3–5]. The synthesis of OSW-1 analogs modified at both aglycone [6–9] and disaccharide fragments [10–12] was the subject of numerous studies. Modification of both parts of OSW-1 gives rise to different cytotoxic properties of its analogs. The disaccharide fragment of **I** consists of 2-*O*-acetyl-L-arabinose and 2-*O*-(*p*-methoxybenzoyl)-D-xylose residues linked through 1→3 glycoside bond.



I

In the present article we describe a new disaccharide building block **II** for OSW-1, as well as some derivatives of its monosaccharide constituents which were synthesized starting from known phenyl 1-thioglycosides **III** and **IV** [3] (Scheme 1).

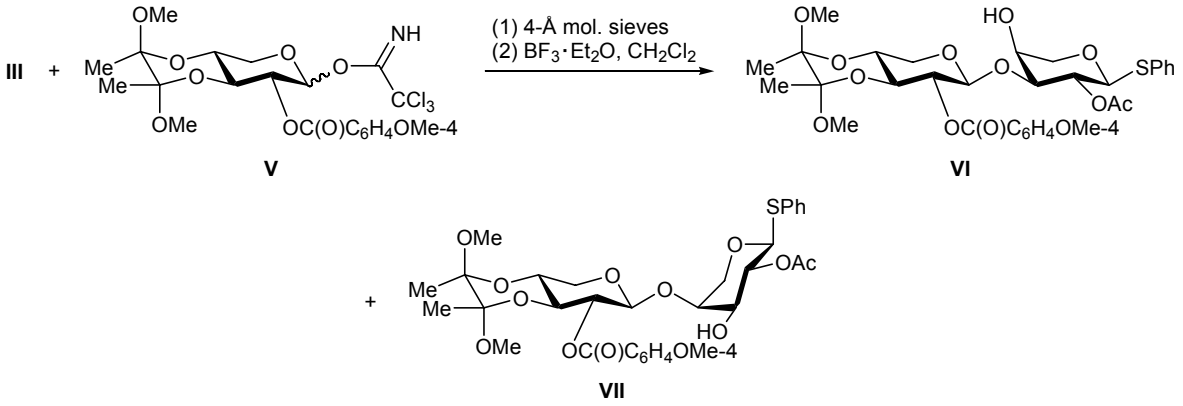
Scheme 1.



We believed that the most efficient method for coupling the glycosyl donor with aglycone in the final step of construction of molecule **I** is the trichloroacetimidate procedure [5] which involves transformation of the anomeric hydroxy group in the disaccharide block into trichloroacetimidoyloxy group. The latter is readily replaced under catalysis by strong Lewis acids. The resulting C^1-carbenium intermediate reacts at the 16-OH group in the aglycone. Hydrolysis of disaccharide **II** at the phenyl thioacetal center, followed by trichloroacetimidation, could lead to the corresponding glycosyl donor.

We initially tried to synthesize C^4-blocked compound **II** [13] via direct reaction of diol **III** with imidate **V**, which seemed to be promising. However, the products were regioisomeric disaccharides **VI** and

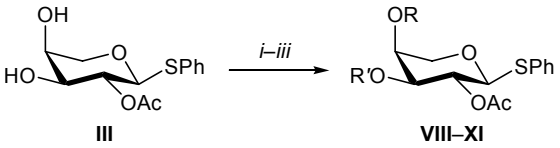
Scheme 2.



VII. Compound **VI** is C^4-deprotected diastereoisomer of **II** differing from the latter by configuration of the $C^{1'}$–O glycoside bond (Scheme 2).

We presumed that change of configuration at $C^{1'}$ is affected by the unprotected OH group on C^4 and performed the reaction with the C^4-protected derivative. Preliminarily, glycosyl acceptors protected at the 4-OH group that are necessary for the synthesis of **II** were prepared from L-arabinose. Selective protection of the axial 4-OH group in **III** was achieved using triethylsilyl trifluoromethanesulfonate at low temperature [3] (Scheme 3). However (see below), further synthesis of disaccharide **II** from silyl ether **VIII** in the presence of a strong Lewis acid ($BF_3 \cdot Et_2O$, NIS–TFA, TfOH) was complicated because of partial hydrolysis of the triethylsilyl group. Therefore, triethylsilyl protection was replaced by more stable *tert*-butyldimethylsilyl group. Silylation of diol **III** with *tert*-butyldimethylsilyl trifluoromethanesulfonate occurred neither at –78°C [3] nor at 0°C nor at 20°C. Acceptable results were obtained using the system *tert*-butyl(chloro)dimethylsilane–imidazole–CH_2Cl_2 in the presence of 4-dimethylaminopyridine at room temperature. Monosubstituted compounds **IX** and **X** thus formed at a ratio of 3:1 were separated by column chromatography on silica gel. Attempts to perform selective chloroacetylation of diol **IV** with 1.3 equiv of chloroacetyl chloride in benzene in the presence of triethylamine were also unsuccessful; in this case uncontrolled formation of regioisomeric mono- and disubstituted products was observed.

Scheme 3.

