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Synthesis of C18–C28 ketone fragment of micromonospolide B possessing 1,3-diene and 1,3-anti-diol functionalities

Liang Sun [a], Jinlong Wu [a], Wei-Min Dai [a,b,*]

[a] *Laboratory of Asymmetric Catalysis and Synthesis, Department of Chemistry, Zhejiang University, Hangzhou 310027, China*
[b] *Department of Chemistry, The Hong Kong University of Science and Technology, Clear Water Bay, Kowloon, Hong Kong SAR, China*

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ABSTRACT

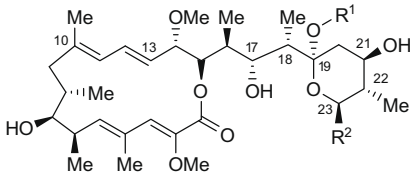
A highly stereocontrolled synthesis of the C18–C28 ketone fragment of the 16-membered plecomacrolide micromonospolide B has been accomplished. The C21–C23 *syn–anti* stereotriad is secured by the *anti*-selective aldol condensation of the ephedrine-derived chiral propionate with (*E*,*E*)-hexa-2,4-dienal and Sharpless asymmetric allylic epoxidation–regioselective reductive epoxide ring opening, respectively. The overall yield of this 14-step sequence is 18.4% and the target C18–C28 ketone was obtained in enantiomerically pure form.

1. Introduction

Micromonospolides A and B **3**, isolated from the fermentation broth filtrate of *Micromonospora* sp.,[1] are the 16-membered plecomacrolides[2] possessing an (*E*,*E*)-1,3-pentadienyl side chain at C23 of the folding hemiacetal ring (Fig. 1). While it is common for most of the 18-membered congeners, concanamycins,[3] TAN-1323,[4] and virustomycin,[5] featuring an (*E*)-1-propenyl substitution at the tetrahydropyran ring, a few other 16-membered plecomacrolides are incorporated with an unsaturated side chain at C23.[2] These are PC-766B[6] and R176502,[7] which are appended with an (*E*,*E*)-1,3-pentadienyl and (*E*,*E*)-1,3-hexadienyl group, respectively. The unsaturated structural motif distinguishes micromonospolides A and B from bafilomycin A_1 **1**[8] in the inhibitory activity against gastrulation of the starfish embryos of *Asterina pectinifera*.[1b] Gastrulation, being one of the fundamental events in embryogenesis, is the first process associated with cellular differentiation.[9] Micromonospolides A and B **3**, and bafilomycin A_1 **1** were reported to deliver the minimum inhibitory concentrations of 0.010, 0.011, and 0.1 μg/mL, respectively. Moreover, the hemiacetal ring was found essential for the inhibitory activity since ca. 100-fold decrease in potency was observed for micromonospolide C, which lacks the tetrahydropyran ring.[1b] Bafilomycin A_1 **1** and concanamycin A[3] have been investigated as vacuolar H^+-ATPase (V-ATPase) inhibitors,[10,11] which are considered promising for the possible treatment of osteoporosis and related diseases.[12] The unique tetraene macrolactone core and the folding hemiacetal subunit, together with its biological function, render bafilomycin A_1 **1** a hot target for chemical synthesis. The research groups of Evans,[13] Toshima,[14] Roush,[15] Hanessin,[16] and Carreira[17] have accomplished the total synthesis of **1**. One of the retrosynthetic bond disconnections is illustrated in Figure 2. Cleavage of the C17–C18 bond according to an aldol condensation provided the macrolactone and the C18–C25 ketone fragments **4** and **5**.[13,14] In our efforts toward the synthesis of 24-demethylbafilomycin A_2 **2** and the related macrolides,[18] we have prepared the ketone intermediate **6**.[19] A highly stereoselective synthesis of the C18–C28 ketone fragment **7** of micromonospolide B **3** by using the *anti*-selective aldol condensation[20] of the chiral propionate (1*R*,2*S*)-**10**[21] with (*E*,*E*)-hexa-2,4-dienal **11** as the key step to secure the C21–C23 *syn–anti* stereotriad is reported herein.[22]

2. Results and discussion

In the total synthesis of concanamycin F, the chiral ketone **8** and aldehyde **9** were employed by Toshima[23] and Paterson,[24] respectively. The chiral ketone **8** was assembled by using the *anti*-selective crotylation of (*E*)-crotonaldehyde with Brown's chiral (*E*)-crot-



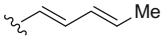
bafilomycin A_1 **1**: R^1 = H, R^2 = *i*-Pr
24-demethylbafilomycin A_2 **2**: R^1 = Me, R^2 = Et
micromonospolide B **3**: R^1 = H, R^2= 

Figure 1. Structures of the 16-membered plecomacrolides **1**–**3**.

* Corresponding author. Tel./fax: +86 571 87953128 (ZJU).
E-mail address: chdai@zju.edu.cn (W.-M. Dai).

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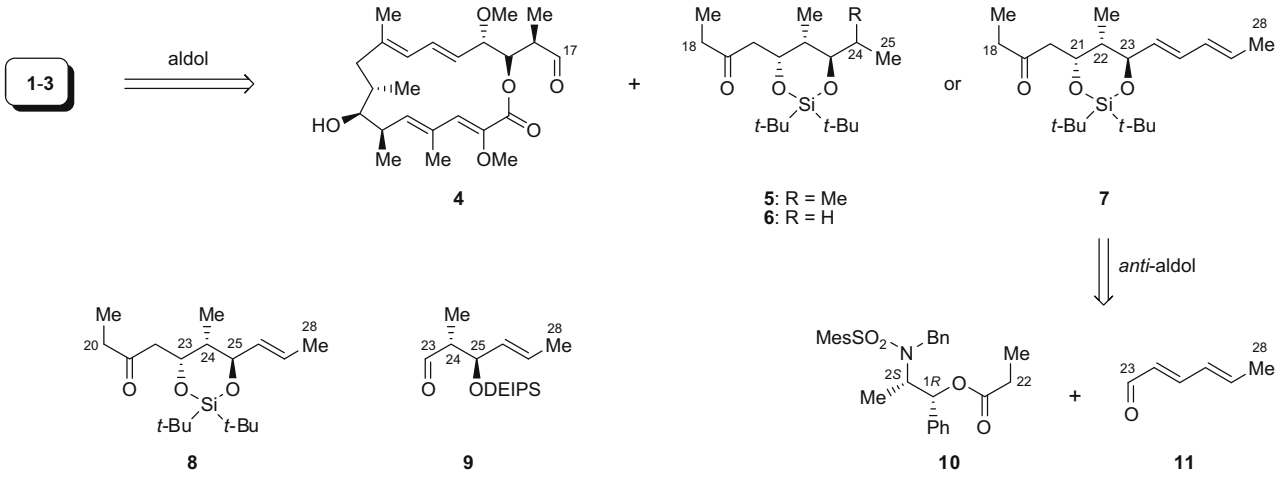
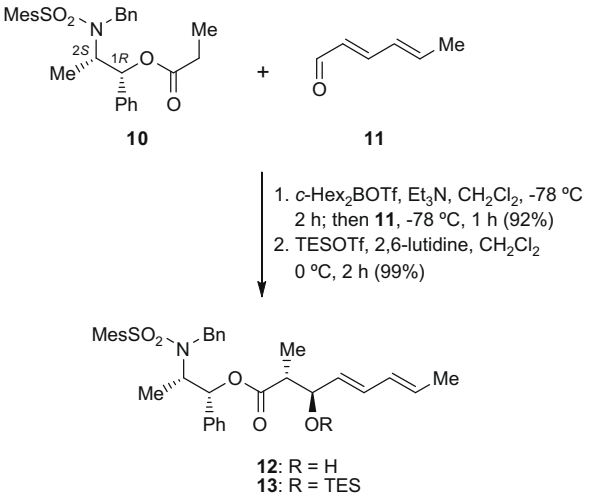


