CHEMICAL OXIDATION OF TAXOIDS WITH \( m \)-CPBA AND DIMETHYL DIOXIRANE: REGIOSELECTIVE EPOXIDATION OF TAXININE J DERIVATIVES

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Abstract- Epoxidation of taxinine J derivative (\(2c\)) with \( m \)-CPBA afforded a mixture of 4\( \alpha \),20-epoxide (\(3\)), 4\( \alpha \),20 : 11\( \beta \),12\( \beta \)-diepoxide (\(4\)) and 11\( \beta \),12\( \beta \)-epoxide (\(5\)). The proportion of the yields was dependent on temperature (\(3 : 4 = 80 : 10\) at room temperature, \(4 : 5 = 68 : 25\) at 0-10°C). The reactions of derivatives of taxinine (\(2b\)) with \( m \)-CPBA and dimethyldioxirane (DMDO) were also investigated.

Paclitaxel (Taxol, \(1a\))\(^1\) and docetaxel (Taxotere, \(1b\))\(^2\) have proved to be successful anticancer drugs for the treatment of a variety of malignancies. Both compounds are substrates for P-gp,\(^3\) and increased expression of this protein is a major factor underlying resistance to taxoids.\(^4\) Interestingly, certain natural and semisynthetic taxoids devoid of cytotoxicity and tubulin affinity are powerful inhibitors of P-gp activity, acting as efficient reversing agents and allowing accumulation of paclitaxel in MDR-cancer cells.\(^5\) Among the natural taxoids, 2-deacetoxytaxinine J\(^6\) (\(2a\)) emerged as the most active member of this class, with potency higher than that of verapamil.\(^5\)
Unlike other cinnamates related to taxine, 2a does not show cardiac toxicity,\textsuperscript{7} and might thus serve as an important starting material for the synthesis of new reversal agents.\textsuperscript{8} Consequently, it is important to synthesize the analogs of 2a. In our previous paper,\textsuperscript{9} we reported that hydroxylation of C-1 position of 2-deacetoxytaxinine J derivative (2c) had been successfully achieved by a simple chemical oxidation using dimethyldioxirane (DMDO)\textsuperscript{10} leading to the 1\textbeta-hydroxy-4\alpha,20-epoxide (6a) and 1\textbeta-hydroxy-4\beta,20-epoxide (6b). Here we report the temperature-dependent regioselective epoxidation of 2c with m-CPBA\textsuperscript{11} and the application of our DMDO oxidation to other taxoids that were not able to be oxidized at 1\textbeta-position.

**Results**

1. Reaction of 2c with m-CPBA

![Scheme 1](image)

<table>
<thead>
<tr>
<th>Run</th>
<th>temperature</th>
<th>3 Yield</th>
<th>4 Yield</th>
<th>5 Yield</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>rt</td>
<td>80%</td>
<td>10%</td>
<td>none</td>
</tr>
<tr>
<td>2</td>
<td>0-10 \degree</td>
<td>none</td>
<td>68%</td>
<td>25%</td>
</tr>
</tbody>
</table>

The oxidation of compound (2c) with m-CPBA (4 eq.) (Table 1.) at room temperature gave the 4\alpha,20-monoepoxide (3) predominantly and a small amount of the diepoxide (4).\textsuperscript{11(b)} While the same reaction at 0-10 \degree gave 4\alpha,20 : 11\beta,12\beta-diepoxide (4) mainly and some amount of the 11\beta, 12\beta-monoepoxide (5).\textsuperscript{11(b)} In this case, compound (3) was not isolated.

2. Reaction of 2c and taxinine derivatives with m-CPBA and DMDO

![Scheme 1](image)

On the other hand, the oxidation of 2c with an excess amount of DMDO gave mixture of 1\textbeta-hydroxy-4\alpha,
20-epoxide (6a) and 1β-hydroxy-4β,20-epoxide (6b) (Scheme 1). The regioselective hydroxylation at C(1) of 2c with excess DMDO is an interesting finding from the viewpoint of the similarity of biogenesis and a synthetic use, so we attempted to apply this method to another type of taxoids prepared from taxinine (2b), a major component of the Japanese yew leaves, as follows (Scheme 2): the compound (7) was reduced by NaBH₄ or LiBH₄ to give a mixture of compounds (8a) and (8b). Next the diol (8a) was acetylated selectively at 13-OH to yield 2-acetyltaxinine E (9a). Protection of the 5-OH group of 9a with TES group gave compound (9b). We also examined about oxidation of these taxoids with m-CPBA.

As shown in Table 2, none of the compounds could be hydroxylated at the C(1) position even by the use of an excess amount of DMDO or m-CPBA. In addition, excess DMDO epoxidized only the exo-double bond of taxoids. The allylic hydroxy groups of compounds (9a) and (7) were oxidized to carbonyl group (13a, 13b, 14a, 14b). Protection of the 5-OH group as TES ether increased β-selectivity in the epoxidation.

On the other hand, m-CPBA could epoxidize both 11,12- and 4 (20)-double bonds. Consequently, the 11,12-double bond was unreactive toward DMDO, which was similar to tendency other electrophilic and nucleophilic addition, but was reactive toward m-CPBA.

3. Biological activity

Biological activity of some derivatives were evaluated in in vitro cytotoxicity assay against human cancer cell lines (TFK-1), and compound (4) was found to be cytotoxic (IC₅₀ of 4 / IC₅₀ of taxol = 80). While compound (2c), (3) and (5) did not show activity in this assay.

Discussion

1. In a closely related compound of 2c, it is reported that a change of the functional group could affect the regioselectivity at the 11,12- and 4,20- double bonds, so the reactions (Table 1) above described is the first example of the temperature-dependent change of the regioselectivity. This may be caused by a
conformational change of the substrate depending on temperature.

2. Generally, O atom-insertion reaction to C-H bond requires an optimum stereoalignment of the dioxirane attack in the proposed mechanism. These different result about C(1) hydroxylation (Table 2.) in competition with 2c might be explained by the disadvantage to dioxirane attack caused by additional steric hindrance of the C(2) acetoxy group in 2c.

3. The proposed relationship of the orientation of 4,20-epoxide with the magnitude of chemical shift differences between the geminal-4,20-epoxide proton of 2-acetoxytaxoids [i.e. $\Delta\delta (\alpha) \leq 0.5 < \Delta\delta (\beta) \leq 1.2$] was also observed here, for example $\Delta\delta (11a) = 0.56$ and $\Delta\delta (11b) = 1.35$, $\Delta\delta (12a) = 0.40$ and $\Delta\delta (12b) = 1.38$. A similar relationship could be observed to the 2-dehydroxytaxoids, $\Delta\delta (6a) = 0$ and $\Delta\delta (6b) = 0.42$. While this rule was unapplicable for 5-oxotaxoids; $\Delta\delta (13a) = 0.66$ and $\Delta\delta (13b) = 0.46$, $\Delta\delta (14a) = 0.65$ and $\Delta\delta (14b) = 0.37$.

