JOC The Journal of Organic Chemistry

Article

pubs.acs.org/joc

Influence of Steric Crowding on Diastereoselective Arabinofuranosylations

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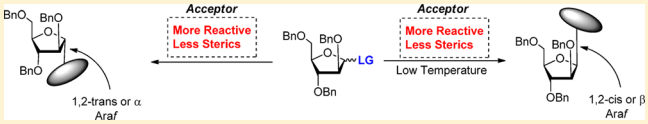
Supporting Information

ABSTRACT: The occurrence of arabinofuranosides on the cell surface of *Mycobacterium tuberculosis* (Mtb) and their significance in controlling disease spurred interest in developing strategies for their diastereoselective synthesis. Mtb uses enzymes to achieve diastereoselectivity through noncovalent interactions. Of the two possible glycosidic linkages, chemically, 1,2-*trans* linkage is relatively easy to synthesize by taking advantage of neighboring group participation, whereas synthesis of the 1,2-*cis* linkage is notoriously difficult. In this article, stereochemical effects on the diastereoselectivity of arabinofuranosidation are investigated with thiopyridyl, imidate, and thiotolyl donors as well as differently crowded glycosyl acceptors; subtle differences in the stereochemical environment of the acceptors were observed to alter the diastereoselectivity of the furanoside formation. Results from this endeavor suggest that 1,2-*cis* arabinofuranosides can be synthesized conveniently by conducting the reaction at lower temperature on sterically demanding and less reactive substrates.



INTRODUCTION

Tuberculosis has plagued mankind for a long time, and it continues to show its socioeconomic impact even now.[1] *Mycobacterium tuberculosis*, the causative agent of tuberculosis, is established to have a thick cell wall, which makes getting small molecules into the cells for eventual killing difficult.[2] Fine structural details of the mycobacterial cell wall have been determined, finding that arabinose and galactose in furanosyl form along with other sugars.[3] Arabinogalactan (AG) and lipoarabinomannan (LAM) are the broad constituents of the mycobacterial cell wall, and the terminal arabinofuranosyl residues of AG are esterified with mycolic acid.[3] The presence of 1,2-*cis* arabinofuranosyl residues at the terminal position of AG is yet another characteristic that distinguishes AG and LAM.

Chemical synthesis of oligosaccharides is important for understanding disease processes and the development of various therapeutic agents.[4a] Chemical synthesis of 1,2-*cis* furanosides is more challenging compared to that of 1,2-*trans* furanosides.[4b] Several approaches have been developed for the synthesis of both 1,2-*trans* and 1,2-*cis* linkages of arabinofuranosides.[5] Various glycosyl donors, such as thio glycosides,[5a−d] alkyl glycosides,[5a,6a] silyl glycosides,[6b] esters,[5g] halo-,[6c,d] imidate,[6e] 1,2-anhydro,[6f,g] and orthoesters[6h−j] were investigated for the synthesis of mycobacterial arabinan fragments. One of the fragments of the mycobacterial cell wall is motif A (**1**), which is a hexaarabinofuranoside containing two 1,2-*cis* and four 1,2-*trans* linkages (Figure 1).[3]

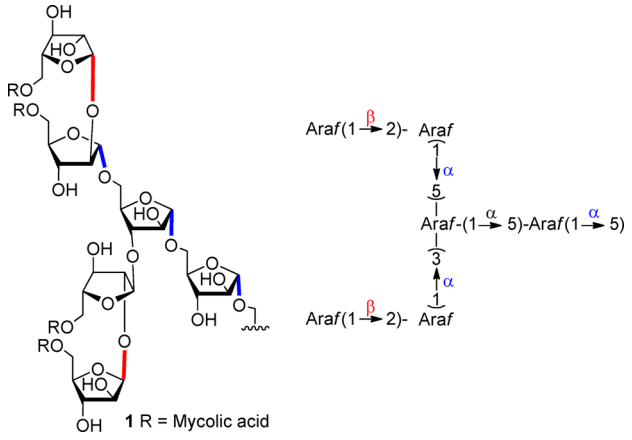


Figure 1. Motif A of the *Mycobacterium tuberculosis* cell wall.

RESULTS AND DISCUSSION

The synthesis of motif A has attracted the attention of many researchers and culminated in the investigation of a variety of glycosyl donors.[7,6a,j,5a,g] A previous report[5a] on the synthesis of pentaarabinofuranosyl motif A of *Mycobacterium tuberculosis* showed stereoselective formation of 1,2-*cis* disaccharide **4** from the thiopyridyl donor **2** and *n*-pentenyl furanoside **3**. However, very little is mentioned about the origin of the selectivity; further investigation on the stereochemical influence of the stereoselectivity might pave the way for a milder and general method for the synthesis of 1,2-*cis* arabinofuranosides. Hence, the initial aim of this research has therefore been to understand the factors that influence stereoselectivity of thiopyridyl-based arabinofuranosidation.

Received: April 29, 2015
Published: July 21, 2015

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DOI: 10.1021/acs.joc.5b00964
J. Org. Chem. 2015, 80, 7937−7945

Scheme 1. Influence of Anomeric Configuration of an Arabinofuranosyl Acceptor on Furanoside Formation

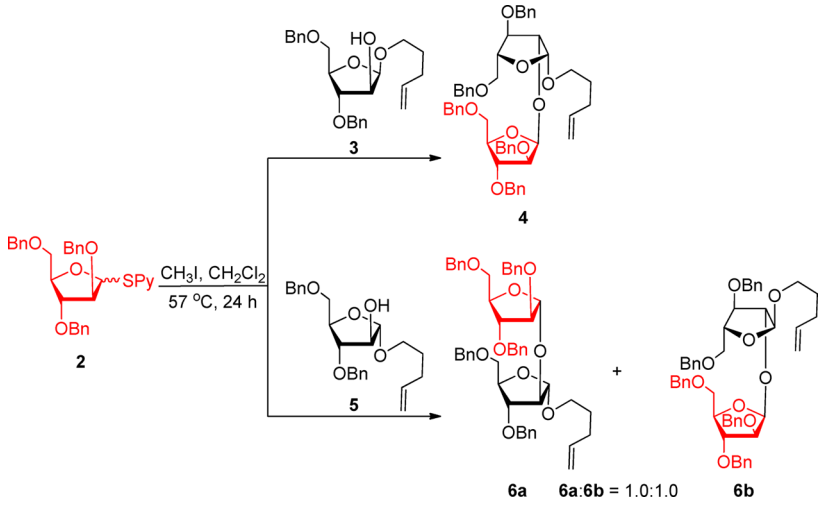
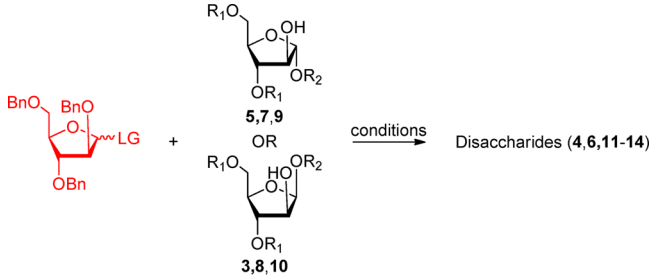


Table 1. Effect of Steric Crowding around the Alcohol of the Glycosyl Acceptor



LG = -SPy (**2**); -OC(=NH)CCl$_3$ (**15**); -STol (**16**)

R$_1$ = -CH$_2$Ph; R$_2$ = -CH$_3$ (**7**,**8**), -(CH$_2$)$_3$CH=CH (**3**,**5**), -(CH$_2$)$_9$CH$_3$ (**9**,**10**)

Donor	Acceptor																	
	5			**3**			**7**			**8**			**9**			**10**		
	Product No.	% Yield	α:β Ratio	Product No.	% Yield	α:β Ratio	Product No.	% Yield	α:β Ratio	Product No.	% Yield	α:β Ratio	Product No.	% Yield	α:β Ratio	Product No.	% Yield	α:β Ratio
2[a]	**6**	71	1.0:1.0	**4**	73	0.0:1.0	**11**	69	1.0:0.3	**12**	75	0.4:1.0	**13**	64	1.0:1.0	**14**	67	0.0:1.0
15[b]	**6**	62	0.1:1.0	**4**	61	0.0:1.0	**11**	60	0.3:1.0	**12**	63	0.1:1.0	**13**	62	0.0:1.0	**14**	63	0.0:1.0
16[c]	ND	ND	ND	ND	ND	ND	**11**	83	1.0:1.0	**12**	88	0.4:1.0	**13**	86	0.3:1.0	**14**	85	0.0:1.0

[a]CH$_3$I, CH$_2$Cl$_2$, 57 °C, 4 Å MS powder, 15 h. [b]TMSOTf, CH$_2$Cl$_2$, −78 to −40 °C; 4 Å MS powder, 1 h. [c]NIS, AgOTf, CH$_2$Cl$_2$, 0 °C, 4 Å MS powder, 15 h; ND denotes not determined.