Figure 2. Retro-synthetic disconnection of C17–C18 bond in **1**–**3**, leading to the macrolactone aldehyde **4** and the ketone fragments **5**–**7**.

yldiisopinocamphenylborane.[25] After conversion of the crotylation product into the PMB-protected aldehyde similar to **9**, a Mukaiyama aldol reaction[26] was used to secure the C23–C24 *syn* stereochemistry by formation of the Cram product. Alternatively, the chiral aldehyde **9** was prepared via the *anti*-selective aldol reaction of an (*S*)-lactate-derived ethyl ketone with (*E*)-crotonaldehyde in the presence of *c*-Hex_2BCl and Me_2NEt.[27] In our previous total synthesis,[28] we used the chiral propionate **10** and its antipode for *anti*-selective aldol reactions with α- and β-substituted chiral aldehydes. We envisaged that the C22–C23 *anti* aldol moiety in the ketone **7** might be assembled from **10** and (*E*,*E*)-hexa-2,4-dienal **11** as shown in Figure 2. Although aldol reactions of chiral boron enolates with 2,4-dienals are not often seen, we found a few examples in the literature. In the total synthesis of (+)-altohyrtin A/spongistatin 1, Paterson et al. used the reaction of a chiral methyl ketone-derived boron enolate with (*E*)-4-chloropenta-2,4-dienal to obtain a chiral 3-hydroxy-4,6-dienone.[29] Shioiri reported the *anti*-selective aldol reaction between the enantiomer of **10** and the aldehyde prepared in situ from (*E*,*E*)-2,4,6,6-tetramethyl-2,4-heptadienol in the total synthesis of antillatoxin.[30] With these precedent aldol reactions of 2,4-dienals, we were confident about the *anti*-selective aldol reaction of **10** with **11**. We needed to select mild reaction conditions for the post-aldol transformations of the intermediates, which possess the acid-/base-labile 2,4-dienol functionality.

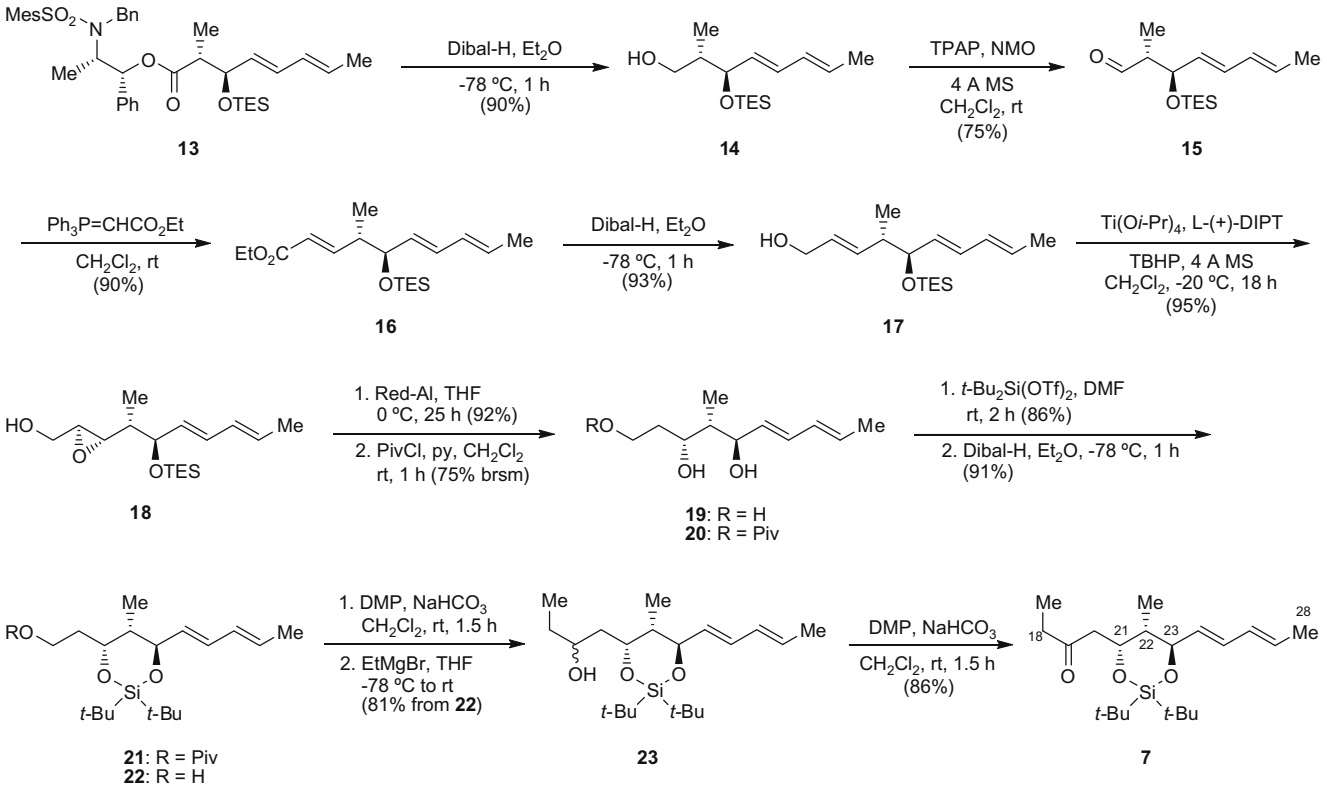


Scheme 1. *Anti*-selective aldol reaction of **10** with **11**.

The *anti*-selective aldol reaction of **10** with **11** was carried out according to the reported protocol (Scheme 1).[21b] Treatment of **10** with *c*-Hex_2BOTf–Et_3N at −78 °C gave the (*E*)-boron enolate, which reacted with **11** to afford the *anti*-aldol **12** in 92% isolated yield and in high diastereoselectivity (>98:2)[21b] as determined by ^1H NMR spectroscopy. Protection of the hydroxyl group in **12** with TESOTf-2,6-lutidine furnished the TES ether **13** in 99% yield.

