A Pummerer-Type Novel Ring Fission of 2-Methylsulfinyl-5,6-dihydro-4*H*-1,3,4-thiadiazine Derivatives: A Homologation of Aldehydes and Ketones

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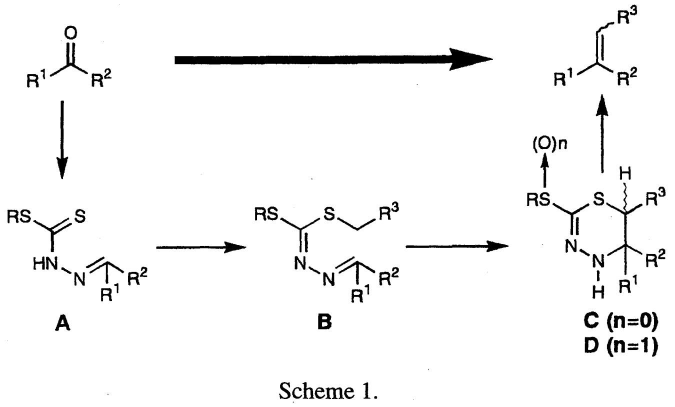
Aldehydes and ketones were converted into 2-methylsulfinyl-5,6-dihydro-4*H*-1,3,4-thiadiazines via the formation and base-induced ring-closure of *N*-alkylidene-*N*′-bis(alkylthio)methylenehydrazines followed by mCPBA oxidation. The subsequent Pummerer-type ring fission of the rings was performed by treating with trifluoroacetic anhydride or trifluoromethanesulfonic anhydride at −78 °C to give α,β-unsaturated esters and ketones in modest yields. Thus, this reaction sequence was regarded as being a new method for the two-carbon homologation of aldehydes and ketones.

Among the derivatives of multifunctionalized dithiocarbamates, alkylidenehydrazinecarbodithioates **A** have been widely studied as the synthetic precursors of 1,3,4-thiadiazine and 1,3,4-thiadiazole ring systems which exhibit various biological activities.[1,2] However, only slight attention has been paid to the synthetic applications of the intramolecular C–C bond formation of *S*,*S*′-dialkylated derivatives **B**, owing to the lack of removing heteroatoms from the ring-closure products **C**. During the course of our studies on the synthetic use of thiocarbonate derivatives, we expected that the multifunctionalized hydrazones **B**, constructed from aldehydes or ketones, hydrazine monohydrate, carbon disulfide, alkyl halide (iodomethane), and alkylating agents, would cause an α-sulfenyl carbanion-induced ring-closure to give 5,6-dihydro-4*H*-1,3,4-thiadiazines **C**.[3] Furthermore, it was also expected that the subsequent removal of the heteroatoms of **C** or **D** could be carried out by eliminative ring fission[4] or [4+2]-type cycloreversion. Recently, we have reported on the trifluoroacetic anhydride-induced eliminative ring fission of 2-methylsulfinyl-5,6-dihydro-4*H*-1,3,4-thiadiazines **C** ($R=CH_3$) under mild reaction conditions[5] via the Pummerer intermediates.[6] This report gives a full account of the homologation of aldehydes and ketones using our original sequence including the formation of **C** and Pummerer-type ring fission of the corresponding sulfoxides **D**, as shown in Scheme 1.

Results and Discussion

Preparation of *N*-Alkylidene-*N*′-bis(alkylthio)methylenehydrazines (5). *S*-Methyl alkylidenehydrazinecarbodithioates (**1**—**4**) were easily prepared either by treating a benzene or a toluene solution of methyl dithiocarbazate ($CH_3SCSNHNH_2$) with 1 equimolar amount of aldehydes or ketones or by a sequential treatment of an ethanolic solution of aldehydes or ketones with hydrazine monohydrate, KOH, carbon disulfide, and iodomethane according to Busch's method.[1] Subsequently, a solution of **1**—**4** was treated with a base (1.1 mol amt. of KOH or NaH in EtOH or THF, respectively) and an alkylating agent (1.1 mol amt. of ethyl bromoacetate, chloroacetone, α-bromoacetophenone, or α-bromoacetonitrile) to give *N*-alkylidene-*N*′-bis(alkyl-