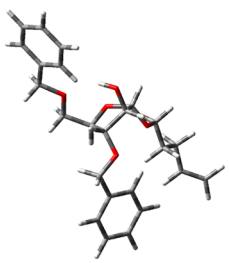
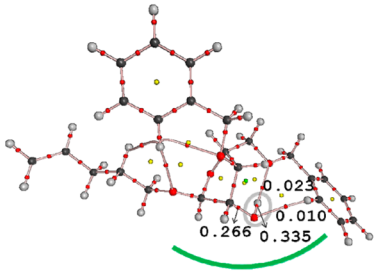
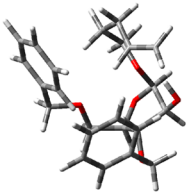
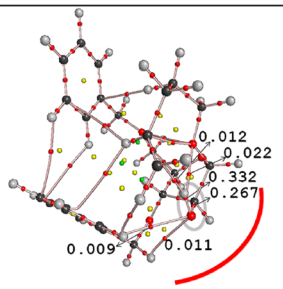
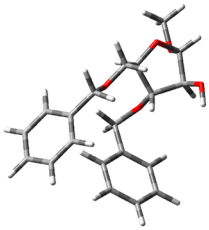
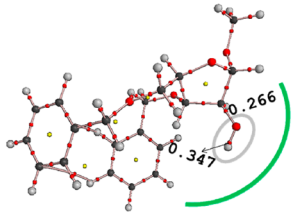
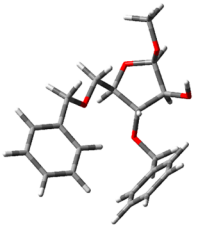
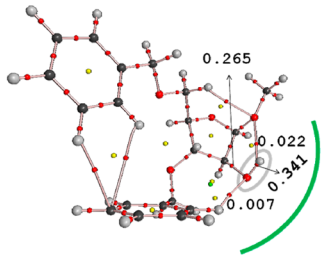
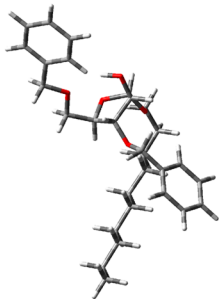
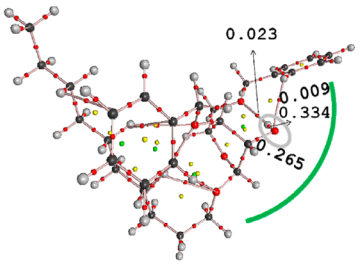
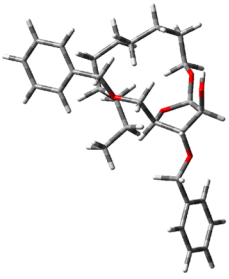
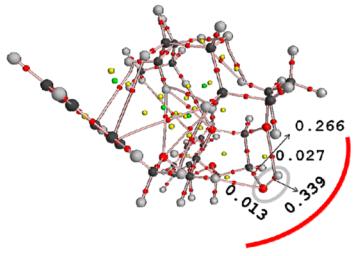
The furanosidation reaction between thiopyridyl donor **2**[5a] and *β*-pentenyl acceptor **3** afforded 1,2-*cis* disaccharide as observed earlier;[5a] surprisingly, the same reaction between *α*-pentenyl acceptor **5** and donor **2** resulted in the formation of disaccharides **6a** and **6b** in a 1:1 ratio (Scheme 1).[8] A possible explanation for the difference in stereoselectivity may be the temperature and the steric environment around the C2-OH of acceptors **3** and **5**. Earlier reports[9a,b] on the reciprocal donor−acceptor selectivity (RDAS) put forward by Fraser-Reid have focused largely on the donor; however, the difference in outcome of the glycosidation due to the acceptor's steric environment in this reaction is unique.[9c]

Formation of 1,2-*trans* disaccharide **6a** at 57 °C with glycosyl acceptor **5** can be ascribed to the lesser steric crowding around acceptor **5** compared to that around acceptor **3**. In lieu of this, sterically less demanding methyl (**7**,**8**) and more demanding decanyl (**9**,**10**) arabinofuranosides were included to study the effect of the C1-substituent of the glycosyl acceptor on stereoselectivity (Table 1). The *α*-acceptors **7** and **9** afforded an *α*,*β*-mixture of disaccharides **11** and **13** with thiopyridyl donor **2**.[8] Gratifyingly, the *β*-selectivity increased from acceptor **7** to acceptor **9**, which in turn was found to be equal to that of acceptor **5**. This can be attributed to the gradual increase in the steric crowding around the − OH of the acceptor. Less hindered *β*-acceptor **8** showed *α*,*β*-mixture (0.4:1.0) of disaccharides **12** whereas the sterically demanding decanyl furanosyl acceptor **10** gave fully *β*-diastereoselective product **14** (Table 1).[8] Here again, the selectivity toward *β*-disaccharide formation was observed to be dependent on the overall steric crowding around the −OH of the acceptor. Very high *β*-selectivity was observed for acceptors **3** and **10** compared to that of acceptor **8**.[8]

Quantum chemical calculations were performed on the reactants and products to unravel the preferred formation of

DOI: 10.1021/acs.joc.5b00964
J. Org. Chem. 2015, 80, 7937−7945

Table 2. Optimized Structures of the Acceptors 3, 5, and 7−10 along with Bond Critical Points and Electron Density (ρ) Values

	Optimized structure	Bond critical points[a]		Optimized structure	Bond critical points[a]
5			3		
7			8		
9			10		

[a]The side of attack by the donor is indicated in green (indicating feasibility of attack) and red (indicating nonfeasibility of attack) curves. The OH group, which is the site of attack, in the acceptor is highlighted.

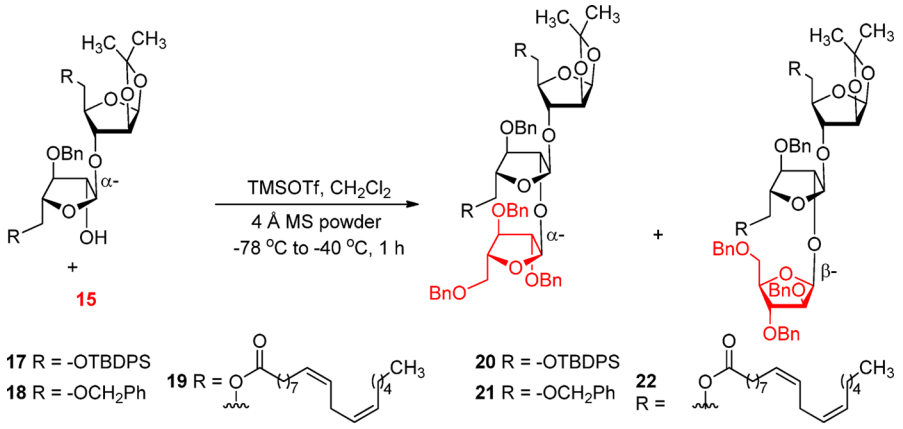
products. Initially, conformations were generated using the macromodel module of Schrodinger[10] by employing the MMFF94 force field with a convergence threshold of 0.005. Among the conformations generated for the complexes, reactants (acceptors), and products, those conformations within an energy cutoff of <5.0 kcal/mol compared to the most stable conformation were selected. The selected structures were optimized at the M06-2X/STO-3G level of theory as the M06-2X method is found to be reliable for modeling noncovalent interactions such as $\pi-\pi$. It was shown previously that noncovalent interactions, such as $\pi-\pi$ and hydrogen bonding interactions, play a major role in deciding the stability of molecules.[11] Among these optimized structures, the most stable structure in each case was considered and further optimized at the M06-2X/6-31G(d) level to understand the relative stability of the α and β isomers. All of the optimizations were performed using the Gaussian 09 program package.[12]

The optimized structures of the most stable conformations show that the β isomer is thermodynamically preferred to the α isomer.[8] However, experimentally, the α isomer is observed in minor quantities in the cases of **5** and **7**−**9**, whereas **3** and **10** show no traces of the α isomer. For this unexpected behavior to be accounted, atoms in molecules (AIM[13]) analysis is carried out by considering the various arabinofuranosyl acceptors **3**, **5**, and **7**−**10**. Fewer bond and cage critical points are observed around the OH group in **5**, **7**, **8**, and **9** (Table 2). This also suggests a small number of noncovalent interactions around the OH group. This in turn causes the donor molecule to experience less steric hindrance from the bulky substituents of acceptor and, therefore, is accessible for attack from both sides, resulting in the formation of α and β isomers, the latter being formed in major quantities. In the case of **3** and **10**, the −OH group is surrounded by various noncovalent interactions and is also crowded by the bulky substituent, which makes the −OH group less accessible for attack from one of the faces. Also, these systems show a greater number of cage critical points, in turn making the OH group less accessible for attack. Thus, in these cases, the donor group can attack from only the side where the steric hindrance from the bulky substituent is lesser, thereby forming the β-isomer alone. These results clearly suggest that the steric and electronic effects from the bulky substitutents and the nature of the substituents have a major influence on product formation.