In order to install the C21 stereogenic center in the target ketone **7**, the TES ether **13** was transformed into the allyl alcohol **17** (Scheme 2). Reduction of **13** using Dibal-H at −78 °C formed the alcohol **14** (90%) which was oxidized to the aldehyde **15** in 75% yield by TPAP–NMO[31] in the presence of 4 Å molecular sieves. This oxidation reaction might be done by using Dess–Martin periodinane (DMP)[32] as in the oxidation of alcohol **22** (vide infra) but it was not tried at the time. The aldehyde **15** was subjected to the Wittig olefination with the ylide $Ph_3P{=}CHCO_2Et$ at room temperature to provide the α,β-unsaturated ester **16** (90%), which was reduced to the allyl alcohol **17** (Dibal-H, −78 °C) in 93% yield. Asymmetric allylic epoxidation of **17** was performed by using $Ti(Oi\text{-}Pr)_4$ and L-(+)-DIPT as the chiral catalyst precursors in the presence of 4 Å molecular sieves at −20 °C.[19] The epoxide **18** was obtained in 95% yield and in high diastereoselectivity (>99:1) as checked by ^1H NMR spectroscopy. The 2,4-dienol silyl ether moiety in **17** survived from the Lewis acidic conditions and no epoxidation reaction occurred on the 1,3-diene functionality. With the chiral hydroxymethyl epoxide **18** in hand, a regioselective reductive epoxide ring opening reaction was carried out by using Red-Al in THF at 0 °C to produce, with concomitant removal of the TES silyl ether,[19] the triol **19** (92%) possessing the desired C21–C23 *syn*–*anti* stereotriad. The sample of **19** was contaminated with an inseparable regioisomer formed during epoxide ring-opening and the regioselectivity was estimated to be 91:9 by ^1H NMR spectroscopy. Fortunately, the minor regioisomer could be separated in the subsequent transformations.

The next task of the synthesis centered on differentiation between the three hydroxyl groups in **19** and installation of the ethyl ketone moiety. This was achieved by first controlled acylation of the primary hydroxyl group with 1 equiv of pivaloyl chloride and pyridine at room temperature for 1 h to give the diol **20** (60%) along with recovered **19** (20%) and some undesired pivalates. The latter could be converted back to the triol **19** by Dibal-H reduction. Treatment of **20** with $t\text{-}Bu_2Si(OTf)_2$ in DMF gave the cyclic silyl ether **21** (86%), which was transformed into the alcohol **22** upon reduction by Dibal-H in 91% yield. Then, the ethyl ketone moiety was installed by DMP oxidation of **22** to the corresponding alde-



Scheme 2. Synthesis of the target ketone **7** from the TES-protected aldol **13**.

hyde followed by addition of EtMgBr, resulting in formation of the diastereomeric alcohols **23** in 81% overall yield from **22**. Finally, DMP oxidation of **23** furnished the ketone **7** in 86% yield. The specific rotation of **7** was $[\alpha]_D^{20} = +97.0$ (*c* 0.35, $CHCl_3$), which are close to $[\alpha]_D^{20} = +85.2$ (*c* 0.89, $CHCl_3$),[14c] $[\alpha]_D^{20} = +80.2$ (*c* 1.75, $CHCl_3$),[19] and $[\alpha]_D^{23} = +101.6$ (*c* 0.50, $CHCl_3$)[23] reported for **5**, **6**, and **8**, respectively.

3. Conclusion

In summary, we have accomplished an efficient synthesis of the C18–C28 fragment **7** of micromonospolide B, which features an acid-labile 3,5-dihydroxy-6,8-dienone structural unit. The C21–C23 *syn–anti* stereotriad was assembled by an *anti*-selective aldol reaction of the chiral propionate **10** with (*E*,*E*)-hexa-2,4-dienal **11** and a sequence of Sharpless asymmetric allylic epoxidation-regioselective reductive epoxide ring opening. Our results are not only of interest for the synthesis of micromonospolide B, but are also applicable to the synthesis of the advanced intermediates which are incorporated with a chiral 3,5-dihydroxy-6,8-dienone subunit.

4. Experimental

^1H and ^{13}C NMR spectra were recorded in acetone-d_6 or $CDCl_3$ (400 or 500 MHz for ^1H and 100 or 125 MHz for ^{13}C, respectively) with residual acetone or $CHCl_3$ as the internal reference, respectively. IR spectra were taken on a FT-IR spectrophotometer. Mass spectra (MS) and high-resolution mass spectra (HRMS) were measured by the +ESI method. All reactions were carried out under a nitrogen atmosphere and monitored by thin-layer chromatography on Silica Gel plates 60 F-254 pre-coated on glass using UV light, or 7% ethanolic phosphomolybdic acid and heating as the visualizing methods. Silica Gel 60 (particle size 0.040–0.063 mm) and petroleum ether (PE, bp 60–90 °C) were used for flash column chromatography. Yields refer to chromatographically and spectroscopically (^1H NMR) homogeneous materials. Anhydrous Et_2O and THF were freshly distilled over Na and benzophenone before use. Anhydrous CH_2Cl_2 and DMF were distilled over CaH_2 under normal and reduced pressure, respectively. Et_3N and pyridine were distilled before use. All reagents were obtained commercially and used as received.

4.1. (1′*R*,2′*S*)-2-[*N*-Benzyl-*N*-(2″,4″,6″-trimethylbenzenesulfonyl)]amino-1-phenyl-1-propyl (2*R*,3*R*,4*E*,6*E*)-3-hydroxy-2-methylocta-4,6-dienoate 12

A flame-dried 500 mL round-bottomed flask was charged with (1*R*,2*S*)-**10** (4.80 g, 10.0 mmol) and dry CH_2Cl_2 (50 mL) under a nitrogen atmosphere followed by Et_3N (3.40 mL, 24.0 mmol). The resultant solution was cooled at −78 °C and a solution of dicyclohexylboron triflate[21b] (1.0 M in hexane, 22 mL, 22.0 mmol) was added dropwise over 20 min followed by stirring at −78 °C for 2 h. (*E*,*E*)-Hexa-2,4-dienal (1.92 g, 20.0 mmol) was added dropwise. The resultant mixture was stirred at −78 °C for 1 h and allowed to warm to room temperature over 1 h. The reaction was quenched with pH 7 buffer (40 mL). To the reaction mixture was added carefully MeOH (200 mL) and 30% hydrogen peroxide (20 mL) followed by stirring vigorously overnight at room temperature. The resultant mixture was concentrated, and the residue was partitioned between water (100 mL) and CH_2Cl_2 (200 mL). The aqueous layer was extracted with CH_2Cl_2 (150 mL × 2) and the combined organic layers were washed with brine, dried over anhydrous Na_2SO_4, filtered, and concentrated under reduced pressure. The residue was purified by column chromatography (silica gel, 10% EtOAc in PE) to give 5.20 g (90%) of the *anti*-aldol **12** as an amorphous solid.