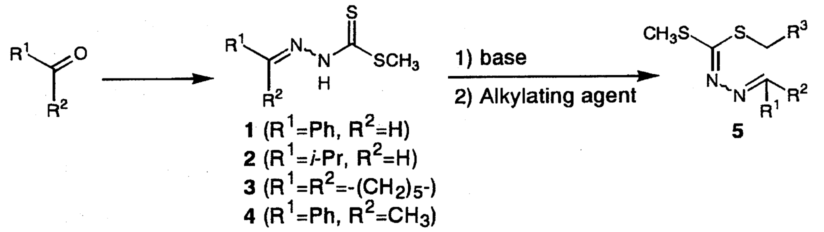


Scheme 1.

thio)methylenehydrazines (**5**) as the inseparable mixture of *syn* and *anti* isomers (Scheme 2).[7] In all cases, the ^{13}C NMR spectra of **5** showed two pairs of the significant signals at the $\delta = 130$—170 ppm regions assigned to the two sp^2 carbons of azine moiety of **5**. These results clearly indicated that **5** possess acyclic structures in contrast with the results of Evans and Myers.[3]

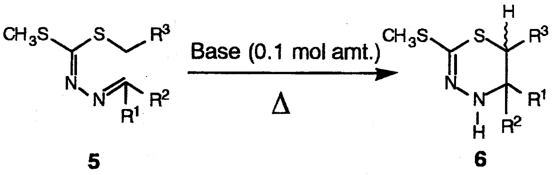
Preparation of 2-Methylthio-5,6-dihydro-4*H*-1,3,4-thiadiazines (6). Heating a THF or a benzene solution of **5** in the presence of a catalytic amount of base (NaH or *t*-BuOK, 0.1 mol amt.) for a few hours under a N_2 atmosphere afforded the ring-closure products **6** as a mixture of *cis* and *trans* isomers; each isomer was separated by column chromatography on silica gel. The MS, IR, and ^{1}H NMR spectra of each isomer showed a similar pattern. The relative stereochemistry of the isomers was confirmed by the *J* values between the H-5 and H-6 protons in the ^{1}H NMR spectra.[7] The treatment of a solution of **5** possessing various substituents with a base also gave the corresponding ring-closure products, 5,6-dihydro-4*H*-1,3,4-thiadiazines **6**, in good yields; all of the results are given in Table 1.

Interestingly, a treatment of **5a** (R^1 = Ph, R^2 = H, R^3 = CO_2Et) with a base under mild reaction conditions (0.1 mol amt. of NaH in benzene at 55 °C) afforded *cis*-**6a** predominantly. On the other hand, *trans*-**6a** was mainly obtained when **5a** was treated with the same base, but at higher temperature, using THF in place of benzene, or by treating *t*-BuOK in place of NaH. Base-induced equilibration was also observed by treating a THF solution of either *trans*-**6a** or *cis*-**6a** with a catalytic amount of NaH or *t*-BuOK under a higher temperature to give the same mixture of *trans*-**6a** and *cis*-**6a** in 95 : 5 ratio, respectively. The use of tertiary amines (triethylamine or DBU) in place of NaH or *t*-BuOK was ineffective for the ring-closure of **5a**, even if an equimolar amount of the amine was treated with the solution of **5a**. In addition, the ring-closure of **5g** was not successful, and the starting **5g** was recovered in all cases. From these results, a few features of the reactions were significantly revealed: (1) The intramolecular complexation of the ester enolates of **5** with the nitrogen atom of the hydrazone moiety promotes the approach of two reaction sites of **5** in the primary stage. (2) The *cis* isomers are formed as the primary ring-closure products owing to a steric repulsion between the phenyl group and the dithiocarbamate moiety, as shown in Scheme 3. (3) The



Scheme 2.