**Table 2. Oxidation Products of Taxinine and Taxinine E Derivatives with DMDO or m-CPBA.**

<table>
<thead>
<tr>
<th>Run</th>
<th>Substrate</th>
<th>DMDO yield [% ($\alpha/\beta$)]</th>
<th>m-CPBA yield [% ($\alpha/\beta$)]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>9a</td>
<td>13a+13b [77(55/22)]</td>
<td>11a [72, 17a 26]</td>
</tr>
<tr>
<td>2</td>
<td>9b</td>
<td>12a+12b [64(22/42)]</td>
<td>12a (11a) [29], 18a+18b (17b) [68(40/28)]</td>
</tr>
<tr>
<td>3</td>
<td>7</td>
<td>14a+14b [77(55/22)]</td>
<td>15a+15b [98(97/1)]</td>
</tr>
<tr>
<td>4</td>
<td>10</td>
<td>16a+16b [86(41/45)]</td>
<td></td>
</tr>
</tbody>
</table>

$^{a}$ 12a and 18b could not be separated with each other, so these structures and yields were estimated from desilylated 11a and 17b, respectively. $^{b}$ See ref 11(a).
Conclusion

It was found that the change of reaction temperature could control a regioselectivity of the epoxidation between the endo- and exo-double bonds of 2-deacetoxytaxinine $J$ with $m$-CPBA. The epoxides will be useful for the synthesis of other analogs by reaction with a strong Lewis acid. On the other hand, the regio-selective oxidation at C(1) position by excess DMDO is not useful for 2-acetoxytaxoids because of its additional steric hindrance at C(1) position.

EXPERIMENTAL

General. $^1$H- and $^{13}$C-NMR spectra were recorded on a Varian UNITY INOVA 500 spectrometer (500 MHz for $^1$H and 125 MHz for $^{13}$C in CDCl$_3$, TMS as internal standards). MS spectra (FAB) were recorded on a JEOL The MStation JMS-700 mass spectrometer. Optical rotation was measured on a HORIBA SEPA-300 polarimeter. Merck silica gel 60 (70-230 mesh) was used for column chromatography and Merck silica gel 60 F254 was used for preparative thin-layer chromatography (PTLC).

Materials. Taxinine and 2-deacetoxytaxinine $J$ were collected from the needles of the Japanese yew (2 g/kg and 200 mg/Kg). $m$-CPBA (Tokyo Chemical Industry Co., LTD) was purified to about 100% before use as follow: $m$-CPBA solution in CHCl$_3$ was washed by phosphate buffer (pH 7.5), dried over Na$_2$SO$_4$, and concentrated in vacuo.

7β,9α,10β,13α-Tetraacetoxy-5α-triethylsilyloxy-taxa-4 (20), 11-diene ($2c$)

The solution of 2 (338 mg, 0.52 mmol), NH$_2$OH·HCl (338 mg, 4.86 mmol) and NaOAc (672 mg, 8.19 mmol) in EtOH (200 mL) and H$_2$O (200 mL) was stirred at 80 ºC for 48 h. The mixture was diluted with CHCl$_3$ (30 mL). The organic layer was washed with a saturated solution of NH$_4$Cl, 5% NaHCO$_3$, and brine, and dried over Na$_2$SO$_4$. The organic layer was concentrated in vacuo. The residue was purified by chromatography (CHCl$_3$ / MeOH = 20 / 1), yielding crude alcohol (260 mg). To the solution of crude alcohol (260 mg) and imidazole (49 mg, 0.72 mmol) in DMF (4 mL) was added TESCl (80 mg, 0.53 mmol) and the mixture was stirred for 2h at rt. The mixture was diluted with ether (30 mL). The organic layer was washed with water, a saturated solution of NH$_4$Cl, and brine, dried over Na$_2$SO$_4$. The organic layer was concentrated in vacuo. The residue was purified by chromatography (CHCl$_3$ / MeOH = 20/1), yielding 2c (267 mg, 80%, 2 steps) As amorphous solid; [α]$_D^{20}$ $+32^\circ$ (c 0.0075, CHCl$_3$); $^1$H-NMR (500 MHz, CDCl$_3$) δ 6.25 (d, 1H, $J = 11.3$ Hz, H-10), 5.97 (m, 1H, H-13), 5.89 (d, 1H, $J = 11.0$ Hz, H-9), 5.65 (dd, 1H, $J = 5.2$, 11.3 Hz, H-7), 5.03 (s, 1H, H-20), 4.75 (s, 1H, H-20), 4.20 (br t, 1H, H-14β), 2.98 (d, 1H, $J = 6.0$ Hz, H-3), 2.56 (ddd, 1H, $J = 9.6$, 9.9, 14.3 Hz, H-14β), 2.15 (d, 3H, $J = 1.4$ Hz, Me-18), 2.05 (s, 3H, Ac), 1.99 (s, 3H, Ac), 1.96 (s, 3H, Ac), 1.91(s, 3H, Ac), 1.85 (m, 2H, H-1, H-2), 1.74 (ddd, 1H, $J = 2.5$, 5.5, 13.5 Hz, H-6α), 1.70 (m, 2H, H-2, H-6), 1.63 (s, 3H, Me-16), 1.16 (s,
3H, Me-17), 1.10 (dd, 1H, J = 9.3, 14.3 Hz, H-14α), 0.96-0.92 (m, 9H, TES), 0.81 (s, 3H, Me-19), 0.70-0.60 (m, 6H, TES); 13C-NMR (125 MHz, CDCl3) δ : 170.94, 170.37, 169.71, 169.20 (4×Ac), 151.98, 137.84, 133.58, 111.54, 77.11, 73.25, 71.72, 70.81, 70.33, 46.35, 40.89, 39.51, 37.99, 36.02, 31.23, 30.99, 27.89, 27.71, 21.54, 21.46, 21.05, 20.91, 14.72, 13.36, 6.81 (TES), 4.53 (TES); IR (film) Зmax (CHCl3) cm⁻¹: 3000-2900 (s), 1740 (s, C=O), 1370 (s), 1240 (s), 1020 (s), 750 (s); HRFABMS calcd 634.3534 for C34H54O9Si; found 634.3541.

Preparation of dimethyldioxirane (DMDO)
DMDO solution was prepared and assayed¹⁰(b) to be 0.075 M solution in acetone.

Reaction by DMDO
Compound (2c) (50 mg, 0.079 mmol) was dissolved into DMDO solution (40 mL, 31 eq. as DMDO) and the mixture was left for 48 h at rt. The reaction mixture was concentrated in vacuo, and the residue was applied to a TLC (hexane / ethylacetate = 2 / 1) to give 6a¹⁰ (23 mg, 45%) and 6b¹⁰ (26 mg, 51%). The same procedure was carried out for 9a¹⁷, 9b, 7¹⁵ and 10¹¹(a).

