

Discussion. Fig. 1 is an *ORTEPII* diagram (Johnson, 1976) of the molecule (deleting the acetonitrile of crystallization) illustrating 50% probability ellipsoids for all non-H atoms and with an arbitrary sphere of radius about 0.4 Å for H atoms. Atomic positions are listed in Table 1 and distances and angles between all non-H atoms are shown in Table 2.* The structure determined for compound (I) shows that it is the 5-chloro (not 8-chloro) isomer. Thus the condensation reaction between 1,2-diamino-3-chlorobenzene and butyl glyoxalate produces 5-chloro-2-quinoxalinol. The distance between the proton on N(3) and N(5) is 1.98 Å which is shorter than the combined van der Waals radii of 2.7 Å suggesting a hydrogen bond between the molecule and solvate (Hamilton & Ibers, 1968).

* Lists of structure factors, anisotropic thermal parameters and H-atom coordinates have been deposited with the British Library Lending Division as Supplementary Publication No. SUP 42149 (20 pp.). Copies may be obtained through The Executive Secretary, International Union of Crystallography, 5 Abbey Square, Chester CH1 2HU, England.

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Structure of Laserolide [*trans,trans*-Germacra-1(10),4-dien-*cis*-6,12-olide], C₂₂H₃₀O₆, from the Family Umbelliferae

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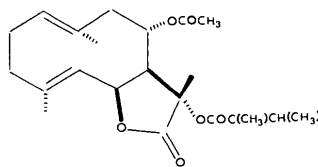
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Abstract. *M_r* = 390.48, monoclinic, *P*2₁, *a* = 6.566 (1), *b* = 12.551 (1), *c* = 12.836 (2) Å, β = 94.83 (1)°, *U* = 1054.1 (2) Å³, *Z* = 2, *D_m* = 1.25, *D_x* = 1.23 Mg m⁻³, Cu *K*α, λ = 1.54184 Å, μ = 0.73 mm⁻¹, *F*(000) = 420, *T* = 293 K, *R* = 0.044 for 1432 observed reflections. Laserolide (I) belongs to a relatively recently discovered stereochemical group of germacranolides which are derived from the (*E,E*)-6αH,7αH-germacra-1(10),4-dien-6,12-olide skeleton. It possesses stereochemical features characteristic for that group [chair-boat conformation of the 10-membered ring and *syn* α orientation of the methyl groups at C(4) and C(10)]. It differs from previously investigated compounds in the degree of saturation as well as in the conformational type of the γ-lactone.

Introduction. The sesquiterpene lactone laserolide (I) was isolated from the root of the species *Laser trilobium* (L.) Borkh. (family Umbelliferae, tribe Laserpitieae) (Holub, de Groote, Herout & Šorm, 1968), and its basic structure was deduced by means of chemical

and spectroscopic methods (Holub, Samek, Popa, Herout & Šorm, 1970). The present X-ray study verifies the stereochemistry of (I) and firmly establishes that laserolide belongs to the group of ursiniolides, relatively recently described *trans,trans*-germacranolides with the lactone ring closed at C(6) and *cis*-annulated to a ten-membered homocycle (Samek, Holub, Rychlewska, Grabarczyk & Drożdż, 1979; Herz, Govindan & Blount, 1980). Moreover, laserolide is the first native substance from the Umbelliferae family which has been demonstrated to belong to this stereochemical group.



(I)

Experimental. Crystal grown from mixture of propanol and isopropyl ether; D_m by flotation; cell parameters by least-squares refinement of setting angles of 15 reflections centered on Syntex $P2_1$ diffractometer; crystal $0.2 \times 0.3 \times 0.4$ mm; $\theta-2\theta$ scan, variable scan rate; graphite-monochromated Cu $K\alpha$ radiation; 1496 reflections, $2\theta \leq 115^\circ$, $h-7$ to 7 , $k0$ to 13 , $l0$ to 13 ; background and integrated intensity for each reflection evaluated from profile analysis according to Lehmann & Larsen (1974) using program *PRARA* (Jaskólski, 1981); no absorption correction; 1435 reflections with $I \geq 1.96\sigma(I)$ considered significant; three additional reflections omitted; structure solved with *MULTAN* (Germain, Main & Woolfson, 1971), and refined with *SHELX76* (Sheldrick, 1976); anisotropic refinement of nonhydrogen atoms. H atoms treated as follows: methyl groups refined as rigid groups with common isotropic temperature factor which refined to $U = 0.17(1) \text{ \AA}^2$; the remaining H atoms placed in calculated positions and refined using a 'riding model'; the common temperature factor for the group converged at $U = 0.082(5) \text{ \AA}^2$. Unit weights used in the refinement based on F ; $R = 0.044$ for 1432 observations and 272 refined parameters; in final cycle of refinement average and max. Δ/σ 0.17 and 2.4, respectively [max. shift corresponded to rotation of the C(20) methyl group]; residual fluctuations in the difference map within the range $\pm 0.19 e \text{ \AA}^{-3}$; atomic scattering factors of *SHELX76* used.