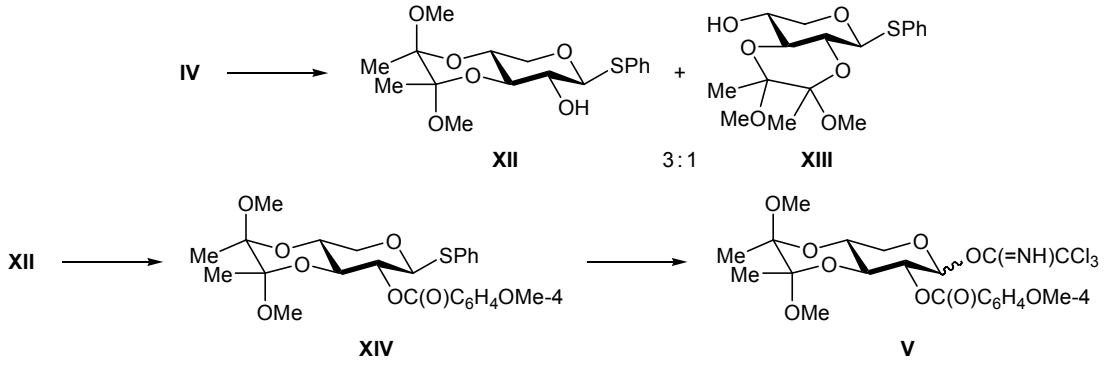


VIII, R = Et_3Si, R′ = H; **IX**, R = *t*-$BuMe_2Si$, R′ = H; **X**; R = H, R′ = *t*-$BuMe_2Si$; **XI**, R = R′ = $ClCH_2C(O)$; *i*: Et_3SiOTf, CH_2Cl_2, 2,4-dimethylpyridine, –78°C; *ii*: *t*-$BuMe_2SiCl$, CH_2Cl_2, imidazole, 4-dimethylaminopyridine, 20°C; *iii*: Et_3N, $ClCH_2COCl$, PhH, 20°C.

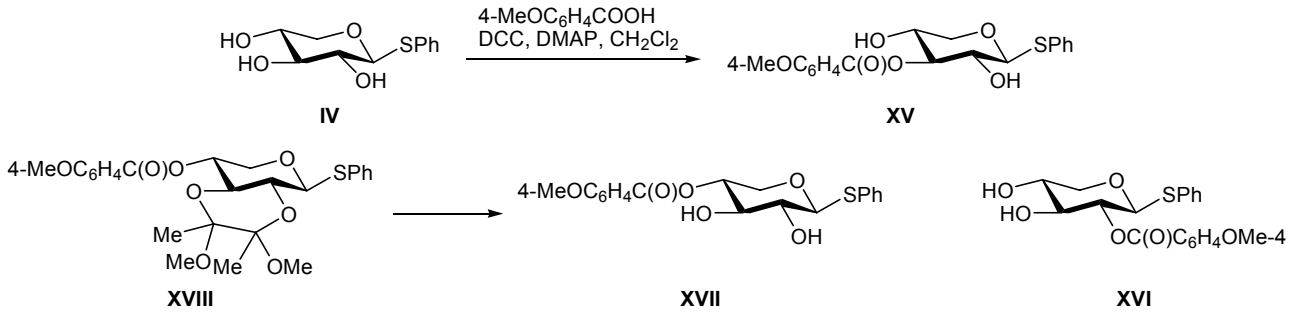
The structure of regioisomeric silyl ethers **IX** and **X** was assigned on the basis of the ^{1}H NMR data. The ^{1}H NMR spectra of **IX** and **X** differed by the position of signals from 3-H and 4-H and methyl protons in the silyl moiety. The positions of the 3-H and 4-H signals of **IX** differed by $\Delta\delta$ ~0.3 ppm, whereas the corresponding signals of **X** almost coincided with each other and appeared as a narrow two-proton multiplet. This may be due to leveling effect of the OAc group on C^2, and downfield shift of the 3-H signal may be related to the effect of the $OSiMe_2Bu$-*t* group on C^4. Methyl groups in the silyl fragment of isomer **IX** gave rise to a six-proton singlet, while those in **X** resonated each as a separate singlet. Obviously, free rotation about the C^3–OSi bond in molecule **X** is hindered, so that the methyl groups on the silicon are shielded to different extents.

As glycosyl donor for the synthesis of disaccharide **II** we planned to use imidate **V** [13] which was prepared according to Scheme 4. In doing so, it was desirable to optimize the stage of synthesis of precursor of the corresponding 3,4-bis-acetal via direct reaction of arabinopyranose phenyl thioacetal **IV** with butane-2,3-dione. The reaction was not selective, and it produced a 3:1 mixture of the target 3,4-bis-acetal and 2,3-isomer as by-product. In order to develop an alternative approach to compound **XIV**, we studied direct *p*-methoxybenzoylation of **IV**. For this purpose, we applied carbodiimide procedure with the use of a slight excess of 4-methoxybenzoic acid. However, the major product was 3-*O*-acyl derivative **XV** (Scheme 5).

Scheme 4.



Scheme 5.