Reaction of 2c by m-CPBA
To a solution of 2c (94 mg, 0.15 mmol) in CH₂Cl₂ (5 mL) were added m-CPBA (104 mg, 0.60 mmol) and NaOAc (100 mg, 1.2 mmol). The reaction mixture was stirred at rt for 3 h, and then extracted with EtOAc and the extract was washed with a saturated solution of NaHCO₃. The organic layer was dried over MgSO₄ and evaporated. The residue was chromatographed on silica gel (EtOAc / hexane = 2 / 1) to give 3 (77 mg, 80%) and 4 (10 mg, 10%). The same procedure was carried out at rt for 9a, 9b and 7. Next, to a solution of 2c (85mg, 0.13 mmol) in CH₂Cl₂ (5 mL) were added m-CPBA (94 mg, 0.52 mmol) and NaOAc (100 mg, 1.2 mmol). The reaction mixture was stirred at 0-10 ° for 48 h, and then extracted with EtOAc and the extract was washed with a saturated solution of NaHCO₃. The organic layer was dried over MgSO₄ and evaporated. The residue was chromatographed on silica gel (EtOAc / hexane = 2 / 1) to give 4 (57 mg, 68%) and 5 (22 mg, 25%).

7β,9α,10β,13α-Tetraacetoxy-4α,20-epoxy-5α-triethylsilyloxy-11-taxene (3)
As amorphous solid; [α]D +95°(c 0.0074, CHCl₃); ¹H-NMR (500 MHz, CDCl₃) δ : 6.18 (d, 1H, J = 11.0 Hz, H-10), 5.89 (m, 1H, H-13), 5.87 (d, 1H, J = 11.0 Hz, H-9), 5.61 (dd, 1H, J = 4.5, 11.0 Hz, H-7), 3.32 (br t, 1H, 5-H), 2.75 (m, 1H, H-3), 2.63 (ddd, 1H, J = 4.67, 9.62, 14.3 Hz, H-14β), 2.73 (d, J = 3.85, 1H, H-20B), 2.37 (d, J = 3.85, 1H, H-20B), 2.13 (s, 3H, Me-18), 2.12 (s, 3H, Ac), 2.07 (s, 3H, Ac), 2.03 (s, 3H, Ac), 2.03 (m, 1H, H-6β), 1.97 (s, 3H, Ac), 1.78 (m, 1H, H-1), 1.70 (m, 1H, H-6α), 1.60 (m, 1H, H-2β), 1.59 (s, 3H, Me-16), 1.12 (s, 3H, Me-17), 1.10 (m, 1H, H-14α), 1.07 (s, 3H, Me-19), 0.95 (m, 9H, TES), 0.82 (m, 1H, H-2α), 0.62 (m, 6H, TES); ¹³C-NMR (500 MHz, CDCl₃) δ :
170.73, 170.34, 169.65, 169.22, 137.90, 134.57, 130.04, 128.25, 76.69, 73.20, 71.68, 70.51, 69.68, 61.11, 47.81, 46.27, 39.87, 39.59, 35.41, 32.80, 31.38, 30.56, 27.34, 22.76, 21.49, 21.33, 21.02, 20.84, 14.98, 14.30, 6.79, 4.71; IR (film) $\nu_{\text{max}}$ (CHCl$_3$) cm$^{-1}$: 2950 (s), 1730 (s, C=O), 1660 (m), 1460 (s), 1340 (s), 1370 (s), 1240 (s), 1140 (s), 1060 (s), 1020 (s), 990 (s), 960 (s), 900 (w), 820 (m), 800 (m), 750 (s), 660 (m); HR-FABMS calcd for C$_{34}$H$_{54}$O$_{10}$NaSi (M+Na)$^+$ 673.3381, found 673.3382.

$\beta,9\alpha,10\beta,13\alpha$-Tetraacetoxy-4$\alpha,20 : 11\beta,12\beta$-diepoxy-5$\alpha$-triethylsilyloxytaxane (4)

As amorphous solid; [α]$^D_{20} +32.0^\circ$ (c 0.12, CHCl$_3$); $^1$H-NMR (500 MHz, CDCl$_3$) δ : 5.97 (d, 1H, J = 11.3 Hz, H-9), 5.75 (dd, 1H, J = 4.7, 11.5 Hz, H-7), 5.45 (d, 1H, J = 11.5 Hz, H-9), 5.36 (dd, 1H, J = 9.6, 10.2 Hz, H-13), 3.43 (br t, 1H, 5-H), 2.60 (m, 1H, H-3), 2.32 (ddd, 1H, J = 9.6, 14.8 Hz, H-14$\beta$), 2.36 (s, 3H, Ac), 2.04 (s, 3H, Ac), 1.91 (m, 1H, H-6$\beta$), 2.00 (s, 3H, Ac), 1.86 (s, 3H, Me-18), 1.82 (m, 1H, H-6), 1.78 (m, 1H, H-1), 1.64 (s, 3H, Me-16), 1.50 (dd, 1H, J = 4.9, 14.8 Hz, H-2), 1.38 (ddd, 1H, J = 1.1, 10.7, 14.8 Hz, H-14$\alpha$), 1.00 (m, 1H, H-2), 1.14-0.94 (m, 12H, Me-19, TES), 0.73 (s, 3H, TES), 0.68 (m, 6H, TES); $^{13}$C-NMR (125 MHz, CDCl$_3$) δ : 170.48, 170.11, 169.33, 168.83 (4×Ac), 76.56, 72.54, 72.32, 70.04, 68.93, 65.60, 64.63, 59.08, 47.82, 45.69, 41.97, 39.15, 36.56, 32.26, 31.23, 28.86, 27.00, 21.27, 21.26, 21.17, 20.74, 20.71, 15.18, 13.25, 6.69 (TES), 4.56 (TES); IR (film) $\nu_{\text{max}}$ (CHCl$_3$) cm$^{-1}$: 2950 (s), 1730 (s, C=O), 1460 (s), 1370 (s), 1240 (s), 1140 (w), 1070 (m), 1020 (s), 990 (s), 960 (s), 900 (w), 820 (m), 750 (s), 660 (m); HR-FABMS calcd for C$_{34}$H$_{54}$O$_{10}$NaSi (M+Na)$^+$ 689.3329, found 689.3332.