The temperature of the reaction is yet another major influencing factor for diastereoselectivity. Accordingly, arabinofuranosyl imidate **15**[6e,5h] and thiotolyl **16**[5d] donors were synthesized and reacted at −78 °C → −40 and 0 °C, respectively, with glycosyl acceptors **3**, **5**, and **7**−**10**.[8] The furanosidation between imidate **15** and acceptors **5**, **7**, and **9** showed an increased ratio of β-disaccharide compared to the corresponding thiopyridyl donor **2**. β-Disaccharides are

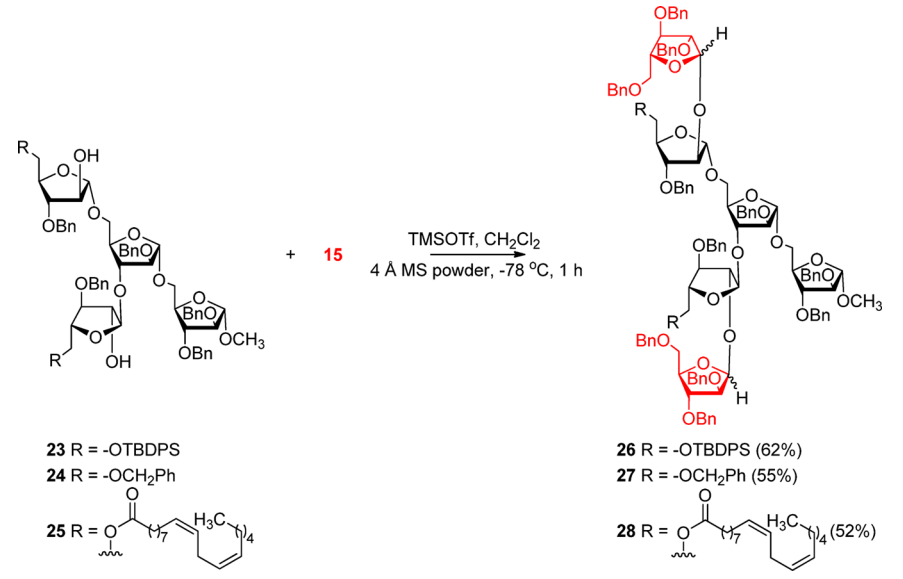
DOI: 10.1021/acs.joc.5b00964
J. Org. Chem. 2015, 80, 7937−7945

Scheme 2. Effect of Protecting Groups at C-5 on Furanoside Formation



Donor	Acceptor	Product	% Yield	α:β Ratio
15	**17**	**20**	60	0.4:1.0
15	**18**	**21**	64	0.1:1.0
15	**19**	**22**	63	0.0:1.0

Scheme 3. Synthesis of Hexaarabinofuranosyl Motif A



observed when the furanosidation was conducted between imidate donor **15** and acceptors **3**, **8**, and **10**.

Activation of thiotolyl donor **16** could not be carried out on glycosyl acceptors **3** and **5** because the conditions employed (NIS/AgOTf) for the activation of thiotolyl donor **16** can also activate *n*-pentenyl glycosides at 0 °C. Furthermore, *α*:*β* ratios were measured for the furanosidation between thiotolyl donor **16** and the acceptors **7**−**10**. A mixture of disaccharides was observed with acceptors **7**, **8**, and **9**, whereas sterically demanding acceptor **10** gave *β*-disaccharide only in good yield (Table 1).[8] Hence, the stereoselectivity of the arabinofuranosidation was observed to also be influenced by the temperature and steric crowding around the glycosyl acceptor.

Furthermore, the C-5 position of the terminal residues of motif A (**1**) is esterified with mycolic acid, which can also impart steric crowding on the C−OH of the glycosyl acceptor. Aforementioned discussions encouraged consideration of three model disaccharides **17**−**19** that are very similar to motif A (**1**) to determine the steric influence of the C-5 substituent on the stereochemical outcome. First, silyl-protected furanosyl acceptor **17** was subjected to furanosidation with donor **15** at −78 °C → −40 °C to afford an *α*:*β* mixture (0.4:1.0) of trisaccharides **20** in 60% yield. Furthermore, furanosidation was performed

DOI: 10.1021/acs.joc.5b00964
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between benzyl-protected disaccharide **18** and donor **15** to observe an α:β mixture (0.1:1.0) of trisaccharides **21** in 64% yield with an increased ratio of β-trisaccharides (Scheme 2). Subsequent furanosidation between linoleate **19** as the glycosyl acceptor and imidate donor **15** resulted in the formation of only β-trisaccharide **22**, suggesting that the overall stereoelectronic conditions around the furanosyl acceptor influence the stereochemical outcome (Scheme 2).[8]

In continuation, tetrasaccharides **23**−**25** reacted with imidate donor **15** to afford an α:β mixture of hexaarabinofuranosides **26**−**28** (Scheme 3). The individual ratios could not be determined; however, the ratio shifted toward more β-hexaarabinofuranoside from **26** → **27** → **28**, which further shows that the diastereoselectivity of the arabinofuranosidation depends on the stereochemical factors around the hydroxyl group of the glycosyl acceptor.[8,15]

CONCLUSIONS

In conclusion, β-arabinofuranosidation was found to be influenced by the stereochemical environment around the hydroxyl group of the acceptor and the temperature of the reaction. 1,2-*cis* Arabinofuranosides can be synthesized conveniently by conducting the reaction at lower temperature on sterically demanding and less reactive substrates. It was noticed that trends in mono- and disaccharides were even followed for a tetrasaccharide acceptor. These observations further support the hypothesis of reciprocal donor−acceptor selectivity matching.[9c]

EXPERIMENTAL SECTION

General Methods. Unless otherwise noted, materials were obtained from commercial suppliers and were used without further purification. Unless otherwise reported, all reactions were performed under argon atmosphere. Removal of solvent in vacuo refers to distillation using a rotary evaporator attached to an efficient vacuum pump. Products obtained as solids or syrups were dried under high vacuum. Analytical thin-layer chromatography was performed on precoated silica plates (F_{254}, 0.25 mm thickness); compounds were visualized by UV light or by staining with anisaldehyde spray. Optical rotations were measured on a digital polarimeter. IR spectra were recorded on an FT-IR spectrometer. NMR spectra were recorded on either a 400 or a 500 MHz spectrometer with $CDCl_3$ as the solvent and TMS as the internal standard. High resolution mass spectroscopy (HRMS) was performed using an ESI-TOF mass analyzer. Low resolution mass spectroscopy (LRMS) was performed on UPLC-MS with a TLC interface.

*(a). Synthesis of Glycosyl Acceptors (**3**, **5**, and **7**−**10**).* 3,5-Di-*O*-benzyl arabinofuranosyl acetonide[5a,14] (4.00 g, 10.8 mmol), PTSA (0.23 g, 1.35 mmol), and alcohol (ROH, 13.5 mmol) were dissolved in anhydrous CH_2Cl_2 and stirred at 60 °C for 2 h. The reaction mixture was cooled to room temperature, neutralized with Et_3N, and purified by silica gel flash column chromatography (*n*-hexane/EtOAc) to afford glycosyl acceptors **3**, **5**, and **7**−**10** in 72−81% yield.

*(b). General Procedure[5a] for Glycosylation Using Thiopyridyl Donor **2**.* To a solution of furanosyl acceptor (**3**, **5**, and **7**−**10**) (250 μmol) and donor **2** (326 μmol) in anhydrous CH_2Cl_2 (10 mL) were added freshly activated 4 Å molecular sieves powder (0.40 g) and 5% CH_3I in CH_2Cl_2 at 25 °C. The reaction mixture was heated to 57 °C for 15 h and then filtered through a pad of Celite. The filtrate was concentrated in vacuo to afford a yellow colored oil, which was purified by silica gel flash column chromatography (*n*-hexane/EtOAc, 9:1, v/v) to obtain the furanosides in 64−75% yield.

*(c). General Procedure[5g,6e] for Glycosylation Using Imidate Donor **15**.* To the solution of acceptor (**3**, **5**, and **7**−**10**) (250 μmol) and donor **15** (326 μmol) in anhydrous CH_2Cl_2 (10 mL) was added freshly activated 4 Å MS powder (0.400 g) at 25 °C. After cooling to −78 °C, TMSOTf (37.6 μmol) was added to the reaction mixture, and the temperature was gradually increased to −40 °C over 5 min. After 1.0 h, the reaction was neutralized by Et_3N and filtered through a bed of Celite. The filtrate was concentrated in vacuo to obtain a brown colored oil that was purified by silica gel flash column chromatography (*n*-hexane/EtOAc, 9:1, v/v) to afford the furanosides in 61−63% yield.

*(d). General Procedure[5d] for Glycosylation using p-Thiotolyl Donor **16**.* To a solution of acceptor (**7**−**10**) (250 μmol) and donor **16** (326 μmol) in anhydrous CH_2Cl_2 (10 mL) was added freshly activated 4 Å MS powder (0.400 g) at 25 °C. After cooling to 0 °C, NIS (502 μmol) and AgOTf (50 μmol) were added to the reaction mixture, and the mixture was stirred for 1.5 h at 0 °C. The reaction was neutralized by Et_3N and filtered through a bed of Celite. The filtrate was concentrated in vacuo to obtain a reddish colored oil that was purified by silica gel flash column chromatography (*n*-hexane/EtOAc, 9:1, v/v) to afford furanosides in 83−88% yield.