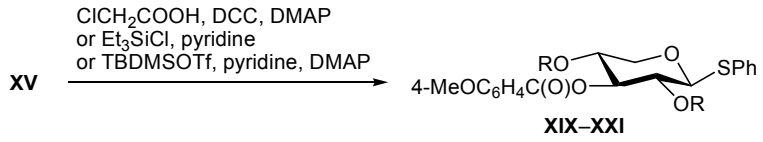


The structure of **XV** was proved by comparing its R_f values (TLC) and spectral parameters (including HSQC correlation data) with those of regioisomeric compounds **XVI** and **XVII** obtained by acid hydrolysis of bis-acetals **XIV** and **XVIII** (the latter were described previously [13]). It should be noted that diol **XV** failed to react with butane-2,3-dione under the conditions of synthesis of **XIV**.

Diols **XV** and **XVII** are appropriate building blocks for the synthesis of C^3- and C^4-*p*-methoxybenzoyloxy derivatives. Following standard procedures, diol **XV** was converted into completely blocked derivatives **XIX**–**XXI** necessary for subsequent transformations (Scheme 6).

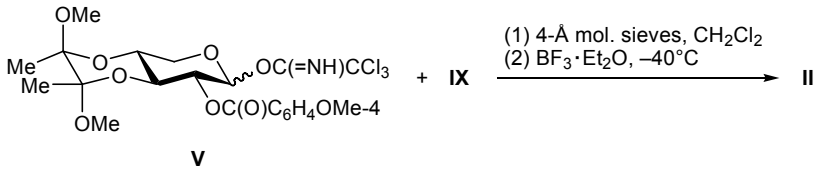
In the final step of our study we examined the key coupling of imidate **V** with glycosyl acceptors **VIII** and **IX**, promoted by $BF_3 \cdot Et_2O$ [14]. The reaction of equimolar amounts of imidate **V**, alcohol **VIII**, and $BF_3 \cdot Et_2O$ in methylene chloride at –40°C gave a complex mixture of products, presumably due to instability of triethylsilyl ether **VIII** under these conditions. Better results were obtained using more stable *tert*-butyldimethylsilyl ether **IX**. The reaction of **IX** with **V**, other conditions being equal, afforded targeted disac-

Scheme 6.



XIX, R = $ClCH_2C(O)$; **XX**, R = Et_3Si; **XXI**, R = *t*-$BuMe_2Si$.

Scheme 7.



charide **II** in a moderate yield (50%; Scheme 7). β-Configuration of the glycoside moiety in **II** was confirmed by the presence of a characteristic doublet from 1′-H at δ 4.75 ppm (J = 7.4 Hz) in the ^{1}H NMR spectrum and $C^{1'}$ signal at δ_C 103.35 ppm ($^1J_{CH}$ = 160 Hz) in the ^{13}C NMR spectrum. The 5′-H proton (δ 3.46 ppm) displayed a vicinal coupling constant ^3J of 10 Hz with 4′-H and a long-range coupling constant with 3′-H (^4J = 2.0 Hz), indicating mutual *W*-orientation of 5′-H and 3′-H. In keeping with the HSQC data, the C^3 and $C^{3'}$ signals of **II** coincided with each other in the ^{13}C NMR spectrum (δ_C 75.17 ppm).

To conclude, we have synthesized new mono- and disaccharide blocks for the synthesis of saponin OSW-1 (**I**) and its analogs. The newly synthesized compounds are characterized by acceptable chemical stability, and optimal conditions for their preparation have been found.

EXPERIMENTAL

The IR spectra were recorded on a Shimadzu IR Prestige-21 spectrometer from samples prepared as thin films or dispersed in mineral oil. The ^{1}H and ^{13}C NMR spectra were measured on Bruker AM-300 (300.13 and 75.47 MHz, respectively) and Bruker Avance-500 (500.13 and 125.77 MHz, respectively) spectrometers using tetramethylsilane as internal reference. The optical rotations were determined on a Perkin Elmer-341 polarimeter. The mass spectra were run on a Thermo Finnigan MAT 95XP instrument. The elemental compositions were determined on a Euro-2000 CHNS(O) analyzer; the results were consistent with the calculated values. The progress of reactions was monitored by TLC on Sorbfil plates (Krasnodar, Russia); spots were detected by treatment with an acidified solution of 4-methoxybenzaldehyde in ethanol. Reaction products were isolated by column chromatography on silica gel (30–60 g of the sorbent per gram of substrate); freshly distilled solvents were used as eluents.

