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Diene-transmissive Hetero Diels-Alder Reactions of Bis(silyloxy) Cross-conjugated Trienes with Azodicarbonyl Compounds

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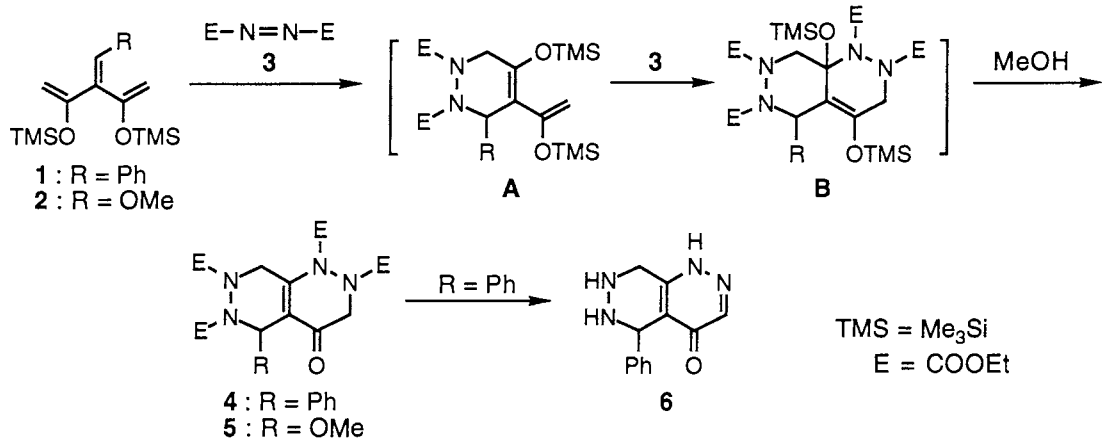
The first example for the diene-transmissive hetero Diels-Alder reaction of two bis(silyloxy) cross conjugated trienes, 3-benzylidene- and 3-(methoxymethylene)-2,4-bis(trimethylsilyloxy)-1,4-pentadiene, is presented by the reactions with azodicarbonyl compounds such as diethyl azodicarboxylate and triazolinediones. The cross type of the diene-transmissive reaction is also described.

The diene-transmissive Diels-Alder reaction of bis(silyloxy) cross-conjugated trienes, 3-benzylidene- **1** and 3-(methoxymethylene)-2,4-bis(trimethylsilyloxy)-1,4-pentadiene **2**, offers a direct and stereoselective synthetic route to highly functionalized hydronaphthalene skeletons.[1] This strategy using heterodienophiles has not been reported despite its apparent potential in synthesis. In this paper we wish to describe the diene-transmissive Diels-Alder reaction of the trienes, **1** and **2**, with acyclic and cyclic azodicarbonyl compounds such as azodicarboxylate and triazolinediones which have proved to be among the most reactive dienophiles and have been used extensively in synthesis.[2] The cross type of diene-transmissive hetero Diels-Alder reactions is also presented.

The reaction of **1** with diethyl azodicarboxylate **3** was first investigated. Even in the reaction with one equivalent of **3** no mono-adduct was obtained, but instead the desilylated diene-transmissive bis-adduct **4** (mp 126-126.5 °C) was formed exclusively and isolated, after the work-up with methanol, in a low yield. In the reaction using two equivalents of **3** the expected bis-adduct **4** was obtained in a moderate yield. Similarly, the only bis-adduct **5** (colorless oil) was isolated in the reaction of **2** with **3** (Table 1[3]).



Scheme 1.

Table 1. Reactions of trienes **1** and **2** with azodicarboxylate **3**[a)]

Entry	Triene	**3** (equiv)	Reaction Conditions		Product (yield/%)[b)]
			Temp	Time/h	
1	**1**	1.0	25 °C	96	**4** (9)
2	**1**	1.0	reflux	24	**4** (16)
3	**1**	2.1	reflux	24	**4** (51)
4	**2**	1.4	25 °C	16	**5** (31)[c)]
5	**2**	2.2	reflux	24	**5** (53)[c)]