Discussion. Final atomic coordinates are given in Table 1.* X-ray analysis establishes the structure and relative stereochemistry of laserolide as shown in (I). Moreover, on the basis of CD studies (Holub, Buděšinský, Smitalová, Saman & Rychlewska, 1984) it can be assumed that (I) also represents the absolute stereochemistry. Fig. 1 shows a view of the β face of the molecule and the atom numbering scheme (*PLUTO78*,

* Lists of structure factors, anisotropic thermal parameters and H-atom parameters have been deposited with the British Library Lending Division as Supplementary Publication No. SUP 42101 (9 pp.). Copies may be obtained through The Executive Secretary, International Union of Crystallography, 5 Abbey Square, Chester CH1 2HU, England.

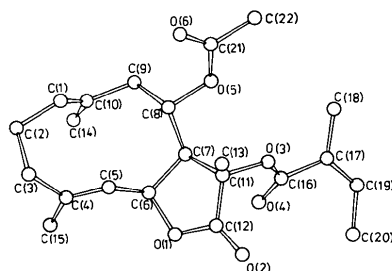


Fig. 1. View of the β face of the molecule of laserolide and the atom-numbering scheme.

Table 1. Final fractional coordinates ($\times 10^4$) and equivalent isotropic thermal parameters ($\text{\AA}^2 \times 10^4$)

$$U_{eq} = (U_{11}U_{22}U_{33})^{1/3}.$$

	<i>x</i>	<i>y</i>	<i>z</i>	U_{eq}
O(1)	-1196 (6)	-1757 (4)	-8346 (3)	626 (14)
O(2)	-1471 (7)	-2747 (4)	-6917 (3)	716 (17)
O(3)	-2899 (5)	-762	-6029 (2)	509 (12)
O(4)	458 (5)	-696 (5)	-6211 (2)	643 (14)
O(5)	-5122 (5)	994 (4)	-7103 (3)	561 (13)
O(6)	-8375 (6)	1328 (5)	-7756 (3)	789 (17)
C(1)	-5255 (10)	1108 (5)	-10541 (4)	664 (23)
C(2)	-4933 (12)	671 (6)	-11628 (4)	715 (25)
C(3)	-4601 (11)	-566 (6)	-11540 (4)	671 (23)
C(4)	-2883 (9)	-803 (5)	-10719 (4)	572 (20)
C(5)	-3354 (8)	-893 (5)	-9734 (3)	492 (18)
C(6)	-1903 (8)	-724 (6)	-8784 (3)	518 (17)
C(7)	-2819 (7)	-132 (5)	-7856 (3)	443 (16)
C(8)	-4610 (8)	634 (5)	-8129 (4)	486 (17)
C(9)	-4141 (9)	1652 (5)	-8742 (4)	572 (21)
C(10)	-3777 (9)	1487 (5)	-9876 (4)	543 (21)
C(11)	-3269 (7)	-1048 (5)	-7125 (3)	474 (17)
C(12)	-1843 (8)	-1947 (6)	-7406 (4)	565 (20)
C(13)	-5459 (9)	-1500 (6)	-7229 (4)	619 (21)
C(14)	-1651 (11)	1759 (7)	-10142 (5)	894 (29)
C(15)	-777 (10)	-756 (7)	-11066 (4)	830 (26)
C(16)	-908 (9)	-587 (5)	-5682 (4)	547 (19)
C(17)	-758 (10)	-210 (6)	-4570 (4)	675 (23)
C(18)	-2307 (12)	617 (7)	-4285 (5)	999 (33)
C(19)	790 (12)	-559 (8)	-3922 (5)	882 (31)
C(20)	2321 (14)	-1383 (8)	-4137 (7)	1183 (42)
C(21)	-7088 (10)	1347 (5)	-7041 (5)	668 (24)
C(22)	-7335 (10)	1781 (7)	-5962 (5)	896 (29)