$\beta,9\alpha,10\beta,13\alpha$-Tetraacetoxy-11$\beta,12\beta$-epoxy-5$\alpha$-triethylsilyloxy-taxane (5)

As amorphous solid; [α]$^D_{20} +21.0^\circ$ (c 0.053, CHCl$_3$); $^1$H-NMR (500 MHz, CDCl$_3$) δ : 6.00 (d, 1H, J = 11.2 Hz, H-9), 5.76 (dd, 1H, J = 5.1, 11.0 Hz, H-7), 5.47 (d, 1H, J = 11.4 Hz, H-10), 5.38 (dd, 1H, J = 10.2, 11.5 Hz, H-13), 5.16 (br s, 1H, H-20B), 4.89 (d, 1H, J = 1.4 Hz, H-20B), 4.31 (dd, 1H, J = 2.8, 3.0 Hz 5-H), 2.78 (m, 1H, H-3), 2.32 (ddd, 1H, J = 8.8, 9.9, 14.8 Hz, H-14$\beta$), 2.11 (s, 3H, Ac), 2.03 (s, 3H, Ac), 2.01 (s, 3H, Ac), 2.00 (s, 3H, TES), 1.86 (m, 2H, H-2), 1.86 (s, 3H, Me-18), 1.80 (m, 1H, H-1), 1.78 (m, 1H, H-6$\beta$), 1.75 (m, 1H, H-6$\alpha$), 1.68 (s, 3H, Me-16), 1.06 (s, 3H, Me-17), 1.16 (dd, 1H, J = 10.7, 14.8 Hz, H-14$\alpha$), 0.85 (s, 3H, Me-19), 0.95 (t, 9H, J =7.7 Hz, TES), 0.68 (m, 6H, TES); IR (film) $\nu_{\text{max}}$ (CHCl$_3$) cm$^{-1}$: 2950 (s), 1730 (s, C=O), 1660 (m), 1460 (s), 1430 (s), 1370 (s), 1310 (m), 1240 (s), 1140 (s), 1060 (s), 990 (s), 960 (s), 900 (w), 820 (m), 800 (m), 750 (s), 660(m); $^{13}$C-NMR (125 MHz, CDCl$_3$) δ : 170.46, 170.12, 169.51, 168.90 (4×Ac), 150.31, 112.66, 73.42, 72.46, 70.17, 69.50, 65.66, 64.57, 45.45, 42.30, 39.14, 37.62, 35.91, 31.32, 29.31, 27.13, 25.95, 21.34, 21.29, 21.25, 21.20, 20.74, 15.18, 13.18, 6.75 (TES), 4.43 (TES); HR-FABMS calcd 673.3388 for
C_{34}H_{54}O_{10}NaSi(M+Na); found 673.3381

Synthesis of compound (9a)\textsuperscript{17} and (9b)

To a stirred suspension of 7 (3.20 g, 6.71 mmol) and CeCl\textsubscript{3} (10 g, 0.16 mmol) in dry MeOH (400 mL) was added NaBH\textsubscript{4} (15 g, 2.38 mmol). After 25 min, acetone (10 mL) was added and stirring was continued for additional 15 min. The crude reaction product was isolated with Et\textsubscript{2}O in usual manner and purified by chromatography (hexane/ EtOAc = 2/1), yielding pure α-alcohol (8a)\textsuperscript{16} (1.79 g, 56%) and β-alcohol (8b) (1.41 g, 46%). To a solution of 8a (350 mg, 0.73 mmol) in dry pyridine (3 mL) was added Ac\textsubscript{2}O (0.11 mL, 2.0 mmol). After the mixture was stirred for 48 h, EtOAc (20 mL) was added. The organic layer was washed with brine, H\textsubscript{2}O, saturated solution of CuSO\textsubscript{4}, H\textsubscript{2}O, and brine. The organic layer was concentrated in vacuo, yielding 9a (334 mg, 88%) as amorphous solid. To the solution of 9a (334 mg, 0.62 mmol) and imidazole (92 mg, 1.2 mmol) in DMF (6 mL) was added TESCl (105 mg, 0.7 mmol). After the mixture was stirred for 2 h at rt, ether (30 mL) was added. The organic layer was washed with water, solution of saturated NH\textsubscript{4}Cl, and brine, dried over Na\textsubscript{2}SO\textsubscript{4}. The organic layer was concentrated in vacuo. The residue was purified by chromatography (hexane / EtOAc = 3 / 1), yielding 9b (394 mg, 100%) as an amorphous solid.

2α,9α,10β-Triacetoxytaxa-4 (20),11-diene-5α,13β-diol (8b)

As amorphous solid; [α]\textsubscript{D}\textsuperscript{20} +63° (c 0.018, CHCl\textsubscript{3}); \textsuperscript{1}H-NMR (500 MHz, CDCl\textsubscript{3}) δ : 6.03 (d, 1H, J = 10.4 Hz, H-10), 5.83 (d, 1H, J = 10.4 Hz, H-9), 5.48 (dd, 1H, J = 1.4, 6.9 Hz, H-2), 5.17 (s, 1H, H-20), 4.69 (s, 1H, H-20), 4.32 (m, 1H, H-13), 4.21 (br s, 1H, 5-H), 3.27 (d, 1H, J = 6.9 Hz, H-3), 2.48 (m, 1H, OH-5), 2.18 (br s, 3H, Me-18), 2.16 (m, 1H, H-14), 2.05, 2.04, 2.01 (s, 9H, 3×Ac), 2.03 (m, 2H, H-1, H-14), 1.98 (s, 3H, Ac), 1.87 (m, 1H, H-7), 1.75 (m, 2H, H-6, H-7), 1.65 (s, 3H, Me-16), 1.64 (m, 1H, H-6), 1.29 (s, 3H, Me-17), 0.85 (s, 3H, Me-19); \textsuperscript{13}C-NMR (125 MHz, CDCl\textsubscript{3}) δ : 170.11, 169.47 (3×Ac), 144.72, 140.14, 136.31, 114.14, 76.66, 76.15, 73.21, 70.50, 70.04, 56.28, 44.78, 42.16, 36.51, 30.81, 29.74, 26.38, 25.80, 21.50, 21.11, 20.79, 18.91, 17.26; IR ν max (CHCl\textsubscript{3}) cm\textsuperscript{-1}: 3450 (m, OH), 3000-2900 (m), 1730 (s, C=O), 1440 (m), 1370 (s), 1250 (s), 1020 (s), 980 (s), 900 (m), 760 (s), 660 (m); HR-FABMS calcd for C\textsubscript{34}H\textsubscript{54}O\textsubscript{9}Si 478.2564, found 478.2565.