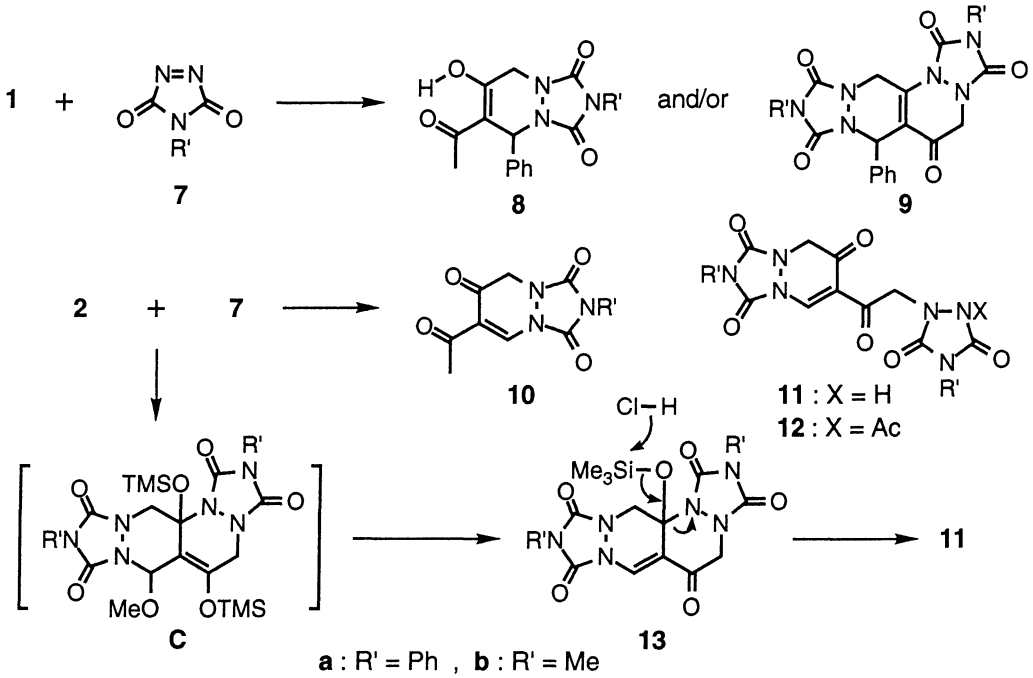
a) All the reactions were carried out in dry benzene under nitrogen.
b) Isolated yields based on the triene.
c) Together with 3 and 8% yields of an unidentified bis-adduct bearing a silyloxy group in entries 4 and 5, respectively.

The above diene-transmissive Diels-Alder reaction is illustrated in Scheme 1. The triene, **1** or **2**, reacts with **3** first to form a mono-cycloadduct **A**, which then smoothly undergoes the second reaction to afford a bis-cycloadduct **B**. Finally, the treatment of **B** with methanol gives the desilylated bis-adduct **4** or **5**, respectively.

Saponification of **4** with 10% aqueous sodium hydroxide in ethanol (at r.t. for 24 h) directly gave the hexahydropyridazinopyridazine **6** (mp 176-178 °C (dec)) in 57% yield.[3)]

The cycloaddition to 4-phenyl- **7a** and 4-methyl-1,2,4-triazoline-3,5-dione **7b** was next investigated. The triazolinediones **7** were found much more reactive than **3**. The reaction of **1** with one equivalent of **7a** in THF at 0 °C gave a mixture of the desilylated mono-adduct **8a** (mp 205-206 °C), and bis-adduct **9a** (mp 290-292 °C) after the work-up with 10% hydrochloric acid, whereas the desilylated bis-adduct **9b** (mp 239-240 °C) was only isolated in the reaction with **7b** under the same conditions. The reaction of **1** with two equivalents of triazolinediones **7a** or **7b** gave the desilylated bis-adduct **9a** or **9b** in fairly good yield, respectively (Table 2).

The activated triene **2** reacted with one equivalent of **7a** at 0 °C for 30 min, after the work-up with 10% hydrochloric acid, to give a good yield of the desilylated mono-adduct **10a** (190.5-191 °C (dec)) accompanied by



Scheme 2.

Table 2. Reaction of trienes **1** and **2** with triazolinediones **7**[a)]