Table 1. Preparation of 2-Methylthio-5,6-dihydro-4*H*-1,3,4-thiadiazines (**6**) by Base-Induced Ring Closure of **5**



Substrate				Base	Solvent	Temp	Time	Yield[a]		Ratio[b]
R^1	R^2	R^3	5			°C	h	%		*cis* : *trans*
Ph	H	CO_2Et	**5a**	NaH	Benzene	55	4	72	(**6a**)	98 : 2
Ph	H	CO_2Et	**5a**	NaH	THF	Reflux	3	89	(**6a**)	7 : 93
Ph	H	CO_2Et	**5a**	Et_3N[c]	Benzene	Reflux	3	0	(**6a**)[d]	—
Ph	H	CO_2Et	**5a**	DBU[c]	Benzene	Reflux	3	0	(**6a**)[d]	—
Ph	H	$COCH_3$	**5b**	NaH	Benzene	65	4	89	(**6b**)	5 : 95
Ph	H	COPh	**5c**	NaH	Benzene	65	4	82	(**6c**)	0 : 100
Ph	H	CN	**5d**	*t*-BuOK	Benzene	Reflux	1	93	(**6d**)	40 : 60[e]
i-Pr	H	CO_2Et	**5e**	NaH	Benzene	65	4	97	(**6e**)	15 : 85
$-(CH_2)_5-$		CO_2Et	**5f**	*t*-BuOK	Benzene	Reflux	1	75	(**6f**)	—
Ph	CH_3	CO_2Et	**5g**	*t*-BuOK	Benzene	Reflux	3	Trace	(**6g**)[d]	—

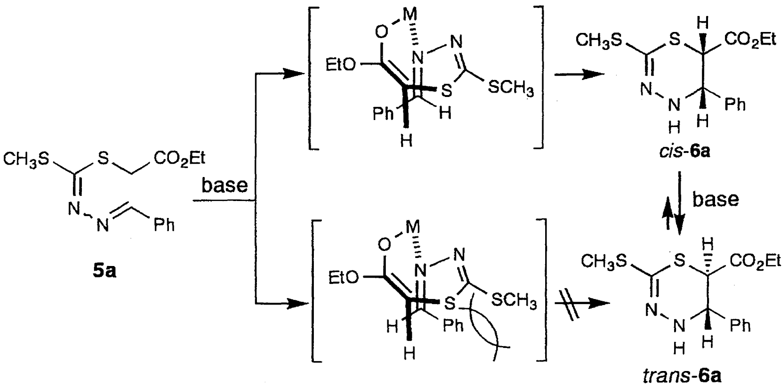
a) Combined yields. b) Determined by the integration of the ^{1}H NMR spectra of the isomeric mixture of **6**. c) 1 Molar amount of amine was treated with a benzene solution of **5a**. d) The starting materials (**5**) were recovered. e) The ratio of the inseparable isomers was determined by the integration of ^{1}H NMR spectrum of **6d**.

cis isomers are urged to isomerize to the thermodynamically more stable *trans* isomers via base-induced equilibration.

mCPBA Oxidation of 2-Methylthio-5,6-dihydro-4*H*-1,3,4-thiadiazines (C). Treating a dichloromethane solution of *cis*-**6** or *trans*-**6** with mCPBA (1.1 mol amt.) at 0 °C afforded the corresponding sulfoxides **7** in high yields as an inseparable diastereomeric mixture at S–O bonds on the sulfur atom of the methylthio groups. All of the physical data and the elemental-analysis data were consistent with the structures of **7**. The significant downfield shift of one methyl signal of *trans*-**7a** in both the ^{1}H NMR and the ^{13}C NMR spectra strongly suggested that **7** possessed methylsulfinyl groups at C-2 position in all cases. It was supposed that the less-crowded sulfur atoms were chemoselectively oxidized by mCPBA to give the corresponding methylsulfinyl derivatives. However, the relative structures of each isomer were not clarified from the spectral data. All results of the oxidation of **6** are given in Table 2.