2α,9α,10β,13α-Tetraacetoxy-5α-triethylsilyloxytaxa-4 (20),11-diene (9b)

As amorphous solid; [α]\textsubscript{D}\textsuperscript{20} +29° (c 0.015, CHCl\textsubscript{3}); \textsuperscript{1}H-NMR (500 MHz, CDCl\textsubscript{3}) δ : 6.06 (d, 1H, J = 10.7 Hz, H-10), 5.95 (ddd, 1H, J = 1.2, 8.3, 10.1 Hz, H-13), 5.93 (d, 1H, J = 10.7 Hz, H-9), 5.42 (dd, 1H, J = 5.1, 2.7 Hz, H-2), 5.11 (s, 1H, H-20A), 4.42 (s, 1H, H-20A), 4.12 (br t, 1H, H-5), 3.36 (d, 1H, J = 7.8 Hz, H-3), 2.42 (dt, 1H, J = 14.7, 9.5 Hz, H-14β), 2.14 (s, 3H, Ac), 2.09 (d, 3H, J = 1.0 Hz, Me-18), 2.04 (s, 3H, Ac), 1.99 (1H, m, H-1), 2.00 (s, 3H, Ac), 1.98 (s, 3H, Ac), 1.83 (dt, 1H, J = 13.2,
9.0, H-7), 1.75 (s, 3H, Me-16), 1.70 (dt, 1H, J = 13.7, 3.4 Hz, H-7), 1.60 (m, 2H, H-2, H-6), 1.57 (dd, 1H, J = 9.8, 15.9 Hz, H-14α), 1.17 (s, 3H, Me-17), 0.96-0.92 (m, 9H, TES), 0.81 (s, 3H, Me-19), 0.70-0.60 (m, 6H, TES); 13C-NMR (125 MHz, CDCl₃) δ: 170.91, 170.17, 169.88, 169.62 (4×Ac), 146.87, 137.55, 131.91, 113.72, 77.11, 76.52, 72.49, 71.79, 70.44, 48.75, 44.33, 42.89, 37.42, 32.30, 31.35, 27.70, 27.40, 26.83, 21.44, 21.41, 21.03, 20.85, 17.99, 14.61, 6.78 (TES), 4.43 (TES); IR (film) ν max (CHCl₃) cm⁻¹: 3000-2900 (s), 1740 (s, C=O), 1450 (m), 1370 (s), 1240 (s), 1020 (s), 900 (m), 760 (s), 660 (m); HR-FABMS calcd for C₃₄H₅₄O₉Si 634.3534, found 634.3535.

2α,9α,10β,13α-Tetraacetoxy-4α,20-epoxy-11-taxen-5α-ol (11a)

As amorphous solid; [α]D²⁰ +60° (c 0.12, CHCl₃); 1H-NMR (500 MHz, CDCl₃) δ: 6.06 (d, 1H, J = 10.3 Hz, H-10), 5.79 (d, 1H, J = 10.3 Hz, H-9), 5.79 (m, 1H, H-13), 5.37 (dd, 1H, J = 1.0, 4.2 Hz, H-2), 3.47 (d, 1H, J = 4.2 Hz, H-3), 3.16 (br t, 1H, H-5), 3.06 (d, J = 4.9 Hz, 1H, H-20A), 2.67 (dd, 1H, J = 8.8, 10.3 Hz, H-14β), 2.50 (d, J = 4.9 Hz, 1H, H-20B), 2.29 (m, 1H, OH-5), 2.17 (d, 3H, J = 1.4 Hz, Me-18), 2.14 (s, 3H, Ac), 2.14 (m, 1H, H-7), 2.07 (s, 3H, Ac), 2.04 (s, 3H, Ac), 2.04 (m, 1H, H-7), 2.01 (s, 3H, Ac), 1.86 (m, 1H, H-6), 1.86 (m, 1H, H-14α), 1.70 (m, 2H, H-1, H-6), 1.69 (s, 3H, Me-16), 1.01 (s, 3H, Me-17), 0.93 (s, 3H, Me-19); 13C-NMR (125 MHz, CDCl₃) δ: 169.93, 169.87, 169.73, 169.71 (4×Ac), 139.10, 134.16, 76.25, 75.98, 72.26, 72.16, 69.66, 62.93, 51.94, 46.82, 44.03, 37.72, 36.24, 31.70, 28.17, 26.00, 25.63, 25.04, 21.42, 20.91, 20.62, 20.60, 17.55, 15.62; IR (film) ν max (CHCl₃) cm⁻¹: 3500 (m), 2950 (s), 1740 (s, C=O), 1460 (m), 1370 (s), 1310 (m), 1240 (s), 1140 (s), 1060 (s), 1020 (s), 990 (s), 960 (s), 820 (m), 760 (s), 660 (m); HR-FABMS calcd for C₂₈H₄₀O₁₀(M⁺) 536.2619, found 536.2624.

7β,9α,10β,13α-Tetraacetoxy-4β,20-epoxy-11-taxen-5α-ol (11b)

As amorphous solid; [α]D²⁰ +73° (c 0.038 CHCl₃); 1H-NMR (500 MHz, CDCl₃) δ: 6.02 (d, 1H, J = 10.7 Hz, H-10), 5.82 (d, 1H, J = 10.4 Hz, H-9), 5.75 (ddd, 1H, J = 1.1, 4.4, 10.1 Hz, H-13), 5.45 (br d, 1H, J = 2.7, H-2), 3.55 (d, J = 5.2, 1H, H-20A), 3.17 (d, 1H, J = 3.6 Hz, H-3), 2.97 (br t, 1H, H-5), 2.77 (ddd, 1H, J = 8.8, 10.4, 15.7 Hz, H-14β), 2.20 (d, J = 5.5 Hz, 1H, H-20B), 2.13 (br s, 6H, Me-18, Ac), 2.07 (s, 3H, Ac), 2.01 (s, 3H, Ac), 1.98 (s, 3H, Ac), 1.86 (m, 1H, H-6), 1.85-1.70 (m, 2H, H-7), 1.66 (m, 2H, H-1, H-6), 1.57 (dd, 1H, J = 4.7, 15.7, H-14α), 1.65 (s, 3H, Me-16), 1.09 (s, 3H, Me-17), 1.02 (s, 3H, Me-19); 13C-NMR (125 MHz, CDCl₃) δ: 170.81, 169.96, 169.87, 169.71 (4×Ac), 139.71, 134.34, 76.37, 76.17, 72.38, 72.30, 69.81, 63.01, 52.08, 46.93, 44.15, 37.84, 36.36, 31.85, 28.31, 26.10, 25.75, 25.16, 21.58, 21.10, 21.07, 21.03, 20.75, 20.74, 17.68, 15.78; IR (film) ν max (CHCl₃) cm⁻¹: 3600-3300 (m), 3000 (s), 1730 (s, C=O), 1430 (s), 1370 (s), 1240 (s), 1120 (s), 1020 (s), 960 (s), 920 (s), 900 (m), 750 (s); HR-FABMS calcd for C₂₈H₄₀O₁₀(M⁺) 536.2619, found 536.2621.
2α,9α,10β,13α-Tetraacetoxy-4α,20-epoxy-5α-triethylsilyloxy-11-taxene (12a)
As amorphous solid; \([\alpha]_D^{20} +28^\circ\) (c 0.0023, CHCl₃); \(^1\)H-NMR (500 MHz, CDCl₃) \(\delta\) : 6.05 (d, 1H, \(J = 10.7\) Hz, H-10), 5.97 (m, 1H, H-13), 5.87 (d, 1H, \(J = 10.7\) Hz, H-9), 5.38 (dd, 1H, \(J = 4.7\) Hz, H-2), 3.15 (d, 1H, \(J = 4.7\) Hz, H-3), 3.05 (br t, 1H, H-5), 2.79 (d, \(J = 5.0\) Hz, H-20A), 2.55 (ddd, 1H, \(J = 9.6, 9.6, 14.8\) Hz, H-14β), 2.39 (d, \(J = 5.0\) Hz, H-14δ), 2.13 (d, 3H, \(J = 1.4\) Hz, Me-18), 2.15 (s, 3H, Ac), 2.06 (s, 3H, Ac), 2.02 (s, 3H, Ac), 1.88 (m, 1H, H-7), 1.76 (m, 1H, H-14α), 1.75 (s, 3H, Me-16), 1.74 (m, 1H, H-1), 1.70 (m, 1H, H-7), 1.68 (m, 1H, H-6), 1.60 (ddd, 1H, \(J = 3.6, 4.9, 10.4\) Hz, H-6), 1.16 (s, 3H, Me-17), 0.98 (t, 9H, \(J = 3.0\) Hz, TES), 0.94 (s, 3H, Me-19), 0.61 (q, 6H, \(J = 7.9\) Hz, TES); \(^{13}\)C-NMR (125 MHz, CDCl₃) \(\delta\) : 171.92, 170.09, 169.98, 169.84 (4× Ac), 138.94, 132.40, 76.96, 76.66, 73.21, 72.03, 70.44, 61.75, 50.90, 48.34, 44.32, 38.45, 37.26, 31.28, 28.76, 27.82, 27.15, 25.21, 21.68, 21.52, 21.04, 20.77, 18.00, 14.98, 6.93, 4.74; IR (film) \(\nu_{max}\) (CHCl₃) (KBr) cm⁻¹: 3400 (w), 2950 (m), 1740 (s, C=O), 1460 (m), 1430 (m), 1370 (s), 1240 (m), 1100 (m), 980 (m), 950 (m), 920 (w), 820 (w), 800 (w), 740 (m); HR-FABMS calcd for C₃₄H₅₄O₁₀Si (M⁺) 650.34830, found 650.3488.