$[\alpha]_D^{20} = +39.2$ (*c* 1.05, $CHCl_3$); $R_f = 0.19$ (10% EtOAc in PE); IR ($CHCl_3$) 3512 (br), 2981, 2938, 1738, 1604, 1497, 1457, 1318, 1152 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) 7.32 (d, *J* = 7.6 Hz, 2H), 7.24–7.16 (m, 6H), 6.89 (s, 2H), 6.84 (d, *J* = 6.4 Hz, 2H), 6.20 (dd, *J* = 15.2, 10.4 Hz, 1H), 6.02 (ddd, *J* = 14.8, 10.8, 1.6 Hz, 1H), 5.81 (d, *J* = 4.0 Hz, 1H), 5.72 (dq, *J* = 14.4, 7.2 Hz, 1H), 5.49 (dd, *J* = 14.8, 7.2 Hz, 1H), 4.80 and 4.57 (ABq, *J* = 16.4 Hz, 2H), 4.18 (dd, *J* = 7.6, 7.6 Hz, 1H), 4.08 (qd, *J* = 7.2, 4.4 Hz, 1H), 2.57–2.53 (m, 1H), 2.50 (s, 6H), 2.29 (s, 3H), 1.76 (d, *J* = 6.8 Hz, 3H), 1.15 (d, *J* = 7.2 Hz, 3H), 1.08 (d, *J* = 7.2 Hz, 3H) (OH is not seen); ^{13}C NMR (100 MHz, $CDCl_3$) 174.2, 142.5, 140.2 (2×), 138.7, 138.2, 133.4, 133.1, 132.1 (2×), 130.9, 130.4, 129.6, 128.4 (2×), 128.3 (2×), 127.9, 127.6 (2×), 127.1, 125.8 (2×), 78.3, 74.5, 56.8, 48.2, 45.8, 22.9 (2×), 20.9, 18.1, 14.0, 13.3; ^{13}C NMR (100 MHz, acetone-d_6) 174.5, 143.8, 141.1 (2×), 140.8, 140.1, 135.2, 133.2, 133.2 (2×), 132.3, 132.1, 130.5, 129.4 (2×), 129.1 (2×), 128.6, 128.6 (2×), 127.8, 126.6 (2×), 78.9, 75.4, 58.1, 49.2, 47.4, 23.3 (2×), 21.0, 18.3, 14.1, 13.7; MS (+ESI) *m/z* 598 ($M+Na^+$, 100); HRMS (+ESI) calcd for $C_{34}H_{41}NO_5SNa$ ($M+Na^+$): 598.2601; found, 598.2600.

4.2. (1′*R*,2′*S*)-2-[*N*-Benzyl-*N*-(2″,4″,6″-trimethylbenzenesulfonyl)]amino-1-phenyl-1-propyl (2*R*,3*R*,4*E*,6*E*)-3-(triethylsilyl)-oxy-2-methylocta-4,6-dienoate 13

To a solution of the *anti*-aldol **12** (260.0 mg, 0.45 mmol) in dry CH_2Cl_2 (5 mL) cooled at 0 °C was added 2,6-lutidine (90 μL, 0.72 mmol) followed by dropwise addition of TESOTf (0.13 mL, 0.54 mmol) under a nitrogen atmosphere. The resultant mixture was stirred for 2 h at 0 °C and the reaction was then quenched with saturated aqueous $NaHCO_3$ (5 mL). The reaction mixture was diluted with Et_2O (10 mL) and the aqueous layer was extracted with Et_2O (10 mL × 2). The combined organic layers were washed with brine, dried over anhydrous Na_2SO_4, filtered, and concentrated under reduced pressure. The residue was purified by column chromatography (silica gel, 5% EtOAc in PE) to give 309.0 mg (99%) of the TES ether **13** as a colorless oil. $[\alpha]_D^{20} = +45.4$ (*c* 5.50, $CHCl_3$); $R_f = 0.59$ (10% EtOAc in PE); IR (film) 2954, 2935, 2876, 1744, 1456, 1326, 1154 cm^{-1}; ^1H NMR (500 MHz, acetone-d_6) 7.47 (d, *J* = 7.0 Hz, 2H), 7.31–7.17 (m, 6H), 7.04 (s, 2H), 6.85 (d, *J* = 7.0 Hz, 2H), 6.19 (dd, *J* = 15.5, 11.0 Hz, 1H), 6.05 (dd, *J* = 14.5, 11.0 Hz, 1H), 5.80 (d, *J* = 4.5 Hz, 1H), 5.71 (dq, *J* = 14.0, 7.0 Hz, 1H), 5.47 (dd, *J* = 15.5, 7.5 Hz, 1H), 4.93 and 4.58 (ABq, *J* = 16.5 Hz, 2H), 4.37 (dd, *J* = 7.5, 7.5 Hz, 1H), 4.00 (dq, *J* = 7.0, 4.5 Hz, 1H), 2.62 (dq, *J* = 7.0, 7.0 Hz, 1H), 2.49 (s, 6H), 2.34 (s, 3H), 1.73 (d, *J* = 7.0 Hz, 3H), 1.10 (d, *J* = 7.0 Hz, 3H), 0.97 (d, *J* = 7.0 Hz, 3H), 0.93 (t, *J* = 8.0 Hz, 9H), 0.58 (q, *J* = 8.0 Hz, 6H); ^{13}C NMR (100 MHz, acetone-d_6) 173.4, 143.7, 141.0 (2×), 140.3, 139.8, 134.6, 133.6, 133.2 (2×), 131.8, 131.4, 130.9, 129.3 (2×), 129.2 (2×), 128.9 (2×), 128.7, 128.1, 126.8 (2×), 78.8, 76.2, 58.0, 49.1, 48.0, 23.3 (2×), 21.0, 18.4, 14.3, 13.5, 7.3 (3×), 5.6 (3×); MS (+ESI) *m/z* 1396 (2 $M+NH_4^+$, 10), 791 ($M+H^+ + Et_3N$, 100), 712 ($M+Na^+$, 3); HRMS (+ESI) calcd for $C_{40}H_{55}NO_5SSiNa$ ($M+Na^+$): 712.3466; found, 712.3462.

4.3. (2*S*,3*R*,4*E*,6*E*)-2-Methyl-3-((triethylsilyl)oxy)octa-4,6-dien-1-ol 14

To a solution of the TES ether **13** (1.14 g, 1.65 mmol) in dry Et_2O (10 mL) cooled at −78 °C was added Dibal-H (1.0 M in hexane, 3.63 mL, 3.63 mmol) under a nitrogen atmosphere followed by stirring for 1 h at the same temperature. The reaction mixture was quenched by carefully adding saturated aqueous Na_2CO_3 (10 mL) and the resultant mixture was diluted with Et_2O (5 mL) with vigorous stirring till the mixture became clear. The organic layer was separated and the aqueous layer was extracted with Et_2O (10 mL × 2). The combined organic layer was washed with brine, dried over anhydrous Na_2SO_4, filtered, and concentrated under reduced pressure. The residue was purified by column chromatography (silica gel, 5% EtOAc in PE) to give 400.0 mg (90%) of the alcohol **14** as a colorless oil. $[\alpha]_D^{20} = -5.0$ (*c* 1.50, $CHCl_3$); $R_f = 0.50$ (10% EtOAc in PE); IR (film) 3416 (br), 2957, 2912, 2876, 1458, 1239, 1062, 1005 cm^{-1}; ^1H NMR (400 MHz, acetone-d_6) 6.16 (dd, *J* = 14.8, 10.8 Hz, 1H), 6.07 (ddq, *J* = 14.4, 10.4, 1.6 Hz, 1H), 5.68 (dq, *J* = 13.6, 6.8 Hz, 1H), 5.54 (dd, *J* = 14.8, 7.6 Hz, 1H), 4.23 (dd, *J* = 6.8, 6.8 Hz, 1H), 3.57–3.42 (m, 3H), 1.78–1.75 (m, 1H), 1.73 (d, *J* = 6.4 Hz, 3H), 0.95 (t, *J* = 8.0 Hz, 9H), 0.83 (d, *J* = 7.2 Hz, 3H), 0.60 (q, *J* = 8.0 Hz, 6H); ^{13}C NMR (100 MHz, acetone-d_6) 132.9, 132.3, 132.1, 129.6, 76.3, 65.1, 43.7, 18.3, 13.0, 7.3 (3×), 5.7 (3×); MS (+ESI) *m/z* 563 (2 $M+Na^+$, 100), 293 ($M+Na^+$, 65); HRMS (+ESI) calcd for $C_{15}H_{30}O_2SiNa$ ($M+Na^+$): 293.1907; found, 293.1899.