General Procedure[2,3] for the Preparation of Trisaccharides (20, 21, and 22) and Hexasaccharides (26, 27, and 28) Using Imidate Donor 15. To the solution of acceptor (**17**−**19** or **23**−**25**) (106 μmol) and donor **15** (320 μmol) in anhydrous CH_2Cl_2 (10 mL) was added freshly activated 4 Å MS powder (0.400 g) at 25 °C, and the mixture was stirred at 25 °C for 10 min. After cooling to −78 °C, TMSOTf (37.6 μmol) was added to the reaction mixture, and the temperature was gradually increased to −40 °C over 5 min. After 1.0 h, the reaction was neutralized by Et_3N and filtered through a bed of Celite. The filtrate was concentrated in vacuo to obtain a brown colored oil that was purified by silica gel flash column chromatography (*n*-hexane/EtOAc) to afford the furanosides in 46−50% yield.

*4-Pentenyl 3,5-Di-O-benzyl-β-D-arabinofuranoside (**3**).* Yield = 3.49 g, 81%; $[\alpha]_D^{25}$ −39.0 (*c* 1.0, $CHCl_3$); ^{1}H NMR (399.78 MHz, $CDCl_3$) δ 1.64 (td, *J* = 15.4, 14.7, 7.6 Hz, 2H), 1.96−2.17 (m, 2H), 2.59 (d, *J* = 9.6 Hz, 1H), 3.44 (dt, *J* = 9.6, 6.6 Hz, 1H), 3.52 (d, *J* = 5.9 Hz, 2H), 3.77 (dt, *J* = 9.6, 6.5 Hz, 1H), 3.83 (t, *J* = 5.7 Hz, 1H), 4.14 (q, *J* = 5.6 Hz, 1H), 4.19−4.30 (m, 1H), 4.56 (s, 2H), 4.62 (d, *J* = 11.9 Hz, 1H), 4.76 (d, *J* = 11.9 Hz, 1H), 4.93−5.04 (m, 3H), 5.78 (ddt, *J* = 16.9, 10.2, 6.7 Hz, 1H), 7.27−7.35 (m, 10H); ^{13}C NMR (100.53 MHz, $CDCl_3$) δ 28.3, 29.9, 67.5, 71.5, 71.8, 72.9, 77.6, 80.4, 84.5, 101.3, 114.6, 127.3(2C), 127.4(4C), 128.0(4C), 137.6(2C), 137.7; IR ($CHCl_3$) 3619, 3030, 2921, 1546, 1455, 1212, 1104, 699 cm^{-1}; HRMS (TOF) *m*/*z* $[M + Na]^+$ calcd for $C_{24}H_{30}NaO_5$ 421.1991, found 421.1989.

*4-Pentenyl 2-O-[2,3,5-Tri-O-benzyl-β-D-arabinofuranosyl]-3,5-di-O-benzyl-β-D-arabinofuranoside (**4**).* Yield = 0.122 g, 61%; $[\alpha]_D^{25}$ −43.8 (*c* 1.0, $CHCl_3$); ^{1}H NMR (399.78 MHz, $CDCl_3$) δ 1.59 (q, *J* = 7.1 Hz, 2H), 2.01 (q, *J* = 7.3 Hz, 2H), 3.38 (dt, *J* = 9.6, 6.6 Hz, 1H), 3.46−3.56 (m, 3H), 3.57−3.62 (m, 1H), 3.71 (dt, *J* = 9.6, 6.9 Hz, 1H), 4.13 (td, *J* = 9.9, 8.7, 5.7 Hz, 5H), 4.29 (d, *J* = 12.0 Hz, 1H), 4.37−4.45 (m, 2H), 4.49 (d, *J* = 11.3 Hz, 1H), 4.52 (s, 2H), 4.57 (s, 2H), 4.60 (d, *J* = 11.8 Hz, 1H), 4.68 (d, *J* = 11.8 Hz, 1H), 4.80 (d, *J* = 11.3 Hz, 1H), 4.90 (t, *J* = 1.2 Hz, 1H), 4.92−4.96 (m, 1H), 5.09 (d, *J* = 4.2 Hz, 1H), 5.16 (d, *J* = 2.5 Hz, 1H), 5.70 (ddt, *J* = 17.1, 10.4, 6.6 Hz, 1H), 7.18−7.41 (m, 25H); ^{13}C NMR (100.53 MHz, $CDCl_3$) δ 28.8, 30.2, 67.1, 71.6, 72.2(2C), 72.4, 72.5, 73.0, 73.2, 79.0, 80.2, 80.7, 82.6, 82.9, 83.9, 98.4, 100.0, 114.9, 127.5, 127.5, 127.6(2C), 127.6(2C), 127.7(2C), 127.7(2C), 127.8, 128.0(2C), 128.3(3C), 128.3(3C), 128.3(3C), 128.3(3C), 137.7(2C), 137.8, 137.9, 138.0, 138.0; IR ($CHCl_3$) 3035, 2920, 1550, 1455, 1212, 1104, 699 cm^{-1}; HRMS (TOF) *m*/*z* $[M + Na]^+$ calcd for $C_{50}H_{56}NaO_9$ 823.3822, found 823.3832.

*4-Pentenyl 3,5-Di-O-benzyl-α-D-arabinofuranoside (**5**).* Yield = 3.49 g, 81%; $[\alpha]_D^{25}$ +97.8 (*c* 1.0, $CHCl_3$); ^{1}H NMR (399.78 MHz, $CDCl_3$) δ 1.70 (dt, *J* = 14.2, 6.9 Hz, 2H), 2.05−2.19 (m, 2H), 3.31 (d, *J* = 10.2 Hz, 1H), 3.40−3.54 (m, 2H), 3.57−3.78 (m, 2H), 3.87 (s, 1H), 4.14 (d, *J* = 9.6 Hz, 1H), 4.26 (s, 1H), 4.50 (t, *J* = 10.8 Hz, 2H), 4.65 (dd, *J* = 22.6, 11.9 Hz, 2H), 4.98 (dt, *J* = 20.9, 10.4 Hz, 3H), 5.82 (td, *J* = 16.7, 16.2, 6.6 Hz, 1H), 7.24−7.35 (m, 10H); ^{13}C NMR (100.53 MHz, $CDCl_3$) δ 28.7, 30.2, 66.9, 69.8, 71.9, 73.7, 77.8, 83.3, 85.2, 109.1, 114.7, 127.7(3C), 127.8(2C), 128.0, 128.4(2C), 128.5(2C), 137.0, 137.9, 138.3; IR ($CHCl_3$) 3615, 3040, 2925,

DOI: 10.1021/acs.joc.5b00964
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1546, 1455, 1212, 1104, 712 cm^{-1}; HRMS (TOF) m/z $[M + Na]^+$ calcd for $C_{24}H_{30}NaO_5$ 421.1991, found 421.1989.

*4-Pentenyl 3,5-Di-O-benzyl-2-O-(2,3,5-tri-O-benzyl-α-arabinofuranosyl)-α-D-arabinofuranoside (**6a**).* Obtained from the 1:1 mixture of disaccharides **6a** and **6b**. ^1H NMR (399.78 MHz, $CDCl_3$) δ 1.68 (q, J = 7.0 Hz, 2H), 2.10 (p, J = 6.9 Hz, 2H), 3.36−3.42 (m, 2H), 3.44 (d, J = 3.0 Hz, 2H), 3.54 (m, 3H), 3.61 (d, J = 3.8 Hz, 2H), 3.73 (dt, J = 9.6, 6.6 Hz, 1H), 3.99 (dd, J = 6.4, 2.9 Hz, 1H), 4.11 (d, J = 2.0 Hz, 1H), 4.20−4.23 (m, 2H), 4.28−4.49 (m, 10H), 5.09 (s, 1H), 5.13 (s, 1H), 5.72−5.81 (m, 1H), 7.24−7.33 (m, 25H); ^{13}C NMR (100.53 MHz, $CDCl_3$) δ 28.7, 28.7, 66.9, 69.8, 71.9, 72.0, 72.5, 73.0, 73.3, 77.2, 80.5, 80.8, 83.5, 84.0(2C), 86.3, 88.4, 105.6, 106.9, 114.8, 127.5(2C), 127.6(3C), 127.9(4C), 128.0, 128.1(4C), 128.2(4C), 128.4(4C), 137.4, 137.6, 137.8, 138.2, 138.3.

*4-Pentenyl 3,5-Di-O-benzyl-2-O-(2,3,5-tri-O-benzyl-α-D-arabinofuranosyl)-β-D-arabinofuranoside (**6b**).* Obtained from the 1:1 mixture of disaccharides **6a** and **6b**. ^1H NMR (399.78 MHz, $CDCl_3$) δ 1.68 (q, J = 7.0 Hz, 2H), 2.10 (p, J = 6.9 Hz, 2H), 3.36−3.42 (m, 2H), 3.44 (d, J = 3.0 Hz, 2H), 3.54 (dd, J = 8.6, 4.7 Hz, 3H), 3.61 (d, J = 3.8 Hz, 2H), 3.73 (dt, J = 9.6, 6.6 Hz, 1H), 3.99 (dd, J = 6.4, 2.9 Hz, 1H), 4.11 (d, J = 2.0 Hz, 1H), 4.20−4.23 (m, 2H), 4.28−4.49 (m, 10H), 4.98 (s, 1H), 5.07 (d, J = 4.2 Hz, 1H), 5.75−5.84 (m, 1H), 7.24−7.33 (m, 25H); ^{13}C NMR (100.53 MHz, $CDCl_3$) δ 28.7, 30.2, 66.8, 70.0, 72.1, 72.3, 72.4, 73.0, 73.2, 77.2, 79.9, 80.9, 82.8, 83.9(2C), 86.0, 92.2, 100.2, 105.8, 114.6, 127.5(2C), 127.6(3C), 127.9(4C), 128.0, 128.1(4C), 128.2(4C), 128.4(4C), 136.9, 137.1, 137.5, 138.0, 138.1.