Phenyl 2-*O*-acetyl-4-*O*-triethylsilyl-1-thio-β-L-arabinopyranoside (VIII). Phenyl 2-*O*-acetyl-1-thio-β-L-arabinopyranoside (**III**), 0.15 g (0.528 mmol), was dissolved in 5 ml of methylene chloride, 0.12 ml of 2,4-dimethylpyridine was added, the mixture was cooled to –60°C, 0.14 ml (0.62 mmol) of triethylsilyl trifluoromethanesulfonate was added, and the mixture was stirred for 1 h at –60°C and for 1 h at –78°C. A saturated solution of sodium hydrogen carbonate, 2 ml, was added at –60°C, the mixture was allowed to warm up to room temperature, the organic phase was separated, the aqueous phase was extracted with methylene chloride, the extracts were combined with the organic phase, washed with a solution of NaCl, dried over $MgSO_4$, and evaporated, and the residue was subjected to chromatography on silica gel using benzene as eluent. Yield 0.16 g (76%), $[\alpha]_D^{20}$ = –29.7 (c = 0.69, $CHCl_3$); published data [5]: $[\alpha]_D^{20}$ = –33.6° (c = 0.7, $CHCl_3$). ^{1}H NMR spectrum ($CDCl_3$), δ, ppm: 0.63 q (6H, $SiCH_2$, J = 7.89 Hz), 0.96 t (9H, CH_3, J = 7.89 Hz), 2.10 s (3H, CH_3CO), 2.56 d (1H, OH, J = 5.2 Hz), 3.52 d.d (1H, J = 3.10, 11.6 Hz) and 4.14 d.d (1H, J = 6.98, 11.6 Hz) (OCH_2), 3.75 m (1H, 3-H), 4.03 m (1H, 4-H), 4.97 d (1H, 1-H, J = 4.9 Hz), 5.18 d.d (1H, 2-H, J = 5.8, 5.0 Hz), 7.25 m (3H) and 7.48 m (2H) (C_6H_5). ^{13}C NMR spectrum, δ_C, ppm: 4.71 ($SiCH_2$), 6.58 (CH_3), 20.89 (**C**H_3CO), 63.82 (C^5), 67.31 (C^4), 70.51 and 71.95 (C^3, C^2), 85.23 (C^1); 127.26, 128.73, 131.53, 134.85 (Ph); 169.79 (C=O).

Reaction of compound III with *tert*-butyl(chloro)dimethylsilane. 4-Dimethylaminopyridine, 50 mg, was added at 0°C to a solution of 0.60 g (2.11 mmol) of compound **III** and 0.18 g (2.64 mmol) of imidazole in 3 ml of methylene chloride, 0.36 g (2.39 mmol) of *tert*-butyl(chloro)dimethylsilane was then added in portions, and the mixture was stirred for 10 h at room temperature and washed in succession with water and brine. The organic phase was dried over $MgSO_4$ and evaporated, and the residue was subjected to chromatography on silica gel using first benzene and then petroleum ether–ethyl acetate (10 : 1) as eluents to isolate 0.04 g (5%) of doubly protected derivative, 0.22 g (26%) of **IX**, 0.14 g (17%) of **X**, and 0.260 g of mixture **IX**/**X** (overall yield 74%) which was separated by repeated chromatography.

Phenyl 2-*O*-acetyl-4-*O*-*tert*-butyldimethylsilyl-1-thio-β-L-arabinopyranoside (IX). $[\alpha]_D^{20}$ = –27.0° (c = 1.0, $CHCl_3$). ^{1}H NMR spectrum ($CDCl_3$), δ, ppm: 0.10 s (6H, $SiCH_3$), 0.90 s (9H, *t*-Bu), 2.10 s (3H, CH_3CO), 2.50 d (1H, OH, J = 5.3 Hz), 3.53 d.d (1H, OCH_2, J = 3.2, 11.7 Hz), 3.75 m (1H, 4-H), 4.03 m (1H, 3-H), 4.15 d.d (1H, OCH_2, J = 6.8, 11.8 Hz), 4.90 d (1H, 1-H, J = 5.0 Hz), 5.18 t (1H, 2-H, J = 5.5 Hz), 7.30 m (3H) and 7.50 m (2H) (C_6H_5). ^{13}C NMR spectrum, δ_C, ppm: –2.00 and –1.74 ($SiCH_3$), 17.95 (**C**Me_3), 20.96 (**C**H_3CO), 25.69 (CH_3), 64.14 (C^5), 67.69 (C^4), 70.70 and 71.82 (C^2 and C^3), 85.14 (C^1); 127.40, 128.82, 131.79, 134.42 (Ph); 169.89 (C=O). Mass spectrum, m/z (I_{rel}, %): 398 (0.1) $[M]^+$, 289 (28) $[M - SPh]^+$, 229 (100) $[M - SPh - AcOH]^+$,

189 (44), 171 (30), 117 (32), 73 (83). Found: *m*/*z* 398.131 $[M]^+$. $C_{19}H_{30}O_5SSi$. Calculated: *M* 398.138.

Phenyl 2-*O*-acetyl-3-*O*-*tert*-butyldimethylsilyl-1-thio-β-L-arabinopyranoside (X). $[\alpha]_D^{20}$ = –34.0° (*c* = 1.0, $CHCl_3$). ^{1}H NMR spectrum ($CDCl_3$), δ, ppm: 0.14 s and 0.18 s (3H each, $SiCH_3$), 0.94 s (9H, *t*-Bu), 2.09 s (3H, CH_3CO), 2.29 d (1H, OH, *J* = 6.3 Hz), 3.58 d.d (1H, OCH_2, *J* = 3.4, 11.9 Hz), 3.89 m (2H, 3-H, 4-H), 4.17 d.d (1H, OCH_2, *J* = 6.3, 11.9 Hz), 4.92 d (1H, 1-H, *J* = 5.64 Hz), 5.14 t (1H, 2-H, *J* = 5.64 Hz), 7.24–7.29 m (3H) and 7.45–7.47 m (2H) (C_6H_5). ^{13}C NMR spectrum, δ_C, ppm: –4.65 and –5.05 ($SiCH_3$), 17.95 (**C**Me_3), 20.94 (**C**H_3CO), 25.66 (CH_3), 63.89 (C^5), 66.89 (C^4), 70.96 and 72.14 (C^2, C^3), 85.98 (C^1); 127.27, 128.78, 131.44, 135.19 (Ph); 169.39 (C=O).