4.4. (2*R*,3*R*,4*E*,6*E*)-2-Methyl-3-((triethylsilyl)oxy)octa-4,6-dienal 15

In an oven-dried 250 mL round-bottomed flask were placed powdered 4 Å molecular sieves (2.49 g), TPAP (106.0 mg, 0.17 mmol), and NMO (1.34 g, 11.1 mmol) rapidly under a nitrogen atmosphere followed by dropwise addition of the alcohol **14** (1.34 g, 4.97 mmol) in dry CH_2Cl_2 (50 mL). The resultant mixture was stirred at room temperature overnight and then the reaction mixture was filtrated through a pad of Celite with washing by CH_2Cl_2. The combined filtrate was concentrated under reduced pressure and the residue was purified by column chromatography (silica gel, 5% EtOAc in PE) to give 1.00 g (75%) of the aldehyde **15** as a pale yellowish oil. $[\alpha]_D^{20} = -21.0$ (*c* 1.25, $CHCl_3$); $R_f = 0.61$ (5% EtOAc in PE); IR (film) 2956, 2913, 2877, 1729, 1458, 1239, 1114, 1061, 1005 cm^{-1}; ^1H NMR (400 MHz, acetone-d_6) 9.72 (d, *J* = 2.4 Hz, 1H), 6.25 (dd, *J* = 15.2, 10.0 Hz, 1H), 6.09 (ddq, *J* = 14.8, 10.8, 1.2 Hz, 1H), 5.75 (dq, *J* = 13.6, 7.2 Hz, 1H), 5.58 (dd, *J* = 15.2, 8.0 Hz, 1H), 4.47 (dd, *J* = 7.2, 7.2 Hz, 1H), 2.48 (qdd, *J* = 6.8, 6.8, 2.4 Hz, 1H), 1.74 (dd, *J* = 6.8, 1.2 Hz, 3H), 0.97 (d, *J* = 6.8 Hz, 3H), 0.94 (t, *J* = 8.0 Hz, 9H), 0.60 (q, *J* = 7.6 Hz, 6H); ^{13}C NMR (100 MHz, acetone-d_6) 204.2, 133.0, 132.0, 131.8, 130.9, 75.7, 53.7, 18.4, 10.8, 7.2 (3×), 5.7 (3×); MS (+ESI) *m/z* 291 ($M+Na^+$, 100); HRMS (+ESI) calcd for $C_{15}H_{28}O_2SiNa$ ($M+Na^+$): 291.1751; found, 291.1751.

4.5. (2*E*,4*S*,5*R*,6*E*,8*E*)-Ethyl 4-methyl-5-((triethylsilyl)oxy)deca-2,6,8-trienoate 16

To a solution of the aldehyde **15** (1.00 g, 3.73 mmol) in dry CH_2Cl_2 (30 mL) was added $Ph_3P{=}CHCO_2Et$ (2.60 g, 7.46 mmol) followed by stirring overnight at room temperature. The reaction mixture was concentrated under reduced pressure and the residue was purified by column chromatography (silica gel, 5% EtOAc in PE) to give 1.13 g (90%) of the α,β-unsaturated ester **16** as a pale yellowish oil. $[\alpha]_D^{20} = -4.3$ (*c* 1.30, $CHCl_3$); $R_f = 0.64$ (5% EtOAc in PE); IR (film) 2957, 2913, 2877, 1722, 1653, 1458, 1367, 1269, 1180 cm^{-1}; ^1H NMR (400 MHz, acetone-d_6) 6.96 (dd, *J* = 16.0, 8.0 Hz, 1H), 6.19 (dd, *J* = 15.2, 10.8 Hz, 1H), 6.08 (ddq, *J* = 14.8, 10.8, 1.6 Hz, 1H), 5.80 (dd, *J* = 16.0, 1.2 Hz, 1H), 5.69 (dq, *J* = 13.6, 7.2 Hz, 1H), 5.51 (dd, *J* = 14.8, 7.2 Hz, 1H), 4.13 (q, *J* = 7.2 Hz, 2H), 4.11 (dd, *J* = 6.4, 6.4 Hz, 1H), 2.44 (dqd, *J* = 13.6, 6.8, 1.2 Hz, 1H), 1.73 (dd, *J* = 6.8, 1.6 Hz, 3H), 1.23 (t, *J* = 7.2 Hz, 3H), 1.02 (d, *J* = 7.2 Hz, 3H), 0.94 (t, *J* = 7.2 Hz, 9H), 0.59 (q, *J* = 7.2 Hz, 6H); ^{13}C NMR (100 MHz, acetone-d_6) 166.7, 151.9, 132.7, 132.6, 132.0, 130.3, 122.2, 77.6, 60.5, 44.6, 18.3, 15.8, 14.7, 7.3 (3×), 5.6 (3×); MS (+ESI) *m/z* 361 ($M+Na^+$, 100); HRMS (+ESI) calcd for $C_{19}H_{34}O_3SiNa$ ($M+Na^+$): 361.2169; found, 31.2159.

4.6. (2*E*,4*S*,5*R*,6*E*,8*E*)-4-Methyl-5-((triethylsilyl)oxy)deca-2,6,8-trien-1-ol 17

To a solution of the ester **16** (1.13 g, 3.34 mmol) in dry Et_2O (30 mL) cooled at −78 °C was added Dibal-H (1.0 M in hexane, 7.35 mL, 7.35 mmol) under a nitrogen atmosphere followed by stirring for 1 h at the same temperature. The reaction was quenched by carefully adding saturated aqueous Na_2CO_3 (10 mL) and the resultant mixture was diluted with Et_2O (20 mL) with vigorous stirring till the mixture became clear. The organic layer was separated and the aqueous layer was extracted with Et_2O (30 mL × 2). The combined organic layers were washed with brine, dried over anhydrous Na_2SO_4, filtered, and concentrated under reduced pressure. The residue was purified by column chromatography (silica gel, 5% EtOAc in PE) to give 922.0 mg (93%) of the allyl alcohol **17** as a colorless oil. $[\alpha]_D^{20} = +8.7$ (*c* 1.00, $CHCl_3$); $R_f = 0.23$ (5% EtOAc in PE); IR (film) 3332 (br), 2957, 2912, 2876, 1458, 1068, 1008 cm^{-1}; ^1H NMR (400 MHz, acetone-d_6) 6.14 (dd, *J* = 14.8, 10.4 Hz, 1H), 6.05 (ddq, *J* = 14.8, 10.8, 1.6 Hz, 1H), 5.71–5.55 (m, 3H), 5.52 (dd, *J* = 14.8, 6.8 Hz, 1H), 4.05 (dd, *J* = 6.4, 6.4 Hz, 1H), 4.02 (dd, *J* = 5.6, 4.8 Hz, 2H), 3.62 (t, *J* = 5.6 Hz, 1H, O*H*), 2.27 (dqd, *J* = 13.6, 6.8, 1.2 Hz, 1H), 1.72 (dd, *J* = 7.2, 1.2 Hz, 3H), 0.95 (t, *J* = 7.6 Hz, 9H), 0.95 (d, *J* = 7.2 Hz, 3H), 0.59 (q, *J* = 7.6 Hz, 6H); ^{13}C NMR (100 MHz, acetone-d_6) 133.5, 132.9, 132.2, 131.8, 131.5, 129.5, 77.9, 63.5, 44.6, 18.3, 16.0, 7.3 (3×), 5.7 (3×); MS (+ESI) *m/z* 319 (M+Na^+, 100); HRMS (+ESI) calcd for $C_{17}H_{32}O_2SiNa$ (M+Na^+): 319.2064; found, 319.2055.