*Methyl 3,5-Di-O-benzyl-α-D-arabinofuranoside (**7**).* Yield = 2.90 g, 78%; $[\alpha]_D^{25}$ +122.8 (c 1.0, $CHCl_3$); ^1H NMR (399.78 MHz, $CDCl_3$) δ 3.39 (s, 3H), 3.43 (m, 2H), 3.63 (dd, J = 10.4, 2.5 Hz, 1H), 3.82 (d, J = 3.3 Hz, 1H), 4.12 (d, J = 6.9 Hz, 1H), 4.21−4.29 (m, 1H), 4.48 (dd, J = 19.6, 12.1 Hz, 2H), 4.58 (d, J = 11.9 Hz, 1H), 4.67 (d, J = 12.3 Hz, 1H), 4.89 (s, 1H), 7.22−7.35 (m, 10H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 55.1, 69.6, 71.9, 73.5, 78.0, 83.2, 84.8, 110.2, 127.7(3C), 127.8(2C), 127.9, 128.3(2C), 128.4(2C), 136.9, 137.6; IR ($CHCl_3$) 3618, 3042, 2925, 1550, 1455, 1215, 1100, 688 cm^{-1}; HRMS (TOF) m/z $[M + Na]^+$ calcd for $C_{20}H_{24}NaO_5$ 367.1521, found 367.1521.

*Methyl 3,5-Di-O-benzyl-β-D-arabinofuranoside (**8**).* Yield = 2.90 g, 78%; $[\alpha]_D^{25}$ −39.8 (c 1.0, $CHCl_3$); ^1H NMR (399.78 MHz, $CDCl_3$) δ 2.67 (bs, 1 H), 3.38 (s, 3H), 3.52 (d, J = 5.7 Hz, 2H), 3.84 (t, J = 5.8 Hz, 1H), 4.14 (q, J = 5.6 Hz, 1H), 4.24 (t, J = 5.3 Hz, 1H), 4.55 (d, J = 2.2 Hz, 2H), 4.61 (d, J = 11.9 Hz, 1H), 4.74 (d, J = 11.9 Hz, 1H), 4.83 (d, J = 4.7 Hz, 1H), 7.23−7.38 (m, 10H); ^{13}C NMR (100.53 MHz, $CDCl_3$) δ 55.3, 71.8, 72.0, 73.2, 77.9, 80.7, 84.5, 102.6, 127.6(4C), 127.7(2C), 128.3(4C), 137.9, 137.9; IR ($CHCl_3$) 3612, 3032, 2922, 1555, 1455, 1218, 1104, 685 cm^{-1}; HRMS (TOF) m/z $[M + Na]^+$ calcd for $C_{20}H_{24}NaO_5$ 367.1521, found 367.1519.

*Decanyl 3,5-Di-O-benzyl-α-D-arabinofuranoside (**9**).* Yield = 3.81 g, 75%; $[\alpha]_D^{25}$ +91.6 (c 1.0, $CHCl_3$); ^1H NMR (399.78 MHz, $CDCl_3$) δ 0.81−0.93 (m, 3H), 1.16−1.38 (m, 14H), 1.59 (q, J = 6.7 Hz, 2H), 3.34−3.53 (m, 3H), 3.61−3.75 (m, 2H), 3.86 (d, J = 3.1 Hz, 1H), 4.14 (s, 1H), 4.21−4.27 (m, 1H), 4.45−4.53 (m, 2H), 4.64 (dd, J = 27.6, 12.1 Hz, 2H), 5.00 (s, 1H), 7.21−7.39 (m, 10H); ^{13}C NMR (10.53 MHz, $CDCl_3$) δ 14.1, 22.6, 26.0, 29.3, 29.4, 29.5, 29.5, 29.6, 31.8, 67.6, 69.7, 71.8, 73.6, 78.0, 83.0, 85.2, 108.9, 127.6, 127.7(2C), 127.8(2C), 127.9, 128.3(2C), 128.5(2C), 137.0, 137.9; IR ($CHCl_3$) 3622, 3030, 2925, 1552, 1455, 1219, 1104, 683 cm^{-1}; HRMS (TOF) m/z $[M + Na]^+$ calcd for $C_{29}H_{42}NaO_5$ 493.2930, found 493.2929.

*Decanyl 3,5-Di-O-benzyl-β-D-arabinofuranoside (**10**).* Yield = 3.66 g, 72%; $[\alpha]_D^{25}$ +39.6 (c 1.0, $CHCl_3$); ^1H NMR (399.78 MHz, $CDCl_3$) δ 0.88 (t, J = 6.8 Hz, 3H), 1.26 (s, 14H), 1.43−1.62 (m, 2H), 2.64 (d, J = 9.0 Hz, 1H), 3.41 (dt, J = 9.5, 6.7 Hz, 1H), 3.53 (d, J = 5.9 Hz, 2H), 3.74 (dt, J = 9.5, 6.8 Hz, 1H), 3.83 (t, J = 5.7 Hz, 1H), 4.14 (q, J = 5.7 Hz, 1H), 4.24 (dt, J = 9.9, 5.5 Hz, 1H), 4.55 (s, 2H), 4.62 (d, J = 11.9 Hz, 1H), 4.76 (d, J = 11.9 Hz, 1H), 4.95 (dd, J = 4.7, 2.8 Hz, 1H), 7.24−7.35 (m, 10H); ^{13}C NMR (100.53 MHz, $CDCl_3$) δ 14.1, 22.6, 26.0, 29.3, 29.4, 29.4, 29.5(2C), 31.8, 68.4, 71.7, 72.1, 73.2, 77.9, 80.6, 84.9, 101.5, 127.6(2C), 127.6(4C), 128.3(4C), 138.0(2C); IR ($CHCl_3$) 3625, 3025, 2921, 1548, 1458, 1212, 1113, 698 cm^{-1}; HRMS (TOF) m/z $[M + Na]^+$ calcd for $C_{29}H_{42}NaO_5$ 493.2930, found 493.2929.

*Methyl 2-O-[2,3,5-Tri-O-benzyl-β-D-arabinofuranosyl]-3,5-di-O-benzyl-α-D-arabinofuranoside (**11**).* An analytical sample, for characterization purposes, was obtained by purification of the residue resulting from the aforementioned general reaction procedure using imidate donor **15** as the glycosyl donor. Yield = 0.13 g, 60%; $[\alpha]_D^{25}$ −49.0 (c 1.0, $CHCl_3$); ^1H NMR (399.78 MHz, $CDCl_3$) δ 3.37 (s, 3H), 3.48−3.63 (m, 3H), 3.94−4. 01 (m, 1H), 4.09 (dd, J = 5.8, 2.5 Hz, 2H), 4.18−4.23 (m, 1H), 4.26 (s, 1H), 4.36 (td, J = 12.3, 1.7 Hz, 2H), 4.43−4.69 (m, 10H), 4.89 (s, 1H), 5.06 (d, J = 3.9 Hz, 1H), 7.16−7.38 (m, 25H); ^{13}C NMR (100.53 MHz, $CDCl_3$) δ 54.9, 70.1, 72.0, 72.2, 72.3, 72.5, 73.0, 73.3, 80.0, 81.3, 82.9, 83.9, 84.0, 85.9, 100.2, 106.9, 127.5(3C), 127.5(3C), 127.6, 127.7(5C), 127.9, 128.0(2C), 128.2(2C), 128.3(5C), 128.4(3C), 137.6, 138.0(2C), 138.1(2C); IR ($CHCl_3$) 3033, 2923, 1552, 1459, 1213, 1101, 695 cm^{-1}; HRMS (TOF) m/z $[M + Na]^+$ calcd for $C_{46}H_{50}NaO_9$ 769.3353, found 769.3358.

*Methyl 2-O-[2,3,5-Tri-O-benzyl-β-D-arabinofuranosyl]-3,5-di-O-benzyl-β-D-arabinofuranoside (**12**).* An analytical sample, for characterization purposes, was obtained by purification of the residue resulting from the aforementioned general reaction procedure using imidate donor **15** as the glycosyl donor. Yield = 0.14 g, 63%; $[\alpha]_D^{25}$ −7.6 (c 1.0, $CHCl_3$); ^1H NMR (399.78 MHz, $CDCl_3$) δ 3.23 (s, 3H), 3.50 (qd, J = 9.8, 6.2 Hz, 2H), 3.56−3.66 (m, 2H), 4.05−4.17 (m, 6H), 4.49−4.55 (m, 6H), 4.57 (s, 1H), 4.58−4.71 (m, 3H), 4.76 (d, J = 4.1 Hz, 1H), 5.17 (d, J = 4.3 Hz, 1H), 7.08−7.37 (m, 25H); ^{13}C NMR (100.53 MHz, $CDCl_3$) δ 54.2, 71.9, 72.2, 72.3, 72.5, 72.6, 73.1, 73.3, 79.7, 80.1, 82.9, 83.1, 83.5, 84.2, 102.0(2C), 127.5(2C), 127.6(3C), 127.7(4C), 127.7(5C), 128.3(5C), 128.3(4C), 128.4(2C), 137.4, 137.9(2C), 137.9, 138.1; IR ($CHCl_3$) 3030, 2921, 1546, 1455, 1212, 1104, 699 cm^{-1}; HRMS (TOF) m/z $[M + Na]^+$ calcd for $C_{46}H_{50}NaO_9$ 769.3353, found 769.3358.