Table 2. Bond distances (\AA) and angles ($^\circ$)

C(1)–C(2)	1.531 (8)	C(11)–O(3)	1.452 (5)
C(1)–C(10)	1.326 (9)	C(11)–C(12)	1.529 (8)
C(2)–C(3)	1.571 (10)	C(11)–C(13)	1.541 (8)
C(3)–C(4)	1.508 (8)	C(12)–O(1)	1.334 (6)
C(4)–C(5)	1.331 (7)	C(12)–O(2)	1.198 (8)
C(4)–C(15)	1.489 (9)	C(16)–O(3)	1.363 (7)
C(5)–C(6)	1.499 (7)	C(16)–O(4)	1.177 (7)
C(6)–O(1)	1.473 (8)	C(16)–C(17)	1.498 (8)
C(6)–C(7)	1.566 (7)	C(17)–C(18)	1.520 (11)
C(7)–C(8)	1.537 (8)	C(17)–C(19)	1.333 (10)
C(7)–C(11)	1.529 (8)	C(19)–C(20)	1.483 (13)
C(8)–O(5)	1.458 (6)	C(21)–O(5)	1.373 (7)
C(8)–C(9)	1.545 (8)	C(21)–O(6)	1.195 (8)
C(9)–C(10)	1.509 (8)	C(21)–C(22)	1.509 (10)
C(10)–C(14)	1.504 (9)		
C(6)–O(1)–C(12)	112.9 (4)	C(1)–C(10)–C(14)	125.4 (5)
C(11)–O(3)–C(16)	115.8 (3)	C(9)–C(10)–C(14)	114.4 (5)
C(8)–O(5)–C(21)	116.2 (4)	O(3)–C(11)–C(7)	112.6 (4)
C(2)–C(1)–C(10)	124.5 (5)	O(3)–C(11)–C(12)	110.8 (4)
C(1)–C(2)–C(3)	108.5 (5)	C(7)–C(11)–C(12)	104.9 (4)
C(2)–C(3)–C(4)	109.7 (5)	O(3)–C(11)–C(13)	104.8 (4)
C(3)–C(4)–C(5)	117.4 (4)	C(7)–C(11)–C(13)	116.8 (4)
C(3)–C(4)–C(15)	116.2 (5)	C(12)–C(11)–C(13)	107.0 (4)
C(5)–C(4)–C(15)	125.7 (5)	O(1)–C(12)–O(2)	123.8 (5)
C(4)–C(5)–C(6)	125.3 (4)	O(1)–C(12)–C(11)	109.2 (4)
C(5)–C(6)–O(1)	110.2 (4)	O(2)–C(12)–C(11)	126.7 (5)
O(1)–C(6)–C(7)	104.9 (4)	O(3)–C(16)–O(4)	123.3 (4)
C(5)–C(6)–C(7)	115.3 (4)	O(3)–C(16)–C(17)	110.3 (4)
C(6)–C(7)–C(8)	117.3 (4)	O(4)–C(16)–C(17)	126.4 (4)
C(6)–C(7)–C(11)	102.5 (4)	C(16)–C(17)–C(18)	116.9 (5)
C(8)–C(7)–C(11)	115.3 (4)	C(16)–C(17)–C(19)	118.5 (5)
C(7)–C(8)–O(5)	102.6 (4)	C(18)–C(17)–C(19)	124.4 (6)
O(5)–C(8)–C(9)	105.9 (4)	C(17)–C(19)–C(20)	127.4 (6)
C(7)–C(8)–C(9)	116.9 (4)	O(5)–C(21)–O(6)	123.8 (5)
C(8)–C(9)–C(10)	115.6 (4)	O(5)–C(21)–C(22)	110.1 (5)
C(1)–C(10)–C(9)	120.2 (5)	O(6)–C(21)–C(22)	126.1 (5)

Table 3. Selected torsion angles ($^{\circ}$) in (*E,E*)-6 α H,7 α H-germacra-1(10),4-dien-6,12-olides