4.7. (2*S*,3*S*,4*S*,5*R*,6*E*,8*E*)-2,3-Epoxy-4-methyl-5-((triethylsilyl)oxy)-deca-6,8-dien-1-ol 18

To a suspension of anhydrous powdered 4 Å molecular sieves (1.40 g) in dry CH_2Cl_2 (20 mL) was added L-(+)-diisopropyl tartrate (89.2 μL, 0.42 mmol). The mixture was cooled at −20 °C and Ti(O*i*-Pr)$_4$ (85.5 μL, 0.28 mmol) was added via a syringe under a nitrogen atmosphere. After stirring for 10 min at −20 °C, *tert*-butyl hydroperoxide (5.0–6.0 M in decane, 3.35 mL, 16.75 mmol) was added dropwise. The resultant mixture was stirred for 30 min and then a solution of the allyl alcohol **17** (827.0 mg, 2.79 mmol) in dry CH_2Cl_2 (20 mL) was added dropwise over a period of 10 min. After stirring at −20 °C for 18 h, the reaction was quenched by adding a minimal amount of H_2O (2 mL). The resultant mixture was allowed to warm to room temperature, diluted with EtOAc with vigorous stirring for 20 min, and filtered through a pad of Celite. Then 30% aqueous NaOH (50 mL in brine) was added to the filtrate followed by stirring for 4 h. The organic layer was separated, dried over anhydrous Na_2SO_4, filtered, and concentrated under reduced pressure. The residue was purified by column chromatography (silica gel, 20% EtOAc in PE) to give 828.0 mg (95%) of the epoxide **18** as a colorless oil. $[\alpha]_D^{20} = -19.0$ (*c* 0.70, $CHCl_3$); $R_f = 0.21$ (5% EtOAc in PE); IR (film) 3436 (br), 2957, 2935, 2876, 1458, 1239, 1104, 1059, 1006 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) 6.09 (dd, *J* = 15.2, 10.8 Hz, 1H), 6.02 (ddq, *J* = 14.0, 10.4, 1.2 Hz, 1H), 5.69 (dq, *J* = 13.6, 7.2 Hz, 1H), 5.46 (dd, *J* = 14.4, 7.2 Hz, 1H), 4.02 (dd, *J* = 7.2, 7.2 Hz, 1H), 3.90 (ddd, *J* = 12.4, 5.6, 2.8 Hz, 1H), 3.59 (ddd,, *J* = 12.0 7.2, 4.4 Hz, 1H), 2.99 (ddd, *J* = 4.4, 2.8, 2.8 Hz, 1H), 2.89 (dd, *J* = 7.6, 2.4 Hz, 1H), 1.76 (dd, *J* = 6.8, 1.2 Hz, 3H), 1.60 (dd, *J* = 7.6, 5.6 Hz, 1H, O*H*), 1.43 (ddq, *J* = 7.2, 7.2, 7.2 Hz, 1H), 0.96 (d, *J* = 6.8 Hz, 3H), 0.94 (t, *J* = 8.0 Hz, 9H), 0.57 (q, *J* = 8.0 Hz, 6H); ^{13}C NMR (100 MHz, $CDCl_3$) 132.0, 131.3, 130.7, 129.7, 76.0, 61.8, 59.0, 58.1, 42.7, 18.1, 13.3, 6.8 (3×), 5.0 (3×); MS (+ESI) *m/z* 335 (M+Na^+, 100); HRMS (+ESI) calcd for $C_{17}H_{32}O_3SiNa$ (M+Na^+): 335.2013; found, 335.2010.

4.8. (3*R*,4*R*,5*R*,6*E*,8*E*)-4-Methyldeca-6,8-diene-1,3,5-triol 19

To a solution of the epoxide **18** (600.0 mg, 1.92 mmol) in dry THF (20 mL) cooled at 0 °C was added Red-Al (65+ wt %, 2.4 mL, 7.7 mmol) dropwise. The resultant mixture was stirred at 0 °C for 25 h followed by quenching with saturated aqueous sodium potassium tartrate (Rochelle's salt) carefully. Diethyl ether (20 mL) was added and the mixture was allowed to warm to room temperature. The organic layer was separated and the aqueous layer was extracted with Et_2O (20 mL × 3). The combined organic layers were washed with brine, dried over anhydrous Na_2SO_4, filtered, and concentrated under reduced pressure. The residue was purified by column chromatography (silica gel, 1% MeOH in CH_2Cl_2) to give 354.0 mg (92% as a 91:9 inseparable mixture of two regioisomers) of the triol **19** as a colorless oil. $[\alpha]_D^{20} = +5.5$ (*c* 0.70, $CHCl_3$); $R_f = 0.50$ (10% MeOH in CH_2Cl_2); IR (film) 3418 (br), 2967, 2919, 2871, 1456, 1371, 1250, 1054 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) 6.20 (dd, *J* = 15.6, 10.8 Hz, 1H), 6.05 (ddq, *J* = 14.8, 104, 1.6 Hz, 1H), 5.72 (dq, *J* = 13.6, 6.4 Hz, 1H), 5.57 (dd, *J* = 14.8,7.2 Hz, 1H), 4.12 (td, *J* = 7.2, 2.0 Hz, 2H), 3.90–3.80 (m, 2H), 3.30–2.50 (br s, 3H, O*H*), 1.91–1.80 (m, 1H), 1.75 (d, *J* = 6.4 Hz, 3H), 1.72–1.65 (m, 1H), 1.57–1.50 (m, 1H), 0.89 (d, *J* = 7.2 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) 132.0, 132.0, 130.7, 130.3, 76.5, 73.8, 62.4, 42.9, 34.6, 18.1, 12.0; HRMS (+ESI) calcd for $C_{11}H_{20}O_3Na$ (M+Na^+): 223.1305; found, 223.1303.