Phenyl 1-thio-β-D-xylopyranoside (IV) was synthesized by reaction of 0.19 g (0.5 mmol) of phenyl 2,3,4-tri-*O*-acetyl-1-thio-D-xylopyranoside [13] with 1.2 mg (0.12 mmol) of sodium methoxide. The product was isolated by column chromatography on silica gel using chloroform–methanol (10:1) as eluent. Yield 0.1 g (83%), $[\alpha]_D^{20}$ = –25.2° (*c* = 0.505, $CHCl_3$). ^{1}H NMR spectrum ($CDCl_3$), δ, ppm: 3.10 m (2H, OH), 3.83 m (3H, 2-H, 3-H, OH), 3.58 d (1H, OCH_2, *J* = 12.0 Hz), 3.69 m (1H, 4-H), 4.08 m (1H, OCH_2), 5.47 m (1H, 1-H), 7.28 m (3H) and 7.52 m (2H) (C_6H_5). ^{13}C NMR spectrum, δ_C, ppm: 70.55 (C^5), 71.10 and 73.93 (C^3, C^4), 79.22 (C^2), 90.32 (C^1); 128.97, 130.31, 133.47, 135.04 (Ph).

Phenyl 3-*O*-(4-methoxybenzoyl)-1-thio-β-D-xylopyranoside (XV). Compound **IV**, 0.5 g (2.0 mmol), was dissolved in 10 ml of CH_2Cl_2–MeCN (1:1), 0.38 g (2.4 mmol) of 4-methoxybenzoic acid and 0.125 g (1.02 mmol) of 4-dimethylaminopyridine were added, the mixture was cooled to 0°C, 0.46 g (2.4 mmol) of *N*,*N*′-dicyclohexylcarbodiimide in 3 ml of methylene chloride was added, and the mixture was stirred for 24 h at room temperature. The product was separated from unreacted compound **IV** by column chromatography on silica gel using petroleum ether–ethyl acetate (2:1) as eluent. Yield 0.3 g (40%), $[\alpha]_D^{20}$ = –47.5° (*c* = 0.04, $CHCl_3$). ^{1}H NMR spectrum ($CDCl_3$), δ, ppm: 2.90 br.s (1H, OH), 3.52 d.d (1H, OCH_2, *J* = 8.8, 11.5 Hz), 4.14 d.d (1H, OCH_2, *J* = 4.6, 11.5 Hz), 3.66 m (1H, 4-H), 3.88 s (3H, OCH_3), 4.64 d (1H, OH, *J* = 5.7 Hz), 4.79 d (1H, 3-H, *J* = 6.4 Hz), 4.94 d (1H, 1-H, *J* = 7.96 Hz), 5.19 t (1H, 2-H, *J* = 7.96 Hz), 7.04 d (2H, *J* = 9.07 Hz) and 8.04 d (2H, *J* = 9.06 Hz) (C_6H_4), 7.29–7.38 m (3H) and 7.54–7.57 m (2H) (C_6H_5). ^{13}C NMR spectrum, δ_C, ppm: 56.57 (OCH_3), 69.58 (C^5), 69.41 and 72.11 (C^3, C^4), 79.17 (C^2), 80.01 (C^1); 115.10, 124.23, 128.71, 130.38, 133.05, 133.21, 135.71, 165.10 (C_{arom}); 166.77 (C=O). Mass spectrum, *m*/*z* (I_{rel}, %): 267 (28) $[M - SPh]^+$, 249 (5), 135 (100) $[MeOC_6H_4C{\equiv}O]^+$, 115 (48), 97 (10).

Phenyl 2-*O*-(4-methoxybenzoyl)-1-thio-β-D-xylopyranoside (XVI). Aqueous trifluoroacetic acid, 0.66 ml, was added to a solution of 0.05 g (0.102 mmol) of compound **XIV** in 1 ml of methylene chloride. The mixture was stirred at room temperature until the initial compound disappeared (TLC), diluted with 2 ml of methylene chloride, washed with saturated solutions of sodium hydrogen carbonate and sodium chloride, dried over $MgSO_4$, and evaporated, and the residue was purified by column chromatography on silica gel using petroleum ether–ethyl acetate (2:1) as eluent. Yield 0.03 g (78%), $[\alpha]_D^{20}$ = –23.0° (*c* = 0.5, $CHCl_3$). ^{1}H NMR spectrum ($CDCl_3$), δ, ppm: 2.01 br.s (1H, OH), 3.24 m (1H, OH), 3.35 t (1H, OCH_2, *J* = 11.3 Hz), 3.74 m (2H, 3-H, 4-H), 3.83 s (3H, OCH_3), 4.16 d.d (1H, OCH_2, *J* = 11.3, 4.4 Hz), 4.81 d (1H, 1-H, *J* = 9.3 Hz), 4.94 t (1H, 2-H, *J* = 8.4 Hz), 6.89 d and 7.99 d (2H each, C_6H_4, *J* = 8.9 Hz), 7.23 m (3H) and 7.39–7.42 m (2H) (C_6H_5). ^{13}C NMR spectrum, δ_C, ppm: 55.49 (OCH_3), 69.06 (C^5), 69.77 and 73.08 (C^3, C^4), 76.60 (C^2), 86.54 (C^1); 113.82, 121.45, 128.03, 128.97, 132.26, 132.50, 132.59, 163.93 (C_{arom}); 166.76 (C=O).