2α,9α,10β,13α-Tetraacetoxy-4β,20-epoxy-5α-triethylsilyloxy-11-taxene (12b)
As amorphous solid; \([\alpha]_D^{20} +25^\circ\) (c 0.0061, CHCl₃); \(^1\)H-NMR (500 MHz, CDCl₃) \(\delta\) : 6.05 (d, 1H, \(J = 10.7\) Hz, H-10), 5.97 (m, 1H, H-13), 5.87 (d, 1H, \(J = 10.7\) Hz, H-9), 5.42 (d, 1H, \(J = 3.0\) Hz, H-2), 3.46 (d, \(J = 5.2\) Hz, H-20A), 2.89 (d, 1H, \(J = 3.9\) Hz, H-3), 2.85 (br t, 1H, H-5), 2.59 (ddd, 1H, \(J = 9.3, 9.6, 14.8\) Hz, H-14β), 2.16 (s, 3H, Ac), 2.06 (br s, 3H, Me-18), 2.06 (s, 3H, Ac), 2.02 (s, 3H, Ac), 1.86 (m, 1H, H-6), 1.80-1.70 (m, 3H, H-1, H-7αβ), 1.69 (m, 1H, H-6), 1.69 (s, 3H, Me-17), 1.12 (s, 3H, Me-19), 0.93 (t, 9H, \(J = 7.9\) Hz, TES), 0.61 (q, 6H, \(J = 7.9\) Hz, TES); \(^{13}\)C-NMR (125 MHz, CDCl₃) \(\delta\) : 170.80, 169.98, 169.90, 168.51 (4× Ac), 138.40, 132.40, 76.96, 76.66, 73.21, 72.03, 70.44, 61.75, 50.90, 48.34, 44.32, 38.45, 37.26, 31.28, 28.76, 27.82, 27.15, 25.21, 21.38, 20.77, 18.00, 14.98, 6.93, 4.74; IR (film) \(\nu_{max}\) (CHCl₃) (KBr) cm⁻¹: 3400 (w), 2950 (m), 1740 (s, C=O), 1660 (m), 1460 (m), 1430 (m), 1370 (m), 1240 (s), 1130 (m), 1030 (m), 980 (m), 950 (m), 920 (w), 820 (w), 800 (w), 740 (m); HR-FABMS calcd for C₃₄H₇₄O₁₀Si (M⁺) 650.34830, found 650.3488.

2α,9α,10β,13α-Tetraacetoxy-4α,20-epoxy-11-taxen-5-one (13a)
As amorphous solid; \([\alpha]_D^{20} +55^\circ\) (c 0.0038, CHCl₃); \(^1\)H-NMR (500 MHz, CDCl₃) \(\delta\) : 5.99 (d, 1H, \(J = 10.5\) Hz, H-10), 5.90 (d, 1H, \(J = 10.5\) Hz, H-10), 5.49 (m, 2H, H-2, H-13), 3.23 (d, 1H, \(J = 4.2\) Hz, H-3), 3.09 (d, 1H, \(J = 6.1\) Hz, H-20), 2.72 (ddd, 1H, \(J = 8.3, 10.0, 16.1\) Hz, H-14β), 2.61 (ddd, 1H, \(J = 2.2, 5.2, 15.9\) Hz, H-6β), 2.52 (dd, 1H, \(J = 6.8, 14.4\) Hz, H-7β), 2.43 (d, 1H, \(J = 6.1\) Hz, H-20), 2.27 (ddd, 1H, \(J = 2.2, 6.8, 13.7\) Hz, H-7α), 2.13 (s, 3H, Ac), 2.10 (s, 3H, Ac), 2.05 (s, 3H, Ac), 2.03 (s, 3H, Ac), 1.99
2α,9α,10β,13α-Tetraacetoxy-4β,20-epoxy-11-taxen-5-one (13b)
As amorphous solid; [α]_D^{20} +96° (c 0.057, CHCl₃); ¹H-NMR (500 MHz, CDCl₃) δ : 5.99 (d, 1H, J = 10.3 Hz, H-10), 5.89 (d, 1H, J = 10.3 Hz, H-9), 5.57 (m, 2H, H-2, H-13), 3.37 (d, 1H, J = 6.4, H-20A), 3.21 (d, 1H, J = 4.4, H-3), 2.91 (d, 1H, J = 6.4, H-20B), 2.85 (ddd, 1H, J = 8.3, 10.3, 16.1, H-14β), 2.66 (ddd, 1H, J = 7.3, 9.0, 15.1, H-6α), 2.52 (ddd, 1H, J = 5.9, 7.3, 15.1, H-6β), 2.10-2.0 (m, 2H, H-7), 2.09, 2.08, 2.03 (s, 9H, 3×Ac), 2.00 (br s, 3H, Me-18), 1.98 (s, 3H, Ac), 1.71 (m, 1H, H-1), 1.65 (s, 3H, Me-16), 1.55 (dd, 1H, J = 3.4, 16.1, H-14α), 1.22 (s, 3H, Me-17), 0.98 (s, 3H, Me-19); ¹³C-NMR (125 MHz, CDCl₃) δ : 205.60 (C5), 170.08, 169.96, 169.72, 168.57 (4×Ac), 137.30, 135.71, 76.08, 72.41, 69.29, 69.21, 62.07, 49.13, 47.31, 41.99, 41.70, 36.96, 34.82, 32.80, 29.46, 29.39, 25.63, 21.15, 20.99, 20.91, 20.66, 20.52, 16.43; IR (film) max (CHCl₃) cm⁻¹: 3000 (m), 1740 (s, C=O), 1680 (m), 1430 (w), 1370 (s), 1240 (s), 1060 (s), 820 (w), 760 (s), 660 (w); HR-FABMS calcd for C_{28}H_{38}O_{10} (M⁺) 534.2463, found 534.2466.