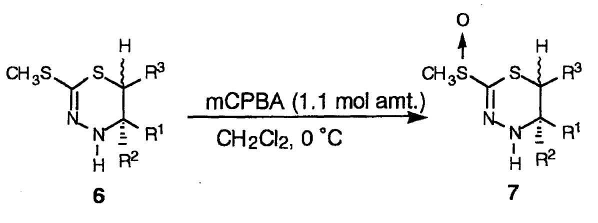
Thermal Ring Fission of 2-Methylthio-5,6-dihydro-4*H*-1,3,4-thiadiazines (6) and 2-Methylsulfinyl-5,6-dihydro-4*H*-1,3,4-thiadiazines (7). When a decalin solution of *trans*-**6a** was heated at 200 °C for 48 h in a sealed tube, a small amount of ethyl cinnamate (*E*-**8a**, 13%) was obtained along with the recovered *trans*-**6a**. This result indicated that the 5,6-dihydro-4*H*-1,3,4-thiadiazine rings are urged to undergo a retro [4+2]-type cycloreversion at a much higher temperature. On the other hand, upon heating of *trans*-**7a** at 125 °C for 26 h in a sealed tube the yield of *E*-**8a** increased to 30% along with the deoxygenation product (*trans*-**6a**, 50%). Heating of a benzene solution of *trans*-**7a** in the presence of $Et_2O{\cdot}BF_3$ (1.0 mol amt.) or chlorotrimethysilane (1.0 mol amt.) at 80 °C for 1 h gave *E*-**8a** in rather low yields (18 and 14%, respectively) along with the deoxygenated product (*trans*-**6a**, 36 and 46%, respectively).

Pummerer-Type Eliminative Ring Fission of 2-Methylsulfinyl-5,6-dihydro-4*H*-1,3,4-thiadiazines (7). Espe-



Scheme 3.

Table 2. Preparation of Diastereomeric Mixtures of 2-Methylsulfinyl-5,6-dihydro-4*H*-1,3,4-thiadiazines (**7**) [a]



Substrate				Yield[b,c]		δ_{CH_3}/ppm[d]		δ_{CH_3}/ppm[e]
R^1	R^2	R^3	**6**	%	(major : minor)[f]	major	minor	
Ph	H	CO_2Et	*trans*-**6a**	84	(5 : 4)	2.80	2.83	40.4 (br)
Ph	H	CO_2Et	*cis*-**6a**	81	(5 : 4)	2.81	2.74	40.2, 40.3
Ph	H	$COCH_3$	*trans*-**6b**	78	(9 : 8)	2.77	2.79	40.1, 40.3
Ph	H	COPh	*trans*-**6c**	96	(3 : 1)	2.69	2.84	40.4, 40.5
Ph	H	CN	**6d**[g]	96	(5 : 4 : 1)	2.81, 2.80, 2.90		40.67, 40.73 40.80
i-Pr	H	CO_2Et	*trans*-**6e**	78	(5 : 4)	2.79	2.81	40.0 (br)
$-(CH_2)_5-$		CO_2Et	**6f**	98	(3 : 2)	2.79	2.75	40.2 (br)

a) A dichloromethane solution of **2** was treated with mCPBA (1.1 mol amt.) at −78 °C for 1 h. b) Isolated yields. c) Combined yields of the diastereomers. d) The ^{1}H NMR chemical shifts of 2-methylsulfinyl group of **7**. e) The ^{13}C NMR chemical shifts of 2-methylsulfinyl group of **7**. f) Determined by the integration of ^{1}H NMR spectra of the mixture. g) A mixture of *cis*-**6d** and *trans*-**6d** was treated with mCPBA.

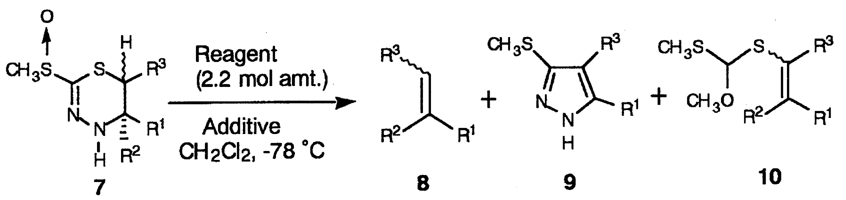
cially, the treatment of a dichloromethane solution of *trans*-**7a** with trifluoroacetic anhydride (2.2 mol amt.) at −78 °C afforded ethyl cinnamate (*E*-**8a**) in 64% yield besides pyrazole **9a** (R^1 =Ph, R^3 =CO_2Et, 20%)[2j] and unidentified several compounds. The use of trifluoromethanesulfonic anhydride in place of trifluoroacetic anhydride was also effective for the reaction. In contrast, acetic anhydride was completely ineffective at all for the reaction, even at room temperature. On the other hand, the treatment of a benzene solution of *trans*-**7a** with trifluoroacetic anhydride in the presence of an excess amount of triethylamine and methanol gave unreacted *trans*-**7a** (61%) along with a small amount of dithioorthoester **10a** (R^1 =Ph, R^2 =H, R^3 =CO_2Et, 14%) and ethyl cinnamate (**8a**, 13%). The treatment of sulfoxides **7** possessing various substituents with trifluoroacetic anhydride also gave olefinic products **8** in modest yields besides several by-products; all results of the reactions are given in Table 3.