Phenyl 4-*O*-(4-methoxybenzoyl)-1-thio-D-xylopyranoside (XVII) was synthesized in a similar way from 0.05 g (0.102 mmol) of **XVIII** [13]. Yield 0.032 g (83%), $[\alpha]_D^{20}$ = +23.0° (*c* = 0.5, $CHCl_3$). ^{1}H NMR spectrum ($CDCl_3$), δ, ppm: 1.90 br.s (1H, OH), 3.14 m (1H, OH), 3.36 m (1H, 3-H), 3.44 d.d (1H, OCH_2, *J* = 11.3, 9.9 Hz), 3.49 t (1H, 2-H, *J* = 8.9 Hz), 3.86 s (3H, OCH_3), 4.29 d.d (1H, OCH_2, *J* = 5.4, 11.6 Hz), 4.60 d (1H, 1-H, *J* = 9.3 Hz), 5.04 m (1H, 4-H, *J* = 5.2 Hz), 6.91 d (2H, *J* = 8.6 Hz) and 7.98 d (2H, *J* = 8.9 Hz) (C_6H_4), 7.33 m (3H) and 7.56–7.59 m (2H) (C_6H_5). ^{13}C NMR spectrum, δ_C, ppm: 55.31 (OCH_3), 66.45 (C^5), 71.15 and 72.24 (C^3 and C^4), 75.36 (C^2), 88.23 (C^1); 113.55, 121.45, 128.11, 128.90, 131.44, 131.52, 131.82, 132.86, 133.79, 163.59 (C_{arom}); 165.80 (C=O).

Phenyl 2,4-di-*O*-chloroacetyl-3-*O*-(4-methoxybenzoyl)-1-thio-D-xylopyranoside (XIX). Compound **XV**, 1.10 g (3.0 mmol), was dissolved in 10 ml of CH_2Cl_2–MeCN (1:1), 0.69 g (7.5 mmol) of chloroacetic acid and 0.13 g (1.39 mmol) of 4-dimethylaminopyridine were added under stirring, the mixture was cooled to 0°C, and 1.50 g (7.5 mmol) of *N*,*N*′-di-

cyclohexylcarbodiimide in 5 ml of methylene chloride was added dropwise. The mixture was stirred at room temperature until the initial compound disappeared (TLC), diluted with 20 ml of methylene chloride, and washed with a saturated solution of $NaHCO_3$. The organic phase was dried over $MgSO_4$ and evaporated, and the residue was purified by column chromatography on silica gel using petroleum ether–ethyl acetate (2:1) as eluent. Yield 1.2 g (87%), $[\alpha]_D^{20}$ = +24.0° (*c* = 0.03, $CHCl_3$). IR spectrum, ν, cm^{-1}: 2980, 2933, 2854, 1773, 1730, 1686, 1605, 1512, 1373, 1317, 1258, 1169, 1089, 1067, 1028, 995, 847, 814, 748, 692, 424, 415. ^1H NMR spectrum ($CDCl_3$), δ, ppm: 3.63 d.d (1H, *J* = 7.74, 11.95 Hz) and 4.43 d.d (1H, *J* = 4.42, 11.94 Hz) (OCH_2), 3.86 s (3H, OCH_3), 4.01 s (2H) and 4.04 d (2H, *J* = 2.43 Hz) (CH_2Cl), 4.99 d (1H, 1-H, *J* = 7.52 Hz), 5.18 m (2H, 4-H, 2-H), 5.48 t (1H, 3-H, *J* = 8.84 Hz), 6.93 d (2H, *J* = 8.85 Hz) and 7.98 d (2H, *J* = 9.07 Hz) (C_6H_4), 7.34–7.36 m (3H) and 7.50–7.53 m (2H) (C_6H_5). ^{13}C NMR spectrum, δ_C, ppm: 40.43 (CH_2Cl), 55.42 (OCH_3), 64.15 (C^5), 69.63 (C^4), 70.82 and 71.11 (C^3, C^2), 85.23 (C^1); 113.86, 120.67, 128.44, 129.11, 132.11, 132.95, 163.99 (C_{arom}); 164.89, 165.88, 166.34 (C=O).