4.9. (3*R*,4*R*,5*R*,6*E*,8*E*)-3,5-Dihydroxy-4-methyldeca-6,8-dien-1-yl trimetylacetate 20

To a solution of the triol **19** (260.0 mg, 1.30 mmol) in CH_2Cl_2 (8 mL) at 0 °C were added dropwise pyridine (156 μL, 1.95 mmol) and trimethylacetyl chloride (160 μL, 1.30 mmol). The resultant mixture was stirred for 1 h at the same temperature followed by quenching with saturated aqueous NH_4Cl. The organic layer was separated and the aqueous layer was extracted with CH_2Cl_2 (10 mL × 3). The combined organic layers were washed with brine, dried over anhydrous Na_2SO_4, filtered, and concentrated under reduced pressure. The residue was purified by column chromatography (silica gel, 1% MeOH in CH_2Cl_2) to give 216.0 mg (60%) of the mono-pivalate **20**, along with 20% recovered starting **19** and other pivalates, as a colorless oil. $[\alpha]_D^{20} = +27.4$ (*c* 0.45, $CHCl_3$); $R_f = 0.54$ (5% MeOH in CH_2Cl_2); IR (film) 3396 (br), 2971, 2935, 2907, 1729, 1481, 1461, 1287, 1164 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) 6.23 (dd, *J* = 15.2, 10.4 Hz, 1H), 6.04 (ddq, *J* = 14.4, 10.4, 1.6 Hz, 1H), 5.72 (dq, *J* = 13.6, 7.2 Hz, 1H), 5.56 (dd, *J* = 14.8, 6.8 Hz, 1H), 4.34 (ddd, *J* = 11.2, 9.2, 5.2 Hz, 1H), 4.19–4.13 (m, 2H), 3.99–3.93 (m, 1H), 3.02 (d, *J* = 4.8 Hz, 1H, O*H*), 2.55 (d, *J* = 4.0 Hz, 1H, O*H*), 1.87–1.80 (m, 1H), 1.76 (d, *J* = 6.4 Hz, 3H), 1.73–1.65 (m, 2H), 1.19 (s, 9H), 0.94 (d, *J* = 7.2 Hz, 3H); ^{13}C NMR (100 MHz, acetone-d_6) 178.5, 134.7, 132.4, 131.5, 129.3, 76.1, 68.9, 62.7, 44.1, 39.4, 34.5, 27.6 (3×), 18.3, 11.4; MS (+ESI) *m/z* 307 (M+Na^+, 100); HRMS (+ESI) calcd for $C_{16}H_{28}O_4Na$ (M+Na^+): 307.1880; found, 307.1873.

4.10. 2-{(4′*R*,5′*S*,6′*R*)-2′,2′-Di-*tert*-butyl-5′-methyl-6′-[(1″*E*,3″*E*)-penta-1″,3″-dienyl]-1′,3′-dioxa-2′-silacyclohex-4′-yl}ethanol 22

To a solution of the diol **20** (276.0 mg, 0.97 mmol) in dry DMF (10 mL) at 0 °C was added dropwise *t*-$Bu_2Si(OTf)_2$ (0.5 mL, 1.48 mmol). The resultant mixture was stirred for 2 h at room temperature followed by quenching with ice-cold water (10 mL). The reaction mixture was extracted with EtOAc (10 mL × 3) and the combined organic layers were washed with brine, dried over anhydrous Na_2SO_4, filtered, and concentrated under reduced pressure. The residue was purified by column chromatography (silica gel,

2% EtOAc in PE) to give 356.0 mg (86%) of the cyclic silyl ether **21** as a colorless oil.

To a solution of the above silyl ether **21** (342.0 mg, 0.81 mmol) in dry CH_2Cl_2 (8 mL) cooled at −78 °C was added Dibal-H (1 M in toluene, 1.8 mL, 1.8 mmol) under a nitrogen atmosphere followed by stirring for 1 h at the same temperature. The reaction was quenched with MeOH (2.0 mL), and then saturated aqueous sodium potassium tartrate (Rochelle's salt) (20 mL) and Et_2O (20 mL) were added with vigorous stirring till the mixture became clear. The organic layer was separated and the aqueous layer was extracted with Et_2O (20 mL × 2). The combined organic layers were washed with brine, dried over anhydrous Na_2SO_4, filtered, and concentrated under reduced pressure. The residue was purified by column chromatography (silica gel, 5% EtOAc in PE) to give 248.0 mg (91%) of the alcohol **22** as a colorless oil. $[\alpha]_D^{20} = +101.3$ (*c* 0.40, $CHCl_3$); R_f = 0.16 (10% EtOAc in PE); IR (film) 3378 (br), 2967, 2934, 2859, 1474, 1134, 1059 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) 6.20 (dd, *J* = 14.8, 10.4 Hz, 1H), 6.06 (ddq, *J* = 14.8, 10.4, 1.2 Hz, 1H), 5.71 (dq, *J* = 13.2, 6.8 Hz, 1H), 5.51 (dd, *J* = 14.8, 6.8 Hz, 1H), 4.28 (dd, *J* = 9.2, 7.2 Hz, 1H), 4.24 (ddd, *J* = 11.2, 4.8, 1.6 Hz, 1H), 3.97–3.89 (m, 2H), 2.40 (t, *J* = 4.4 Hz, 1H, O*H*), 2.21–2.12 (m, 1H), 1.90–1.80 (m, 1H), 1.76 (d, *J* = 6.0 Hz, 3H), 1.70–1.63 (m, 1H), 1.03 (s, 9H), 1.01 (s, 9H), 0.73 (d, *J* = 6.8 Hz, 3H); ^{13}C NMR: (100 MHz, acetone-d_6) 133.3, 132.1, 131.5, 129.7, 75.9, 74.8, 60.0 (and 59.9), 42.8, 34.4 (and 34.4), 28.2 (3×), 27.8 (3×), 21.8, 21.2, 18.2, 14.5 (two sets of signals with ca. equal intensity are observed for HO*C*H_2*C*H_2– presumably arising from two preferential conformations of the side chain); MS (+ESI) *m/z* 703 (2 M+Na^+, 100), 363 (M+Na^+, 64); HRMS (+ESI) calcd for $C_{19}H_{37}O_3Si$ (M+H^+): 341.2506; found, 341.2513.

4.11. 2-{(4′*R*,5′*S*,6′*R*)-2′,2′-Di-*tert*-butyl-5′-methyl-6′-[(1″*E*,3″*E*)-penta-1″,3″-dienyl]-1′,3′-dioxa-2′-silacyclohex-4′-yl}acetaldehyde

To a solution of the alcohol **22** (240.0 mg, 0.71 mmol) in dry CH_2Cl_2 (15 mL) cooled at 0 °C under a nitrogen atmosphere was added solid $NaHCO_3$ (596 mg, 7.1 mmol) followed by a careful addition of a solution of Dess–Martin periodinane reagent (0.3 M in CH_2Cl_2, 4.73 mL, 1.42 mmol). The resultant mixture was stirred at room temperature for 1.5 h, followed by treatment with saturated aqueous $NaHCO_3$ (3 mL) and $Na_2S_2O_3$ (1.5 M, 3 mL) simultaneously at 0 °C. The mixture was then diluted with Et_2O (15 mL) and stirred for 15 min at room temperature. The aqueous layer was extracted with Et_2O (15 mL × 2), and the combined organic layers were dried over anhydrous Na_2SO_4, filtered, and concentrated under reduced pressure to give the corresponding aldehyde, which was used in the next step without further purification. An analytic sample was obtained by column chromatography as a colorless oil. $[\alpha]_D^{20} = +95.0$ (*c* 0.35, $CHCl_3$); R_f = 0.53 (10% EtOAc in PE); IR (film) 2963, 2933, 2859, 1731, 1473, 1132, 1063, 1035, 1008 cm^{-1}; ^1H NMR (500 MHz, $CDCl_3$) 9.86 (d, *J* = 3.5 Hz, 1H), 6.21 (dd, *J* = 15.0, 11.0 Hz, 1H), 6.06 (dd, *J* = 15.0, 10.5 Hz, 1H), 5.72 (dq, *J* = 13.0, 6.0 Hz, 1H), 5.50 (dd, *J* = 15.0, 7.0 Hz, 1H), 4.70 (ddd, *J* = 11.0, 5.0, 3.5 Hz, 1H), 4.24 (dd, *J* = 9.0, 7.0 Hz, 1H), 2.68 (ddd, *J* = 14.5, 11.0, 3.5 Hz, 1H), 2.44 (dd, *J* = 14.5, 3.0 Hz, 1H), 2.27–2.20 (m, 1H), 1.76 (d, *J* = 6.5 Hz, 3H), 1.02 (s, 9H), 0.98 (s, 9H), 0.72 (d, *J* = 6.5 Hz, 3H); ^{13}C NMR (100 MHz, acetone-d_6) 202.2, 132.7, 132.1, 132.0, 130.1, 75.5, 73.6, 46.2, 42.4, 28.1 (3×), 27.7 (3×), 22.0, 21.2, 18.4, 14.4; MS (+ESI) *m/z* 361 (M+Na^+, 100); HRMS (+ESI) calcd for $C_{19}H_{35}O_3Si$ (M+H^+): 339.2350; found, 339.2362.