*Decanyl 3,5-Di-O-benzyl-2-O-(2,3,5-tri-O-benzyl-α-D-arabinofuranosyl)-β-D-arabinofuranoside (**13**).* An analytical sample, for characterization purposes, was obtained by purification of the residue resulting from the aforementioned general reaction procedure using imidate donor **15** as the glycosyl donor. Yield = 0.11 g, 62%; $[\alpha]_D^{25}$ −31.4 (c 1.0, $CHCl_3$); ^1H NMR (399.78 MHz, $CDCl_3$) δ 0.87 (t, J = 6.8 Hz, 3H), 1.24 (s, 14H), 1.52−1.59 (m, 2H), 3.42 (d, J = 3.0 Hz, 1H), 3.45 (d, J = 2.9 Hz, 1H), 3.83 (dd, J = 6.4, 2.8 Hz, 1H), 4.06 (d, J = 4.2 Hz, 1H), 4.11 (dt, J = 7.5, 4.3 Hz, 3H), 4.14−4.27 (m, 5H), 4.45−4.61 (m, 10H), 5.02 (d, J = 4.3 Hz, 1H), 5.19 (s, 1H), 7.27−7.34 (m, 25H); ^{13}C NMR (100.53 MHz, $CDCl_3$) δ 14.1, 22.7, 26.1, 29.3, 29.4, 29.6(2C), 31.9, 67.8, 69.1, 70.0 71.8, 72.2, 73.8, 73.6, 80.8, 80.6, 81.1, 81.4, 82.9, 83.2, 83.9, 87.4, 100.4, 106.2, 127.6(3C), 127.7(4C), 127.8(2C), 128.0(2C), 128.2, 128.3(3C), 128.4(4C), 128.5(2C), 136.9(4C), 136.9, 137.1, 137.6, 138.1(2C); IR ($CHCl_3$) 3014, 2928, 1555, 1453, 1219, 1117, 696 cm^{-1}; HRMS (TOF) m/z $[M + Na]^+$ calcd for $C_{55}H_{68}NaO_9$ 895.4761, found 895.4752.

*Decanyl 2-O-[2,3,5-Tri-O-benzyl-β-D-arabinofuranosyl]-3,5-di-O-benzyl-β-D-arabinofuranoside (**14**).* An analytical sample, for characterization purposes, was obtained by purification of the residue resulting from the aforementioned general reaction procedure using imidate donor **15** as the glycosyl donor. Yield = 0.12 g, 63%; $[\alpha]_D^{25}$ +5.4 (c 1.0, $CHCl_3$); ^1H NMR (399.78 MHz, $CDCl_3$) δ 0.88 (t, J = 6.8 Hz, 3H), 1.25 (s, 14H), 1.52 (s, 2H), 3.21−3.32 (m, 1H), 3.56 (dddd, J = 39.9, 18.2, 9.6, 6.4 Hz, 5H), 4.06−4.16 (m, 6H), 4.47−4.63 (m, 8H), 4.67 (d, J = 11.9 Hz, 2H), 4.86 (d, J = 4.1 Hz, 1H), 5.18 (d, J = 3.9 Hz, 1H), 7.16−7.38 (m, 25H); ^{13}C NMR (100.53 MHz, $CDCl_3$) δ 14.1, 22.7, 26.3, 29.4, 29.6, 29.6, 29.7, 29.8, 31.9, 67.6, 71.9, 72.4, 72.5, 72.6, 72.9, 73.0, 73.3, 79.5, 80.0, 83.2(2C), 83.5, 84.5, 101.0, 102.2, 127.5, 127.5(5C), 127.6, 127.7(5C), 127.7, 128.3(5C), 128.3(5C), 128.4(2C), 137.7, 137.8, 138.0, 138.1, 138.1; IR ($CHCl_3$) 3012, 2928, 1552, 1455, 1218, 1114, 697 cm^{-1}; HRMS (TOF) m/z $[M + Na]^+$ calcd for $C_{55}H_{68}NaO_9$ 895.4761, found 895.4752.

*1,2-O-Isopropylidene 3-O-[3-O-Benzyl-5-O-tert-butyldiphenylsilyl-α-D-arabinofuranosyl]-5-O-tert-butyldiphenylsilyl-β-D-arabinofuranose (**17**).* $[\alpha]_D^{25}$ +58.2 (c 1.0, $CHCl_3$); ^1H NMR (399.78 MHz, $CDCl_3$) δ 1.07 (s, 9H), 1.10 (s, 9H), 1.37 (s, 3H), 1.42 (s, 3H), 3.52−

DOI: 10.1021/acs.joc.5b00964
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3.62 (m, 2H), 3.79−3.88 (m, 2H), 3.89−3.97 (m, 1H), 4.10 (s, 1H), 4.20 (s, 1H), 4.30 (dd, J = 10.6, 2.7 Hz, 2H), 4.57 (dd, J = 12.1, 1.7 Hz, 1H), 4.67 (s, 1H), 4.69−4.75 (m, 2H), 5.28−5.39 (m, 1H), 5.96 (d, J = 3.6 Hz, 1H), 7.30−7.40 (m, 11H), 7.41−7.55 (m, 6H), 7.65−7.69 (m, 2H), 7.73 (td, J = 7.5, 3.9 Hz, 6H); ^{13}C NMR (100.53 MHz, $CDCl_3$) δ 19.0, 19.1, 26.0, 26.7(3C), 26.7(3C), 26.9, 63.2, 63.8, 71.8, 77.4, 78.8, 84.6, 84.6, 84.9, 85.9, 105.8, 107.2, 112.4, 127.6(5C), 127.7, 127.9(4C), 128.3(2C), 129.6, 129.6, 130.0, 130.0, 132.0, 132.2, 133.1, 133.2, 135.5(4C), 135.5(5C), 137.8; IR ($CHCl_3$) 3618, 3031, 2921, 1547, 1456, 1212, 1104, 691 cm^{-1}; HRMS (TOF) m/z [M + Na]$^+$ calcd for $C_{52}H_{64}NaO_9Si_2$ 911.3987, found 911.3979.

*1,2-O-Isopropylidene 3-O-[3,5-Di-O-benzyl-α-D-arabinofuranosyl]-5-O-benzyl-β-D-arabinofuranose (**18**).* $[\alpha]_D^{25}$ +42.2 (c 1.0, $CHCl_3$); ^{1}H NMR (399.78 MHz, $CDCl_3$) δ 1.32 (s, 3H), 1.52 (s, 3H), 2.34 (s, 1H), 3.60 (td, J = 11.8, 11.3, 3.9 Hz, 2H), 3.70−3.80 (m, 2H), 3.92−3.96 (m, 1H), 3.99−4.02 (m, 1H), 4.15 (dd, J = 8.7, 3.5 Hz, 2H), 4.17−4.20 (m, 1H), 4.41−4.60 (m, 7H), 5.16 (s, 1H), 5.85 (d, J = 3.9 Hz, 1H), 7.23−7.38 (m, 15H); ^{13}C NMR (100.53 MHz, $CDCl_3$) δ 26.3, 27.1, 62.5, 69.4, 72.1, 72.2, 73.3, 80.4, 80.7, 83.4, 85.5, 86.2, 88.3, 105.2, 105.8, 112.9, 127.6, 127.7(4C), 127.9(4C), 128.3(4C), 128.4(2C), 137.3, 137.6, 137.8; IR ($CHCl_3$) 3617, 3036, 2918, 1549, 1445, 1222, 1114, 689 cm^{-1}; HRMS (TOF) m/z [M + Na]$^+$ calcd for $C_{34}H_{40}NaO_9$ 615.2570, found 615.2561.

*1,2-O-Isopropylidene 3-O-[3-O-Benzyl-5-O-((9Z,12Z)-octadeca-9,12-dienoyl)-α-D-arabinofuranosyl]-5-O-[((9Z,12Z)-octadeca-9,12-dienoyl)]-β-D-arabinofuranose (**19**).* $[\alpha]_D^{25}$ +49.6 (c 1.0, $CHCl_3$); ^{1}H NMR (399.78 MHz, $CDCl_3$) δ 0.87−0.89 (m, 6H), 1.20−1.37 (m, 35H), 1.53 (s, 3H), 1.59 (d, J = 7.2 Hz, 2H), 2.04 (dt, J = 14.9, 7.2 Hz, 8H), 2.30 (dt, J = 11.4, 7.4 Hz, 4H), 2.77 (t, J = 6.4 Hz, 2H), 3.76 (d, J = 5.8 Hz, 3H), 4.10−4.19 (m, 3H), 4.20−4.26 (m, 3H), 4.52 (d, J = 12.0 Hz, 1H), 4.64−4.72 (m, 2H), 5.10 (d, J = 1.7 Hz, 1H), 5.13 (s, 1H), 5.35 (tq, J = 7.3, 4.7, 3.6 Hz, 8H), 5.90 (d, J = 4.1 Hz, 1H), 7.28−7.37 (m, 5H); ^{13}C NMR (100.53 MHz, $CDCl_3$) δ 14.1, 14.1, 22.5, 22.6, 24.8, 24.8, 25.6, 26.4, 27.2(4C), 29.1(4C), 29.2, 29.3(3C), 29.5, 29.6, 29.7, 29.7, 31.5, 31.9, 34.0, 34.0, 63.3, 63.5, 72.3, 80.1, 80.2, 80.6, 82.6, 85.0, 85.1, 105.4, 107.5, 113.3, 127.7(2C), 127.8, 128.0, 128.0, 128.5(2C), 129.7, 129.7, 130.0, 130.0, 130.0, 130.2, 137.4, 173.2, 173.4; IR ($CHCl_3$) 3627, 3031, 2921, 1753, 1551, 1448, 1218, 1104, 698 cm^{-1}; HRMS (TOF) m/z [M + Na]$^+$ calcd for $C_{56}H_{88}NaO_{11}$ 959.6224, found 959.6216.