Phenyl 3-*O*-(4-methoxybenzoyl)-2,4-di-*O*-triethylsilyl-1-thio-D-xylopyranoside (XX). Chlorotriethylsilane, 0.79 ml (4.70 mmol), was added under stirring at 20°C to a solution of 0.44 g (1.17 mmol) of compound **XV** in 5 ml of pyridine, and the mixture was stirred at 20°C until the initial compound disappeared (~4 h, TLC). The mixture was then diluted with ethyl acetate, washed with ice water, 10% aqueous HCl, and brine, dried over $MgSO_4$, and evaporated. The residue was purified by column chromatography on silica gel using first petroleum ether and then petroleum ether–ethyl acetate (3:1) as eluents. Yield 0.32 g (45%), $[\alpha]_D^{20}$ = +24.0° (*c* = 0.115, $CHCl_3$). ^1H NMR spectrum ($CDCl_3$), δ, ppm: 0.46 q (6H, $SiCH_2$, *J* = 8.1, 7.5 Hz), 0.56 q (6H, $SiCH_2$, *J* = 8.1, 7.6 Hz), 0.81 t (9H, CH_3, *J* = 8.2, 7.8 Hz), 0.88 t (9H, CH_3, *J* = 7.8 Hz), 3.37 t (1H, OCH_2, *J* = 10.3 Hz), 4.00 d.d (1H, OCH_2, *J* = 5.0, 11.0 Hz), 3.79 t (1H, 2-H, *J* = 9.0 Hz), 3.88 s (3H, OCH_3), 3.92 m (1H, 4-H, *J* = 9.0 Hz), 4.72 d (1H, 1-H, *J* = 9.2 Hz), 5.26 t (1H, 3-H, *J* = 8.7 Hz), 6.89 d (2H, *J* = 8.84 Hz) and 8.0 d (2H, *J* = 8.8 Hz) (C_6H_4). 7.25 m (3H) and 7.46 d (2H, *J* = 6.42 Hz) (C_6H_5). ^{13}C NMR spectrum, δ_C, ppm: 4.67 and 5.31 ($SiCH_2$), 6.55 and 6.84 (CH_3), 55.34 (OCH_3), 69.35 (C^4), 69.87 (C^5), 72.49 and 79.22 (C^3, C^2), 90.52 (C^1); 113.48, 122.93, 127.37, 128.88, 131.27, 131.74, 134.42, 163.28 (C_{arom}); 165.01 (C=O).

Phenyl 2,4-di-*O*-(*tert*-butyldimethylsilyl)-3-*O*-(4-methoxybenzoyl)-1-thio-D-xylopyranoside (XXI). A solution of 0.10 g (0.26 mmol) of compound **XV** and 0.007 g (0.057 mmol) of 4-dimethylaminopyridine in 5 ml of pyridine was cooled to 0°C, and 0.18 ml (0.80 mmol) of *tert*-butyldimethylsilyl trifluoromethanesulfonate was added under stirring. The mixture was stirred first for 30 min at 0°C and then at 60°C until the initial compound disappeared (TLC), 5 ml of methanol was added, and the mixture was diluted with ethyl acetate, washed in succession with ice water, 10% aqueous HCl, and brine, dried over $MgSO_4$, and evaporated. The residue was purified by column chromatography on silica gel using petroleum ether–ethyl acetate (2:1) as eluent. Yield 0.12 g (75%), $[\alpha]_D^{20}$ = +1.8° (*c* = 0.44, $CHCl_3$). ^1H NMR spectrum ($CDCl_3$), δ, ppm: –0.19 s, –0.18 s, –0.12 s, and –0.02 s (3H each, $SiMe_2$); 0.72 s and 0.82 s (9H each, *t*-Bu), 3.36 t (1H, *J* = 11.06 Hz) and 3.99 d.d (1H, *J* = 5.34, 11.3 Hz) (OCH_2), 3.79 t (1H, 2-H, *J* = 8.85 Hz), 3.86 s (3H, OCH_3), 3.87 m (1H, 4-H), 4.72 d (1H, 1-H, *J* = 9.07 Hz), 5.29 t (1H, 3-H, *J* = 8.84 Hz), 6.94 d (2H, *J* = 8.85 Hz) and 8.03 d (2H, *J* = 9.06 Hz) (C_6H_4), 7.25–7.35 m (3H) and 7.51 d (2H, *J* = 7.96 Hz) (C_6H_5). ^{13}C NMR spectrum, δ_C, ppm: –5.04, 4.59, and 3.75 ($SiCH_3$); 25.45 and 25.96 (CH_3), 55.42 (OCH_3), 69.87 (C^5), 69.58 (C^4), 72.36 and 79.38 (C^3, C^2), 90.58 (C^1); 113.55, 123.04, 127.41, 129.06, 130.11, 131.98, 134.55, 163.31 (C_{arom}); 165.11 (C=O).

Phenyl 3,4-*O*-(2,3-dimethoxybutane-2,3-diyl)-2-*O*-(4-methoxybenzoyl)-β-D-xylopyranosyl(1→3)-2-*O*-acetyl-4-*O*-*tert*-butyldimethylsilyl-1-thio-α-L-arabinopyranoside (II). Finely ground freshly calcined 4-Å molecular sieves, 5 mg, were added to a mixture of 0.03 g (0.047 mmol) of compound **V** [13] and 0.019 g (0.047 mmol) of **IX** in anhydrous methylene chloride. The mixture was stirred for 30 min at room temperature and cooled to –70°C, 0.0235 ml of a 0.1 M solution of $BF_3 \cdot Et_2O$ in methylene chloride was added, and the mixture was stirred for 30 min at –70°C and for 2 h at –40°C. The reaction was terminated by adding triethylamine, the mixture was filtered, the filtrate was evaporated, and the residue was purified by column chromatography on silica gel using petroleum ether–ethyl acetate (10:1, 5:1, 2:1) as eluent. Yield 0.021 g (~50%), $[\alpha]_D^{20}$ = +16.0° (*c* = 1.0, $CHCl_3$). ^1H NMR spectrum ($CDCl_3$), δ, ppm: –0.01 s (6H, $SiMe_2$), 0.96 s (9H, *t*-Bu), 1.22 s (3H, CH_3), 1.27 s (3H, CH_3), 2.03 s (3H, CH_3CO), 3.15 s (3H, OCH_3), 3.26 s (3H, OCH_3), 3.46 t.d (1H, 5′-H, ^2J = 10.5, ^4J = 2.0 Hz), 3.77 d.d (1H, 3′-H, *J* = 4.0, 10.2, ^4J = 2.0 Hz), 3.83–3.97 m (5H, OCH_2, OCH), 3.87 s