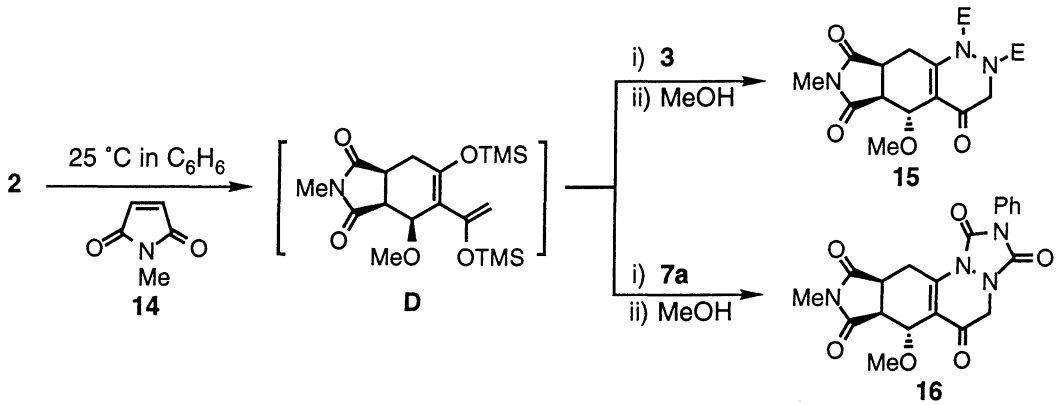
Entry	Triene	**7** (equiv)	Reaction Conditions			Product (yield/%)[b)]	
			Solvent	Temp	Time/h	Mono-adduct	Bis-adduct
1	**1**	**7a** (1.0)	THF	0 °C	1	**8a** (18)	**9a** (21)
2	**1**	**7a** (2.1)	THF	25 °C	5		**9a** (51)
3	**1**	**7a** (2.1)	DME	reflux	5		**9a** (62)
4	**1**	**7b** (1.0)	THF	0 °C	1		**9b** (19)
5	**1**	**7b** (2.1)	THF	25 °C	5		**9b** (60)
6	**1**	**7b** (2.1)	DME	reflux	5		**9b** (79)
7	**2**	**7a** (1.0)	THF	0 °C	0.5	**10a** (76)	
8	**2**	**7a** (2.0)	THF	25 °C	0.5		**11a** (88)
9	**2**	**7a** (2.2)	DME	reflux	5		**11a** (99)
10	**2**	**7b** (1.0)	THF	0 °C	0.5		**11b** (21)
11	**2**	**7b** (2.2)	DME	reflux	5		**11b** (79)

a) All the reactions were carried out in dry solvent under Nitrogen.
b) Isolated yields based on the triene.

the elimination of methanol.[4)] The reaction of **2** with two equivalents of **7a** in THF at 25 °C or in refluxing 1,2-dimethoxyethane (DME) afforded a desilylated ring-opening bis-adduct **11a** (mp 276-277 °C (dec)), which gave N-acetyl derivative **12a** (mp 256-258 °C (dec)) by the acetylation with acetic anhydride, in an excellent yield, respectively. In the reaction with **7b**, however, a similar novel ring-opening bis-adduct **11b** (mp 253-254 °C (dec)) was only isolated regardless of the reaction conditions (Table 2[5)]).

The mono-silyloxylated bis-adduct **13**[6)] was newly isolated, after the work-up with methanol, from the reaction of **2** with **7b** under the same reaction conditions as those of entry 11 in Table 2. This is the first example for the isolation of stable silyloxylated adduct from the reaction using **2**. On the treatment with 10% hydrochloric acid **13** was readily converted to **11b**. The isolation of **13** is noteworthy in connection with the pathway leading to the novel ring-opening bis-adduct **11**. The formation of **11** from the initial bis-cycloadduct **C** may be considered as illustrated in Scheme 2: The elimination of methanol from **C** and ring-opening of **13** arise from the process wherein the corresponding silyl enol ether in **C** or **13** is converted to the ketone, respectively.

Of great value as a synthetic tool is the cross type of diene-transmissive hetero Diels-Alder reaction. We have previously established that the most promising cross process of diene-transmissive Diels-Alder reaction of the trienes is achieved by using the reaction of **2** with cyclic electrophilic olefins at the first stage.[1b)] Thus, the first reaction of **2** with an equivalent of N-methylmaleimide **14** in benzene at 25 °C for 48 h followed by the second reaction with an equivalent of azodicarboxylate **3** (in refluxing benzene for 34 h) or triazolinedione **7a** (in



Scheme 3.

benzene at 25 °C for 5 h) after the work-up with methanol, the cross bis-adduct **15** (mp 53-54 °C) or **16** (213-214 °C (dec)) in 35 or 36% yield, respectively (Scheme 3). It was assigned on the basis of spectral data[7] that the initially formed ring of **15** or **16** had trans configuration. It means that the stereochemistry of the initial endo mono- cycloadduct **D** of **2** to **14** was inverted; such an inversition of stereochemistry has been often observed in the diene-transmissive Diels-Alder reactions of **2**.[1]

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References

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2) As reviews: S. M. Weinreb and R. R. Staib, *Tetrahedron*, **38**, 3087 (1982); C. J. Moody, *Adv. Heterocycl. Chem.*, **30**, 1 (1982).