Interestingly, the geometry of the double bond of product **8a** was *E* exclusively when *trans*-**7a** was treated with trifluoroacetic anhydride, and *Z*-**8a** was also mainly obtained by treating *cis*-**7a** with trifluoroacetic anhydride under the same reaction conditions. These results suggested that the olefinic products **8** were afforded through the regioselective fragmentation of 2-methylsulfinyl-5,6-dihydro-4*H*-1,3,4-thiadiazines (**7**). It was supposed that the Pummerer-type intermediates **E** were initially generated by the reaction of sulfoxides **7** with the reagent, and, thus, these results suggested that the olefinic products **8** were afforded by the retro [4+2]-type cycloreversion of **E**, even at −78 °C, and that the generation of pyrazole derivatives **9** could also be explained by the mechanisms including a sulfur extrusion of **E**,[8,9] as shown in Scheme 4. Compound **10** was also generated from intermediate **E** by the addition of methanol, followed by base-induced fragmentation of the ring system. However, all attempts to trap or detect the intermediates of the reactions were unsuccessful, and the compounds containing sulfur atoms originated from **7** were not identified at all in the crude reaction mixture.

Homologation of α,β-Unsaturated Aldehydes. Furthermore, we attempted the homologation of cinnamaldehyde (**11**) and geranial (**17**) by using the sequence shown above. In both cases, the aldehydes were at first converted into the corresponding hydrazinecarbodithioates, followed by a base-induced ring closure in high yields. The isomers of the ring-closure products were separated by column chromatography, and then the trans isomers were submitted to the oxidation. The isomeric mixture of sulfoxides was subsequently treated with trifluoroacetic anhydride or trifluoromethanesulfonic anhydride without purification. However, the final steps of the sequence gave unsatisfactory results in which the yields of the products, ethyl 5-phenyl-(2*E*,4*E*)-2,4-pentadienoate (**16**) and ethyl 5,9-dimethyl-(2*E*,4*E*,8*E*)-2,4,8-decatrienoate (**22**), were 32 and 28%, respectively. It was supposed that a further Michael-type addition of the nucleophiles, such as trifluoroacetic acid or methanethiol, to the products might lower the yields of $\alpha,\beta,\gamma,\delta$-unsaturated esters. All of the reactions are summarized in Schemes 5 and 6.

Conclusions. We have found a novel two-carbon homologation of aldehydes and ketones, including the forma-

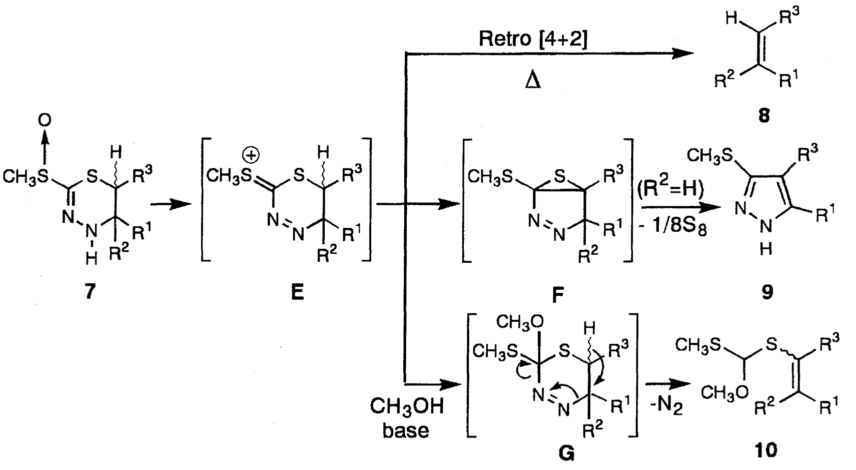
Table 3. Eliminative Ring Fission of 2-Methylsulfinyl-5,6-dihydro-4*H*-1,3,4-thiadiazines (**7**)[a)]