2α,9α,10β,13α-Tetraacetoxy-4β,20-epoxy-11-taxene-5,13-dione (14a)
As amorphous solid; [α]_D^{20} +56° (c 0.016, CHCl₃); ¹H-NMR (500 MHz, CDCl₃) δ : 6.02 (d, 1H, J = 10.5 Hz, H-10), 5.99 (d, 1H, J = 10.5 Hz, H-9), 5.62 (dd, 1H, J = 1.2, 5.6 Hz, H-2), 3.13 (d, 1H, J = 6.1, H-20), 2.47 (m, 1H, H-7β), 2.93 (d, 1H, J = 4.4, H-3), 2.82 (dd, 1H, J = 6.8, 20.0 Hz, H-14β), 2.65 (d, 1H, J = 19.8, H-14α), 2.61 (ddd, 1H, J = 2.2, 5.1, 16.6 Hz, H-6β), 2.48 (d, 1H, J = 6.4, H-20), 2.13 (d, 3H, J = 1.2 Hz, Me-18), 2.09 (s, 3H, Ac), 2.06 (s, 6H, 2×Ac), 2.07 (m, 1H, H-1), 1.74 (dt, 1H, J = 5.1, 13.9 Hz, H-6α), 1.76 (s, 3H, Me-16), 1.11 (s, 3H, Me-17), 1.23 (s, 3H, Me-19); ¹³C-NMR (125 MHz, CDCl₃) δ : 203.86 (C5), 198.86 (C13), 169.78, 169.64, 169.54 (3×Ac), 149.14, 138.60, 74.90, 72.28, 70.58, 62.60, 51.86, 47.55, 43.47, 42.91, 38.23, 36.67, 35.94, 35.84, 29.52, 25.06, 21.48, 20.84, 20.66, 17.99, 14.14; IR (film) max (CHCl₃) cm⁻¹: 2950 (s), 1740 (s, C=O), 1680 (m), 1430 (w), 1370 (s), 1240 (s), 1060 (s), 820 (m), 760 (s), 660 (m); HR-FABMS calcd for C_{26}H_{32}O_{9} (M⁺) 490.2200, found 490.2204.

2α,9α,10β-Triacetoxy-4β,20-epoxy-11-taxene-5,13-dione (14b)
As amorphous solid; [α]_D^{20} +38° (c 0.021, CHCl₃); ¹H-NMR (500 MHz, CDCl₃) δ : 6.02 (d, 1H, J = 10.3 Hz, H-10), 5.99 (d, 1H, J = 10.3 Hz, H-9), 5.62 (dd, 1H, J = 1.2, 5.6 Hz, H-2), 3.13 (d, 1H, J = 6.1, H-20), 2.47 (m, 1H, H-7β), 2.93 (d, 1H, J = 4.4, H-3), 2.82 (dd, 1H, J = 6.8, 20.0 Hz, H-14β), 2.65 (d, 1H, J = 19.8, H-14α), 2.61 (ddd, 1H, J = 2.2, 5.1, 16.6 Hz, H-6β), 2.48 (d, 1H, J = 6.4, H-20), 2.13 (d, 3H, J = 1.2 Hz, Me-18), 2.09 (s, 3H, Ac), 2.06 (s, 6H, 2×Ac), 2.07 (m, 1H, H-1), 1.74 (dt, 1H, J = 5.1, 13.9 Hz, H-6α), 1.76 (s, 3H, Me-16), 1.11 (s, 3H, Me-17), 1.23 (s, 3H, Me-19); ¹³C-NMR (125 MHz, CDCl₃) δ : 203.86 (C5), 198.86 (C13), 169.78, 169.64, 169.54 (3×Ac), 149.14, 138.60, 74.90, 72.28, 70.58, 62.60, 51.86, 47.55, 43.47, 42.91, 38.23, 36.67, 35.94, 35.84, 29.52, 25.06, 21.48, 20.84, 20.66, 17.99, 14.14; IR (film) max (CHCl₃) cm⁻¹: 2950 (s), 1740 (s, C=O), 1680 (m), 1430 (w), 1370 (s), 1240 (s), 1060 (s), 820 (m), 760 (s), 660 (m); HR-FABMS calcd for C_{26}H_{32}O_{9} (M⁺) 490.2200, found 490.2204.
Hz, H-10), 6.00 (d, 1H, J = 10.5 Hz, H-9), 5.70 (dd, 1H, J = 1.5, 4.9 Hz, H-2), 3.25 (d, 1H, J = 6.3 Hz, H-20A), 2.98 (dd, 1H, J = 7.1, 19.8 Hz, H-14β), 2.91 (d, 1H, J = 4.9 Hz, H-3), 2.88 (d, 1H, J = 6.4 Hz, H-20B), 2.61 (ddd, 1H, J = 7.8, 8.1, 15.9 Hz, H-6), 2.43 (ddd, 1H, J = 6.3, 8.5, 15.9 Hz, H-6), 2.34 (d, 1H, J = 19.8 Hz, H-14α), 2.20 (m, 1H, H-1), 2.12 (s, 3H, Ac), 2.07 (s, 3H, Ac), 2.03 (m, 1H, H-7), 2.01 (s, 3H, Ac), 1.99 (d, 3H, J = 1.22 Hz, Me-18), 1.73 (s, 3H, Me-16), 1.23 (s, 3H, Me-19), 1.12 (s, 3H, Me-17); 13C-NMR (125 MHz, CDCl3) δ: 205.22 (C5), 198.54 (C13), 169.74, 169.65, 168.57 (4×Ac), 150.64, 137.80, 75.25, 72.86, 68.03, 61.34, 49.97, 48.58, 41.96, 41.92, 37.83, 36.82, 36.38, 34.36, 28.72, 25.44, 21.14, 20.88, 20.85, 20.64, 13.94; IR (film) νmax (CHCl3) cm−1: 3400 (w), 2950 (m), 1740 (s, C=O), 1670 (m), 1450 (s), 1370 (s), 1240 (s), 1140 (s), 1030 (s), 760 (s), 660 (m); HR-FABMS calcd for C26H34O9 (M+)[M+H] 490.2200, found 490.2204.