*1,2-O-Isopropylidene 3-O-[(3-O-Benzyl-5-O-tert-butyldiphenylsilyl-α-D-arabinofuranosyl)-2-O-(2,3,5-tri-O-benzyl β-D-arabnofuranosyl)]-5-O-tert-butyldiphenylsilyl-β-D-arabinofuranose (**20**).* Resonances for the major β-isomer are as obtained from the 0.4:1.0 α,β mixture of trisaccharides. ^{1}H NMR (399.78 MHz, $CDCl_3$) δ 0.89 (s, 9H), 0.95 (s, 9H), 1.20 (s, 3H), 1.25 (s, 3H), 3.48 (d, J = 5.2 Hz, 2H), 3.67−3.73 (m, 4H), 3.98−4.02 (m, 1H), 4.02−4.06 (m, 2H), 4.12 (dd, J = 6.0, 3.2 Hz, 3H), 4.27 (d, J = 3.5 Hz, 2H), 4.31−4.36 (m, 1H), 4.37−4.61 (m, 8H), 4.95 (d, J = 4.1 Hz, 1H), 5.05 (s, 1H), 5.74 (d, J = 4.0 Hz, 1H), 7.16−7.28 (m, 32H), 7.53−7.59 (m, 8H); ^{13}C NMR (100.53 MHz, $CDCl_3$) δ 19.1, 19.3, 26.7(3C), 26.9(3C), 63.3, 72.2, 72.2, 72.3, 72.5, 73.1, 79.4, 80.0, 80.8, 82.8, 83.1, 83.8, 84.0, 84.8, 85.7, 88.5, 99.9, 104.2, 105.6, 112.5, 127.4(2C), 127.5(5C), 127.6(13C), 127.9(3C), 128.2(2C), 128.3(2C), 128.3(2C), 128.4(2C), 129.5, 129.69, 133.1, 133.2, 133.3, 133.4, 135.6(9C), 137.7, 137.9, 138.1(2C).

*1,2-O-Isopropylidene 3-O-[(3,5-Di-O-benzyl-α-D-arabinofuranosyl)-2-O-(2,3,5-tri-O-benzyl-β-D-arabnofuranosyl)]-5-O-benzyl-β-D-arabinofuranose (**21**).* Resonances for the major β-isomer are as obtained from the 0.1:1.0 α,β mixture of trisaccharides. ^{1}H NMR (399.78 MHz, $CDCl_3$) δ 1.32 (s, 3H), 1.51 (s, 3H), 3.49−3.63 (m, 4H), 3.65−3.83 (m, 2H), 3.93−4.23 (m, 9H), 4.50 (ddd, J = 15.4, 10.0, 2.7 Hz, 12H), 5.12 (d, J = 3.8 Hz,1H), 5.18 (s, 1H), 5.86 (d, J = 4.1 Hz, 1H), 7.24−7.34 (m, 30H); ^{13}C NMR (100.53 MHz, $CDCl_3$) δ 26.4, 27.1, 66.5, 69.3, 71.8, 72.1(3C), 72.7, 73.1, 73.3, 80.1, 80.2, 81.0, 83.4, 84.1, 84.4, 85.2, 88.3, 88.5, 100.9, 105.3, 105.5, 112.9, 127.6(6C), 127.8(4C), 127.8(4C), 128.2(5C), 128.2(5C), 128.4(6C), 137.4, 137.7, 137.9(2C), 138.1(2C).

*1,2-O-Isopropylidene 3-O-[3-O-Benzyl-5-O-((9Z,12Z)-octadeca-9,12-dienoyl)-2-O-(2,3,5-tri-O-benzyl-β-D-arabinofuranosyl)-α-D-arabinofuranosyl]-5-O-[((9Z,12Z)-octadeca-9,12-dienoyl)]-β-D-arabinofuranose (**22**).* Yield = 90 mg, 63%; $[\alpha]_D^{25}$ +20.4 (c 1.0, $CHCl_3$); ^{1}H NMR (399.78 MHz, $CDCl_3$) δ 0.64−1.04(m, 6H), 1.23−1.34 (m, 35H), 1.51 (s, 3H), 1.56 (d, J = 7.2 Hz, 2H), 1.97−2.08 (m, 8H), 2.19−2.26 (m, 2H), 2.30 (t, J = 7.5 Hz, 2H), 2.77 (t, J = 6.1 Hz, 2H), 3.52−3.58 (m, 2H), 3.65−3.73 (m, 1H), 3.77 (dd, J = 11.2, 4.3 Hz, 2H), 4.07 (dd, J = 4.5, 2.3 Hz, 2H), 4.09−4.14 (m, 2H), 4.19 (d, J = 3.6 Hz, 2H), 4.23 (dd, J = 7.0, 3.6 Hz, 2H), 4.47−4.55 (m, 4H), 4.55−4.60 (m, 2H), 4.65 (dd, J = 13.6, 3.9 Hz, 2H), 4.68−4.75 (m, 2H), 5.09 (d, J = 3.2 Hz, 1H), 5.18 (d, J = 3.4 Hz, 1H), 5.28−5.42 (m, 8H), 5.90 (d, J = 4.1 Hz, 1H), 7.29 (m, 20H); ^{13}C NMR (100.53 MHz, $CDCl_3$) δ 14.1, 14.1, 24.8, 25.6, 26.4, 27.0, 27.2(2C), 29.1(3C), 29.2, 29.2, 29.3(3C), 29.5, 29.6, 29.7(2C), 29.7(2C), 31.5(2C), 31.9, 33.9, 34.0, 66.6, 71.9, 72.1(2C), 72.2, 72.6, 73.2(2C), 80.2, 80.4, 80.7, 81.3, 83.1, 83.2, 84.0, 84.2, 85.0, 100.8, 105.4, 105.6, 112.9, 127.5(2C), 127.7(3C), 127.7(3C), 127.8(3C), 127.8, 127.9, 128.1(3C), 128.3(3C), 128.3(3C), 128.4(2C), 129.9, 130.0, 130.0, 130.2, 137.2, 137.8, 138.2(2C), 172.7, 173.3; IR ($CHCl_3$) 3032, 2917, 1749, 1546, 1455, 1212, 1117, 693 cm^{-1}; HRMS (TOF) m/z [M + Na]$^+$ calcd for $C_{82}H_{114}NaO_{15}$ 1361.8055, found 1361.8049.

*Methyl 2,3-Di-O-benzyl-5-O-[2-O-benzyl-3,5-di-O-(3-O-benzyl-5-O-tert-butyldiphenylsilyl-α-D-arabinofuranosyl)-α-D-arabinofuranosyl]-α-D-arabinofuranoside (**23**).* $[\alpha]_D^{25}$ +81.8 (c 1.0, $CHCl_3$); ^{1}H NMR (399.78 MHz, $CDCl_3$) δ 1.05 (d, J = 2.9 Hz, 18H), 3.37 (d, J = 9.3 Hz, 1H), 3.42 (s, 3H), 3.44 (d, J = 8.7 Hz, 1H), 3.55 (ddd, J = 10.9, 7.5, 2.2 Hz, 2H), 3.72 (t, J = 3.2 Hz, 1H), 3.74 (d, J = 3.8 Hz, 2H), 3.79 (dd, J = 13.2, 2.2 Hz, 1H), 3.93 (dd, J = 11.4, 4.3 Hz, 1H), 4.00−4.07 (m, 4H), 4.09 (dd, J = 6.7, 3.2 Hz, 1H), 4.16 (dd, J = 3.1, 1.1 Hz, 1H), 4.17−4.27 (m, 6H), 4.42−4.48 (m, 2H), 4.48−4.54 (m, 2H), 4.56−4.63 (m, 5H), 4.65 (dd, J = 12.1, 3.8 Hz, 2H), 4.97 (s, 1H), 5.18 (s, 1H), 5.22 (s, 1H), 5.22 (s, 1H), 7.27−7.41 (m, 35H), 7.42−7.48 (m, 2H), 7.62 (ddd, J = 5.4, 4.0, 1.9 Hz, 4H), 7.66−7.70 (m, 4H); ^{13}C NMR (100.53 MHz, $CDCl_3$) δ 19.0, 19.0, 26.6(3C), 26.6(3C), 54.9, 63.7, 63.7(2C), 65.7, 71.7(3C), 71.9, 72.2, 77.8, 78.1, 79.0, 80.3, 81.0, 83.0, 83.3, 83.7, 84.1, 84.3, 87.6, 88.3, 106.1, 107.1, 107.4, 108.9, 127.5, 127.6(2C), 127.7(5C), 127.7(3C), 127.7(3C), 127.8-(5C),127.8, 127.9(2C), 127.9(3C), 128.3(4C), 128.3(3C), 128.3(3C), 128.4(2C), 129.7, 129.8 (2C), 129.8, 132.4, 132.4, 132.4, 132.5, 135.5(3C), 135.5, 137.3, 137.4, 137.8(2C), 137.9; IR ($CHCl_3$) 3619, 3035, 2920, 1546, 1455, 1210, 1100, 693 cm^{-1}; HRMS (TOF) m/z [M + Na]$^+$ calcd for $C_{88}H_{102}NaO_{17}Si_2$ 1509.6553, found 1509.6548.