3) All the new compounds reported herein were characterized by spectroscopy and microanalysis. Spectroscopic data for **4**: IR (KBr) 1738, 1688 cm^{-1}; ^1H NMR ($CDCl_3$) δ=0.72 (3H, t, J=7.2 Hz), 1.28, 1.29, 1.36 (each 3H, t, J=7.0 Hz), 3.26-5.43 (12H, m), 6.21 (1H, br s, 5-H), 7.26 (5H, s); MS m/z 518 (M^+). **6**: IR (KBr) 3262, 1658 cm^{-1}; ^1H NMR ($(CD_3)_2CO$-DMSO-d_6) δ=2.85-3.80 (3H, br, N**H**), 3.82 (2H, s), 4.80 (1H, s, 5-**H**), 7.26 (5H, s), 7.63 (1H, s, 3-**H**); MS m/z 228 (M^+).

4) Adducts accompanied by the elimination of methanol were often formed in the reaction using **2**.[1]

5) Spectroscopic data of **9b**, **10a** and **11b** are shown. **9b**: IR (KBr) 1775, 1740, 1715, 1676 cm^{-1}; ^1H NMR ($CDCl_3$-DMSO-d_6) δ=2.91, 3.19 (each 3H, s), 4.32, 4.34 (each 1H, s), 4.63 (1H, dd, J=1.0, 18.6 Hz, changed to a doublet on irradiation at δ=5.94), 5.54 (1H, d, J=18.6 Hz), 5.94 (1H, d, J=1.0 Hz, 7-H), 7.30 (5H, s); ^{13}C NMR ($CDCl_3$-DMSO-d_6) δ=25.27, 25.75, 43.14, 50.57, 54.72, 111.40, 128.29, 128.59, 129.13, 135.15, 140.40, 147.22, 151.38, 152.87, 154.26, 180.92; MS m/z 396 (M^+). **10a**: IR (KBr) 1742, 1711, 1688, 1661 cm^{-1}; ^1H NMR ($CDCl_3$-DMSO-d_6) δ=2.47 (3H, s), 4.46 (2H, s), 7.53 (5H, s), 8.46 (1H, s, =C**H**); ^{13}C NMR ($CDCl_3$-DMSO-d_6) δ=29.84, 50.12, 112.66, 125.37, 128.36, 128.63, 129.90, 136.32, 144.85, 149.50, 182.02, 192.24; MS m/z 285 (M^+). **11b**: IR (KBr) 3260, 1800, 1752, 1698, 1676 cm^{-1}; ^1H NMR (DMSO-d_6) δ=2.92, 3.07 (each 3H, s), 4.38 , 4.72 (each 2H, s), 8.40 (1H, s, =C**H**), 9.94 (1H, br s, N**H**); ^{13}C NMR (DMSO-d_6) δ=24.63, 25.54, 50.26, 55.03, 109.73, 137.23, 146.24, 151.35, 154.25, 155.71, 183.13, 188.27; MS m/z 336 (M^+).

6) **13**: Mp 202-206 °C (dec), colorless prisms. IR (KBr) 1777, 1729, 1700 cm^{-1}; ^1H NMR ($CDCl_3$-DMSO-d_6) δ=0.04 (9H, s, $Si(CH_3)_3$), 3.04, 3.08 (each 3H, s), 3.64, 4.98 (each 1H, d, J=11.7 Hz), 4.11, 4.52 (each 1H, d, J=17.9 Hz), 7.91 (1H, s, =C**H**); ^{13}C NMR ($CDCl_3$-DMSO-d_6) δ=0.01, 24.09, 24.52, 48.78, 50.90, 81.27, 107.90, 124.64, 145.64, 151.31, 151.96, 153.17, 184.11; MS m/z 408 (M^+).

7) **15**: IR (KBr) 1770 (sh), 1720, 1709, 1665 cm^{-1}; ^1H NMR ($CDCl_3$) δ=1.28, 1.37 (each 3H, t, J=7.1 Hz), 2.90-3.17 (10H, m), 4.12-4.47 (6H, m), 5.07 (1H, d, J=3.9 Hz, 5-**H**); MS m/z 409 (M^+). **16**: IR (KBr) 1773, 1731, 1698, 1676 cm^{-1}; ^1H NMR (DMSO-d_6) δ=2.58-4.66 (6H, m), 2.86 (3H, s), 3.02 (3H, s), 3.13 (1H, dd, J=4.0, 11.9 Hz, 7a-**H**, changed to doublet on irradiation at δ=4.91), 4.91 (1H, d, J=4.0 Hz, 7-**H**), 7.53 (5H, s); ^{13}C NMR (DMSO-d_6) δ=20.87, 24.27, 35.46,, 44.90, 50.24, 55.84, 67.29, 110.78, 126.68, 128.80, 129.10, 130.39, 146.56, 149.94, 150.35, 175.74, 178.76, 182.23; MS m/z 410 (M^+).

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