2α,9α,10β,13α-Tetraacetoxy-4α,20 : 11β,12β-diepoxytaxan-5α-ol (17a)

As amorphous solid; [α]D20 +12° (c 0.019, CHCl3); 1H-NMR (500 MHz, CDCl3) δ: 5.93 (d, 1H, J = 10.7 Hz, H-9), 5.51 (d, 1H, J = 3.4 Hz, H-2), 5.42 (d, 1H, J = 10.4 Hz, H-10), 5.31 (dd, 1H, J = 7.6 Hz, 10.0 Hz, H-13), 3.24 (br s, 1H, H-5), 3.20 (d, J = 4.6 Hz, 1H, H-20A), 3.00 (d, 1H, J = 3.9 Hz, H-3), 2.56 (d, 1H, J = 4.6 Hz, 1H, H-20B), 2.42 (dd, 1H, J = 9.8, 10.0, 15.9 Hz, H-14β), 2.13 (s, 3H, Ac), 2.05 (s, 3H, Ac), 2.04 (s, 3H, Ac), 1.90 (m, 1H, H-6), 1.89 (m, 2H, H-7, H-6), 1.88 (s, 3H, Me-18), 1.84 (dd, 1H, J = 7.6, 15.9 Hz, H-14α), 1.76 (m, 1H, H-6), 1.76 (s, 3H, Me-16), 1.70 (m, 1H, H-7), 1.00 (s, 3H, Me-19), 0.91 (s, 3H, Me-17); 13C-NMR (125 MHz, CDCl3) δ: 170.13, 169.91, 169.88, 168.60 (4×Ac), 77.22, 72.33, 70.48, 68.14, 64.48, 64.38, 61.29, 60.33, 50.11, 49.41, 42.49, 37.87, 36.74, 30.29, 28.06, 26.07, 25.42, 24.86, 21.05, 20.92, 20.67, 20.42, 16.25, 14.03; IR (film) νmax (CHCl3) cm−1: 3560 (m), 3500 (m), 2950 (s), 1730 (s, C=O), 1460 (s), 1430 (s), 1370 (s), 1220 (s), 1140 (m), 1060 (s), 1020 (s), 990 (s), 960 (s), 900 (w), 830 (m), 760 (s), 670 (m); HR-FABMS calcd for C28H40O11 (M+)[M+H] 552.2568, found 552.2570.

2α,9α,10β,13α-Tetraacetoxy-4β,20 : 11β,12α-diepoxytaxan-5α-ol (17b)

As amorphous solid; [α]D20 +12° (c 0.023, CHCl3); 1H-NMR (500 MHz, CDCl3) δ: (d, 1H, J = 11.0 Hz, H-9), 5.57 (d, 1H, J = 2.4 Hz, H-2), 5.39 (d, 1H, J = 10.7 Hz, H-10), 5.30 (dd, 1H, J = 7.8, 10.3 Hz, H-13), 3.59 (d, J = 5.1, 1H, H-20A), 2.76 (d, 1H, J = 3.1 Hz, H-3), 3.06 (br s, 1H, H-5), 2.48 (ddd, 1H, J = 9.8, 10.0, 15.9 Hz, H-14β), 2.29 (d, 1H, J = 5.1 Hz, 1H, H-20B), 2.12 (s, 3H, Ac), 2.02 (s, 6H, 2×Ac), 2.00 (s, 3H, Ac), 1.98 (m, 1H, H-6), 1.89 (dd, 1H, J = 3.9, 14.1 Hz, H-7), 1.83 (s, 3H, Me-18), 1.77 (m, 1H, H-7), 1.74 (s, 3H, Me-16), 1.77 (m, 1H, H-7), 1.74 (s, 3H, Me-16), 1.74 (m, 1H, H-7), 1.59 (m, 2H, H-1, H-14α), 1.15 (s, 3H, Me-19), 0.94 (s, 3H, Me-17); 13C-NMR (125 MHz, CDCl3) δ: 169.98, 169.77, 169.75, 168.45, 77.17, 76.57, 72.30, 70.45, 68.12, 64.47, 64.38, 61.32,
2α,9α,10β,13α-Tetraacetoxy-4α,20 : 11β,12β-diepoxo-5α-triethylsilyloxytaxane (18b)

As amorphous solid; $[\alpha]_D^{20} +28^\circ$ (c 0.0094, CHCl$_3$); $^1$H-NMR (500 MHz, CDCl$_3$) $\delta$: 5.97 (d, 1H, $J = 11.0$ Hz, H-9), 5.50 (br d, 1H, $J = 3.2$ Hz, H-2), 5.36 (d, 1H, $J = 11.0$ Hz, H-10), 5.36 (dd, 1H, $J = 9.8$, 9.8 Hz, H-13), 3.14 (br s, 1H, H-5), 2.96 (d, $J = 4.9$ Hz, H-20A), 2.90 (d, 1H, $J = 4.2$ Hz, H-3), 2.39 (d, 1H, $J = 4.9$ Hz, H-20B), 2.33 (ddd, 1H, $J = 9.8$, 9.8, 15.4 Hz, H-14β), 2.15 (s, 3H, Ac), 2.04 (s, 3H, Ac), 2.03 (s, 3H, Ac), 2.03 (s, 3H, Ac), 1.88 (m, 1H, H-7), 1.85 (s, 3H, Me-18), 1.82 (m, 1H, H-7), 1.82 (m, 1H, H-14α), 1.78 (s, 3H, Me-16), 1.76 (m, 1H, H-6), 1.75 (m, 1H, H-7), 1.66 (m, 2H, H-1, H-6), 1.03 (s, 3H, Me-17), 1.00-0.94 (m, 12H, Me-19, TES), 0.76 (m, 6H, TES); $^{13}$C-NMR (125 MHz, CDCl$_3$) $\delta$: 170.44, 169.87, 169.81, 169.69 (4×Ac), 77.20, 76.75, 72.63, 72.49, 69.53, 64.07, 64.64, 61.37, 50.98, 50.12, 43.75, 37.98, 37.36, 31.11, 28.58, 26.54, 26.51, 24.93, 21.66, 21.26, 20.82, 20.30, 18.02, 15.90, 6.84 (TES), 4.65 (TES); IR (film) $\nu$ max (CHCl$_3$) cm$^{-1}$: 2950 (m), 1740 (s, C=O), 1460 (m), 1370 (s), 1240 (s), 1140 (m), 1030 (m), 980 (s), 960 (s), 890 (w), 820 (m), 800 (w), 750 (m), 670 (w); HR-FABMS calcd for C$_{38}$H$_{55}$O$_{11}$Si (M+H)$^+$ 667.3510, found 667.3517.

REFERENCES
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18. The epoxide orientation of taxoids were decided by NOE correlation and distinguished with its diastereomer.\(^{11(a)}\) All 11,12-epoxides are \(\beta\)-oriented and it was confirmed by NOE correlation between H-18 and H-9. And all 4\(\alpha\),20-epoxides show NOE correlation between H-20A and H-19, for example