*Methyl 2,3-Di-O-benzyl-5-O-[2-O-benzyl-3,5-di-O-(3,5-di-O-benzyl-α-D-arabinofuranosyl)-α-D-arabinofuranosyl]-α-D-arabinofuranoside (**24**).* $[\alpha]_D^{25}$ −31.8 (c 1.0, $CHCl_3$); ^{1}H NMR (399.78 MHz, $CDCl_3$) δ 3.39 (s, 3H), 3.49 (qd, J = 7.1, 6.5, 4.2 Hz, 4H), 3.61 (dd, J = 10.5, 2.5 Hz, 1H), 3.65 (d, J = 2.4 Hz, 1H), 3.69 (dd, J = 11.7, 4.2 Hz, 1H), 3.75 (dd, J = 10.8, 5.7 Hz, 1H), 3.85 (dd, J = 4.4, 1.8 Hz, 1H), 3.87−3.98 (m, 3H), 4.00−4.06 (m, 2H), 4.16 (dq, J = 10.2, 3.5 Hz, 3H), 4.22 (t, J = 5.6 Hz, 2H), 4.26 (d, J = 4.0 Hz, 1H), 4.32 (dd, J = 6.9, 4.8 Hz, 2H), 4.42−4.52 (m, 4H), 4.52−4.61 (m, 6H), 4.62−4.72 (m, 4H), 4.94 (s, 1H), 5.11 (s, 1H), 5.15 (s, 1H), 5.18 (s, 1H), 7.31 (ddt, J = 15.3, 7.3, 4.4 Hz, 35H); ^{13}C NMR (100.53 MHz, $CDCl_3$) δ 54.9, 66.3, 68.0, 69.6, 69.6, 71.7, 71.8, 71.8, 71.9, 72.2, 73.4, 73.5, 78.3, 78.7, 80.1, 80.4, 82.6, 82.7, 82.8, 83.2, 84.6, 84.8, 88.1, 88.5, 106.4, 107.0, 108.7, 109.1, 127.4, 127.5, 127.6(3C), 127.7(3C), 127.7(6C), 127.8, 127.8(3C), 127.9(3C), 128.1(2C), 128.2(2C), 128.3(6C), 128.4(2C), 128.4(2C), 137.1, 137.2, 137.4, 137.6, 137.8(2C), 137.9; IR ($CHCl_3$) 3621, 3028, 2921, 1556, 1455, 1218, 1111, 699 cm^{-1}; HRMS (TOF) m/z [M + Na]$^+$ calcd for $C_{70}H_{78}NaO_{17}$ 1213.5137, found 1213.5134.

*Methyl 2,3-Di-O-benzyl-5-O-[2-O-benzyl-3,5-di-O-(3-O-benzyl-5-O-((9Z,12Z)-octadeca-9,12-dienoyl)-α-D-arabinofuranosyl)-α-D-arabinofuranosyl]-α-D-arabinofuranoside (**25**).* $[\alpha]_D^{25}$ +80.0 (c 1.0, $CHCl_3$); ^{1}H NMR (399.78 MHz, $CDCl_3$) δ 0.88 (t, J = 3.5 Hz, 6H), 1.30 (m, 32H), 1.56 (d, J = 6.7 Hz, 2H), 1.91−2.11 (m, 8H), 2.27 (td, J = 7.8, 4.2 Hz, 4H), 2.77 (t, J = 6.4 Hz, 2H), 3.35 (s, 3H), 3.63 (dd, J = 11.3, 3.1 Hz, 1H), 3.71 (dt, J = 9.1, 2.8 Hz, 3H), 3.85 (dd, J = 11.3, 3.8 Hz, 1H), 3.92 (dd, J = 12.1, 3.5 Hz, 1H), 4.00 (dd, J = 3.2, 1.0 Hz, 1H), 4.02−4.08 (m, 3H), 4.14 (ddq, J = 14.0, 7.0, 2.3 Hz, 6H), 4.18−4.19 (m, 1H), 4.21 (dd, J = 6.1, 2.4 Hz, 2H), 4.23−4.25 (m, 1H), 4.28 (dd, J = 5.5, 1.9 Hz, 1H), 4.40−4.66 (m, 11H), 4.89 (s, 1H), 4.94 (d, J

DOI: 10.1021/acs.joc.5b00964
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= 1.7 Hz, 1H), 5.01 (d, J = 2.5 Hz, 1H), 5.13 (s, 1H), 5.27−5.44 (m, 8H), 7.23−7.34 (m, 25H); ^{13}C NMR (100.53 MHz, $CDCl_3$) δ 14.1, 14.1, 22.5, 22.7, 24.8, 25.6, 27.2(3C), 29.1(2C), 29.1(2C), 29.2, 29.3(2C), 29.3(2C), 29.5, 29.6(2C), 29.7, 29.7, 31.5, 31.9, 34.0, 54.9, 63.4, 63.5, 64.8, 66.6, 71.9, 72.0, 72.2, 72.2, 72.3, 79.0, 79.4, 79.6, 80.0, 80.6, 80.7, 82.3, 82.9, 83.2, 84.3, 86.5, 88.4, 105.7, 106.8, 107.1, 109.1, 127.7(2C), 127.8(2C), 127.8(3C), 127.9(2C), 128.0(2C), 128.1, 128.1, 128.2(3C), 128.2(3C), 128.4(2C), 128.4(2C), 128.42(2C), 128.5(4C), 129.7, 130.0, 130.0, 130.2, 136.9, 137.1, 137.5, 137.7, 137.7, 173.4(2C); IR ($CHCl_3$) 3622, 3031, 2917, 1761, 1546, 1455, 1217, 1104, 699 cm^{-1}; HRMS (TOF) m/z [M + Na]$^+$ calcd for $C_{92}H_{126}NaO_{19}$ 1557.8791, found 1557.8787.

Hexasaccharides (26). Individual resonances could not be determined due to overlapping signals in the anomeric region. However, the ratio of isomers was obtained by taking both the ^{13}C and ^{1}H NMR signals. The integration ratio of -OCH_3 (δ 3.18−3.22 ppm) present at the reducing end showed that the ratio is 0.4:1.0. The anomeric proton resonances were noticed from δ 4.73 to 5.38 ppm with overlapping signals. The ^{13}C NMR spectrum showed that the resonances diagnostic for β-isomer were noticed from δ 99.4 to 100.1 ppm, and those of the α-isomer were noticed from δ 104.7 to 107.2 ppm.

Hexasaccharides (27). Individual resonances could not be determined due to overlapping signals in the anomeric region. However, the ratio of isomers was obtained by taking both the ^{13}C and ^{1}H NMR signals. The anomeric proton resonances were noticed from δ 4.83 to 5.45 ppm with overlapping signals. The ^{13}C NMR spectrum showed that the resonances diagnostic for β-isomer were noticed from δ 100.3 to 101.0 ppm, and those of the α-isomer were noticed from δ 105.7 to 107.0 ppm.

Hexasaccharides (28). Individual resonances could not be determined due to overlapping signals in the anomeric region. However, the ratio of isomers was obtained by taking both the ^{13}C and ^{1}H NMR signals. The integration ratio of -OCH_3 (δ 3.28−3.31 ppm) present at the reducing end showed that the ratio is 0.2:1.0. The anomeric proton resonances were noticed from δ 4.85 to 5.42 ppm with overlapping signals. The ^{13}C NMR spectrum showed that the resonances diagnostic for β-isomer were noticed from δ 99.7 to 100.2 ppm, and those of the α-isomer were noticed from δ 105.0 to 107.2 ppm.

■ ASSOCIATED CONTENT

Supporting Information

. The Supporting Information is available free of charge on the ACS Publications website at DOI: 10.1021/acs.joc.5b00964.

Computational data and copies of ^{1}H, ^{13}C, and DEPT NMR spectra for all compounds (PDF)

Cartesian coordinates for the optimized geometries of the reactants and products (PDF)

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Notes

The authors declare no competing financial interest.

■ ACKNOWLEDGMENTS

M.I. thanks the CSIR New Delhi and G.G. and S.H. thank the DST New Delhi for financial assistance in the form of a Fast Track Young Scientist (G.G.) and Swarna Jayanthi (S.H.) fellowships. The authors thank and acknowledge fruitful discussions with Dr. Harinath Chakrapani (IISER Pune) and Dr. G. Narahari Sastry (IICT Hyderabad).

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DOI: 10.1021/acs.joc.5b00964
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