(3H, OCH_3), 4.41 t (1H, OCH_2, J = 10.2 Hz), 4.75 d (1H, 1′-H, J = 7.4 Hz), 5.02 d.d (1H, 2-H, J = 2.1, 4.4 Hz), 5.09 br.s (1H, 1-H), 5.12 d.d (1H, 2′-H, J = 7.4, 10.2 Hz), 6.92 d.d (2H, C_6H_4, J = 1.9, 7.4 Hz), 7.19–7.28 m (3H) and 7.45 m (2H) (C_6H_5), 7.98 d.d (2H, C_6H_4, J = 1.5, 7.5 Hz). ^{13}C NMR spectrum, δ_C, ppm: –5.04 and –4.98 ($SiCH_3$), 17.52 (CH_3), 17.63 (CH_3), 18.20 (**C**Me_3), 21.06 (CH_3), 25.81 (C**Me**$_3$), 47.61 (OCH_3), 47.93 (OCH_3), 55.41 (OCH_3), 63.97 (C^5, $C^{5'}$), 65.63 (C^4), 71.13 ($C^{2'}$), 71.32 ($C^{4'}$), 74.56 (C^2), 75.17 (C^3, $C^{3'}$), 86.10 (C^1), 99.46 and 99.73 ($C^{2''}$, $C^{3''}$), 103.35 ($C^{1'}$); 113.54, 122.53, 126.97, 128.75, 131.21, 131.71, 163.30 (C_{arom}); 164.40, 169.36 (C=O). Mass spectrum, m/z (I_{rel}, %): 750 (0.2) $[M]^+$, 749 (0.5) $[M - H]^+$, 381 (68), 135 (100) $[COC_6H_4OCH_3]^+$. Found: m/z 750.299 $[M]^+$. $C_{36}H_{50}O_{13}SSi$. Calculated: M 750.274.

This study was performed under financial support by the Russian Foundation for Basic Research (project no. 11-03-00780a).

REFERENCES

1. Kubo, S., Mimaki, Y., Terao, M., Sashida, Y., Nikaida, T., and Ohmato, T., *Phytochemistry*, 1992, vol. 31, p. 3969.
2. Mimaki, Y., Kuroda, M., Kameyama, A., Sashida, Y., Hirano, T., Maekawa, R., Wada, T., Sugita, K., and Beutler, A.J., *Bioorg. Med. Chem. Lett*., 1997, vol. 7, p. 633.
3. Deng, S.J., Yu, B., Lou, Y., and Hui, Y.Z., *J. Org. Chem*., 1999, vol. 64, p. 202.
4. Ma, X., Yu, B., Hui, Y., Miao, Z., and Ding, J., *Carbohydr. Res*., 2001, vol. 334, p. 159.
5. Yu, W.S. and Jin, Z.D., *J. Am. Chem. Soc*., 2002, vol. 124, p. 6576.
6. Deng, L., Wu, H., Yu, B., Jiang, M., and Wu, J., *Bioorg. Med. Chem. Lett*., 2004, vol. 14, p. 2781.
7. Matsuya, Y., Itoh, T., and Nemoto, H., *Eur. J. Org. Chem*., 2003, p. 2221.
8. Shi, B., Wu, H., Yu, B., and Wu, J., *Angew. Chem., Int. Ed*., 2004, vol. 43, p. 4324.
9. Wojtkielewicz, A., Dugosz, M., Maj, J., Morzycki, J.W., Nowakowski, M., Renkiewicz, J., Strnad, M., Swaczynov, J., Wilczewska, A.Z., and Wjcik, J., *J. Med. Chem*., 2007, vol. 50, p. 3667.
10. Tang, P., Mamdani, F., Hu, X., Liu, J.O., and Yu, B., *Bioorg. Med. Chem. Lett*., 2007, vol. 17, p. 1003.
11. Zheng, D., Zhou, L., Guan, Y., Chen, X., Zhou, W., Chen, X., and Lei, P., *Bioorg. Med. Chem. Lett*., 2010, vol. 20, p. 5439.
12. Guan, Y., Zheng, D., Zhou, L., Wang, H., Yan, Zh., Wang, N., Chang, H., She, P., and Lei, P., *Bioorg. Med. Chem. Lett*., 2011, vol. 21, p. 2921.
13. Khasanova, L.S., Gimalova, F.A., Torosyan, S.A., Fatykhov, A.A., and Miftakhov, M.S., *Russ. J. Org. Chem*., 2011, vol. 47, p. 1125.
14. Bock, K. and Pedersen, C., *J. Chem. Soc., Perkin Trans. 2*, 1974, p. 293.