4.12. 2-{(4′*R*,5′*S*,6′*R*)-2′,2′-Di-*tert*-butyl-5′-methyl-6′-[(1″*E*,3″*E*)-penta-1″,3″-dienyl]-1′,3′-dioxa-2′-silacyclohex-4′-yl}butan-2-ol 23

To a solution of the above aldehyde (78.0 mg, 0.23 mmol) in dry THF (3 mL) cooled at −78 °C was added dropwise EtMgBr (2.0 M in Et_2O, 0.23 mL, 0.46 mmol) under a nitrogen atmosphere followed by stirring at the same temperature for 2 h. The reaction mixture was allowed to warm to room temperature and the reaction was quenched with saturated NH_4Cl (0.5 mL). The resultant mixture was extracted with EtOAc (5 mL × 2) and the combined organic layers were washed with brine, dried over anhydrous Na_2SO_4, filtered, and concentrated under reduced pressure. The residue was purified by column chromatography (silica gel, 5% EtOAc in PE) to give 74.0 mg (81% yield for the two-step sequence from **22**) of the diastereomeric alcohols **23** (dr = ca. 1:1) as a colorless oil. R_f = 0.34 and 0.51 (10% EtOAc in PE); IR (film) 3396 (br), 2962, 2933, 2860, 1475, 1387, 1363, 1136, 1049 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) 6.25 (dd, *J* = 15.6, 10.8 Hz, 0.5H), 6.24 (dd, *J* = 15.2, 10.4 Hz, 0.5H), 6.09 (dd, *J* = 14.4, 10.4 Hz, 1H), 5.74–5.64 (m, 1H), 5.58 (dd, *J* = 15.2, 6.8 Hz, 0.5H), 5.57 (dd, *J* = 14.8, 6.4 Hz, 0.5H), 4.40–4.22 (m, 2H), 3.92–3.80 (m, 1H), 3.68 (d, *J* = 3.2 Hz, 0.5H, O*H*), 3.48 (d, *J* = 6.0 Hz, 0.5H, O*H*), 2.24–2.13 (m, 1H), 1.85–1.54 (m, 2H), 1.72 (d, *J* = 6.8 Hz, 3H), 1.51–1.35 (m, 2H), 1.03 (s, 13.5H), 1.00 (s, 4.5H), 0.95 (t, *J* = 7.2 Hz, 1.5H), 0.94 (t, *J* = 7.2 Hz, 1.5H), 0.76 (d, *J* = 7.2 Hz, 1.5H), 0.72 (d, *J* = 6.8 Hz, 1.5H); ^{13}C NMR (100 MHz, acetone-d_6) 133.0 and 132.8, 131.8 and 131.7, 131.3 and 131.1, 129.5 and 129.3, 76.8 and 75.5, 75.6 and 73.8, 71.7 and 68.6, 42.6 and 42.4, 38.2 and 37.8, 31.8 (one peak overlapped with solvent), 27.9 and 27.9 (3×), 27.5 and 27.4 (3×), 21.6 and 21.5, 21.0 and 20.9, 17.8, 14.2 and 14.2, 10.3 and 9.6; MS (+ESI) *m/z* 391 (M+Na^+, 100); HRMS (+ESI) calcd for $C_{21}H_{40}O_3SiNa$ (M+Na^+): 391.2639; found, 391.2628.

4.13. 2-{(4′*R*,5′*S*,6′*R*)-2′,2′-Di-*tert*-butyl-5′-methyl-6′-[(1″*E*,3″*E*)-penta-1″,3″-dienyl]-1′,3′-dioxa-2′-silacyclohex-4′-yl}butan-2-one 7

To a solution of the diastereomeric alcohols **23** (70.0 mg, 0.19 mmol) in dry CH_2Cl_2 (5 mL) cooled at 0 °C under a nitrogen atmosphere was added solid $NaHCO_3$ (160 mg, 1.9 mmol) followed by a careful addition of a solution of Dess–Martin periodinane (0.3 M in CH_2Cl_2, 1.27 mL, 0.38 mmol). The resultant mixture was stirred at room temperature for 1.5 h, followed by treatment with saturated aqueous $NaHCO_3$ (1 mL) and $Na_2S_2O_3$ (1.5 M, 1 mL) simultaneously at 0 °C. The resultant mixture was diluted with Et_2O (5 mL) and stirred for 15 min at room temperature. The aqueous layers were extracted with Et_2O (5 mL × 2), and the combined organic layers were dried over anhydrous Na_2SO_4, filtered, and concentrated under reduced pressure. The residue was purified by column chromatography (silica gel, 5% EtOAc in PE) to give 60.0 mg (86%) of the ketone **7** as a colorless oil. $[\alpha]_D^{20} = +97.0$ (*c* 0.35, $CHCl_3$); R_f = 0.58 (10% EtOAc in PE); IR (film) 2963, 2934, 2859, 1718, 1475, 1135, 1040 cm^{-1}; ^1H NMR (400 MHz, acetone-d_6) 6.21 (dd, *J* = 15.2, 10.4 Hz, 1H), 6.10 (ddq, *J* = 14.8, 10.4, 1.2 Hz, 1H), 5.70 (dq, *J* = 13.5, 6.4 Hz, 1H), 5.53 (dd, *J* = 14.8, 6.4 Hz, 1H), 4.67 (ddd, *J* = 9.6, 5.6, 3.6 Hz, 1H), 4.31 (dd, *J* = 9.2, 6.8 Hz, 1H), 2.72 (dd, *J* = 15.2, 10.4 Hz, 1H), 2.65–2.47 (m, 3H), 2.27-2.16 (m, 1H), 1.73 (dd, *J* = 6.8, 1.2 Hz, 3H), 1.01 (s, 9H), 0.99 (t, *J* = 7.2 Hz, 3H), 0.98 (s, 9H), 0.69 (d, *J* = 6.8 Hz, 3H); ^{13}C NMR: (125 MHz, acetone-d_6) 208.3, 132.0, 131.1, 130.8, 129.0, 74.5, 73.4, 44.8, 41.7, 34.8, 27.1 (3×), 26.7 (3×), 21.0, 20.3, 17.3, 13.4, 7.1; MS (+ESI) *m/z* 389 (M+Na^+, 100); HRMS (+ESI) calcd for $C_{21}H_{39}O_3Si$ (M+H^+): 367.2663; found, 367.2678.

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