	(I)	(II)	(III)	(IV)	(V)
C(10)–C(1)–C(2)–C(3)	92.8	91.3	99.8	96.3	106
C(1)–C(2)–C(3)–C(4)	–54.3	–53.6	–53.5	–52.4	–54
C(2)–C(3)–C(4)–C(5)	86.9	80.3	86.5	87.2	80
C(3)–C(4)–C(5)–C(6)	–156.1	–163.2	–161.1	–167.3	–172
C(4)–C(5)–C(6)–C(7)	140.5	122.5	106.6	107.9	83
C(5)–C(6)–C(7)–C(8)	–27.0	14.4	28.7	27.9	50
C(6)–C(7)–C(8)–C(9)	–67.2	–78.7	–103.4	–93.6	–118
C(7)–C(8)–C(9)–C(10)	72.5	43.3	58.9	51.7	57
C(8)–C(9)–C(10)–C(1)	63.1	91.3	73.2	79.5	61
C(9)–C(10)–C(1)–C(2)	–165.3	–166.2	–165.7	–164.8	–172
O(1)–C(6)–C(7)–C(11)	–21.0	16.2	29.5	26.5	
C(6)–C(7)–C(11)–C(12)	23.2	–12.8	–24.5	–23.7	
C(7)–C(11)–C(12)–O(1)	–18.2	4.4	10.7	12.2	
C(11)–C(12)–O(1)–C(6)	4.3	7.0	9.8	6.6	
C(12)–O(1)–C(6)–C(7)	11.0	–15.0	–25.6	–21.8	

Motherwell & Clegg, 1978). Bond lengths and angles are listed in Table 2. The conformation of the ten-membered ring in laserolide can be described as a chair–boat, which is one of the two frequently occurring conformations for cyclodeca-*trans,trans*-1(10),4-diene (Bovill, Cox, Cradwick, Guy, Sim & White, 1976). The methyl groups at C(10) and C(14) are *syn* and on the α face of the macrocycle. The spatial arrangement of the substituents at the double bonds can be described by the two-dimensional representation given by Samek & Harmatha (1978) as ${}^1D_{14}, {}_{15}D^5$. Similar chair–boat conformations of the cyclodecadiene ring have been found in all three *trans,trans*-germacranolides with *cis*-fused γ -lactone rings previously studied by X-ray methods (Herz, Govindan & Blount, 1980; Rychlewska, 1981). The torsion angles for these ten-membered rings are listed in Table 3 and are compared with the theoretical values obtained for one of the forms of dimethylcyclodecadiene (Guy, Sim & White, 1976); the torsion angles are substantially similar for all compounds. Some differences appear as a result of different orientations of the substituents at C(8) [α in (I), (III) and (IV), β in (II)] and the presence of the saturated lactone in (I). The chair–boat conformation enables the formation of the fully equatorial *cis*-fused γ -lactone at C(6)–C(7). *cis*-Fusion, however, introduces some strain to the cyclodecadiene skeleton owing to a requirement for both torsion angles at the junction to be nearly identical. This is reflected in the difference between the value of 50° calculated for the C(5)–C(6)–C(7)–C(8) torsion angle and the range of observed values [14.4 to 28.7° with an average of 24.5 (6.7°)].

The C(5)–C(6)–C(7)–C(8) torsion angle in laserolide [-27.0 (5°)] is comparable in magnitude to the values found in other structures, but is of opposite sign. The change in sign at the ring fusion, presumably introduced to minimize unfavourable interactions between axial H atoms at C(5) and C(8), causes a change in the conformational type of the γ -lactone ring. The γ -lactone ring in laserolide adopts a conformation in which the C(7)–H(7) and C(6)–O(1) bonds are synclinal giving rise to a negative torsion angle at the junction [O(1)–C(6)–C(7)–C(11)], while in the compounds studied previously the mutual orientation of the C(7)–H(7) and C(6)–O(1) bonds was antiperiplanar (*A* type) causing the torsion angle at the junction to be positive (Table 3). Thus if we extend the notation of Samek (1978) (originally used for α -methylene- γ -lactones) to the saturated γ -lactones, the present compound has conformational type *S* while all previous examples (Herz, Govindan & Blount, 1980; Rychlewska, 1981) are type *A*.

The mode of puckering of the γ -lactone ring in laserolide is also somewhat different from that observed previously. The five-membered ring adopts the 7- α -envelope conformation, common among saturated sesquiterpenoid γ -lactones (McPhail & Onan, 1976). In the three previous structures the conformation of the α -methylene- γ -lactone more closely resembles a half-chair form.

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