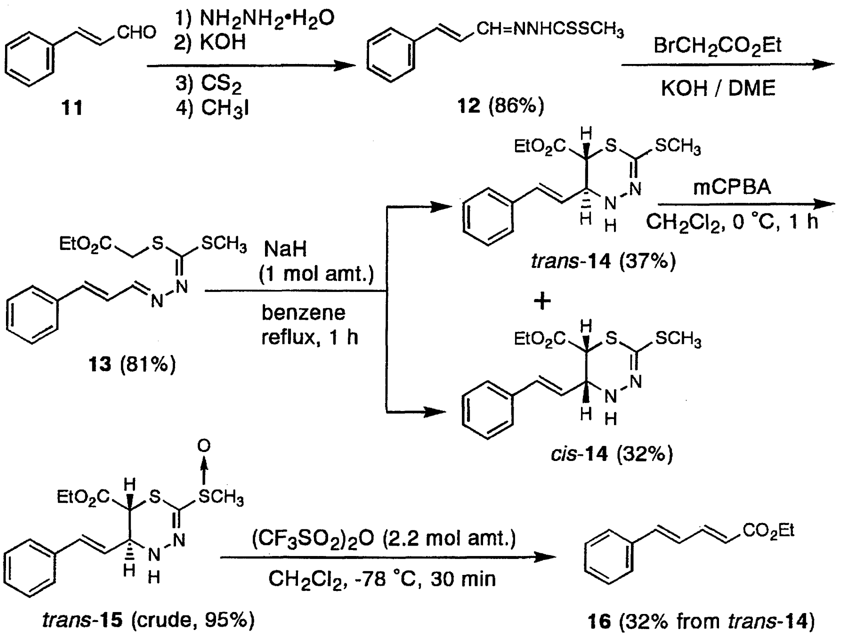
R^1	R^2	R^3	**7**	Reagent	Additive (mol amt.)	*E*-**8**	*Z*-**8**	**9**
Ph	H	CO_2Et	*trans*-**7a**	$(CF_3CO)_2O$	—	64	0	20
Ph	H	CO_2Et	*trans*-**7a**	$(CF_3CO)_2O$	Et_3N (5.0)	Complex mixture[c)]		
Ph	H	CO_2Et	*trans*-**7a**	$(CF_3SO_2)_2O$	—	42	0	5
Ph	H	CO_2Et	*cis*-**7a**	$(CF_3CO)_2O$	—	7	58	—[d)]
Ph	H	CO_2Et	*cis*-**7a**	$(CF_3SO_2)_2O$	—	0	27	—[d)]
Ph	H	$COCH_3$	*trans*-**7b**	$(CF_3CO)_2O$	—	81	0	—[d)]
Ph	H	$COCH_3$	*trans*-**7b**	$(CF_3SO_2)_2O$	—	89	0	—[d)]
Ph	H	COPh	*trans*-**7c**	$(CF_3CO)_2O$	—	63	0	—[d)]
Ph	H	CN	**7d**[e)]	$(CF_3CO)_2O$	—	Complex mixture		
i-Pr	H	CO_2Et	*trans*-**7e**	$(CF_3CO)_2O$	—	50	0	—[d)]
i-Pr	H	CO_2Et	*trans*-**7e**	$(CF_3SO_2)_2O$	—	49	0	—[d)]
$-(CH_2)_5-$		CO_2Et	**7f**	$(CF_3CO)_2O$	—	60	—	—

Yield/%[b)] refers to columns *E*-**8**, *Z*-**8**, **9**; Substrate refers to R^1, R^2, R^3, **7**.

a) A dichloromethane solution of **7** was treated with the reagent (2.2 mol amt.) at −78 °C for 0.5 h.
b) Isolated yields. c) Compound **10a** (R^1 = Ph, R^2 = H, R^3 = CO_2Et) was obtained in 19% yield.
d) Not isolated. e) An isomeric mixture was treated with $(CF_3CO)_2O$.



Scheme 4.



Scheme 5.

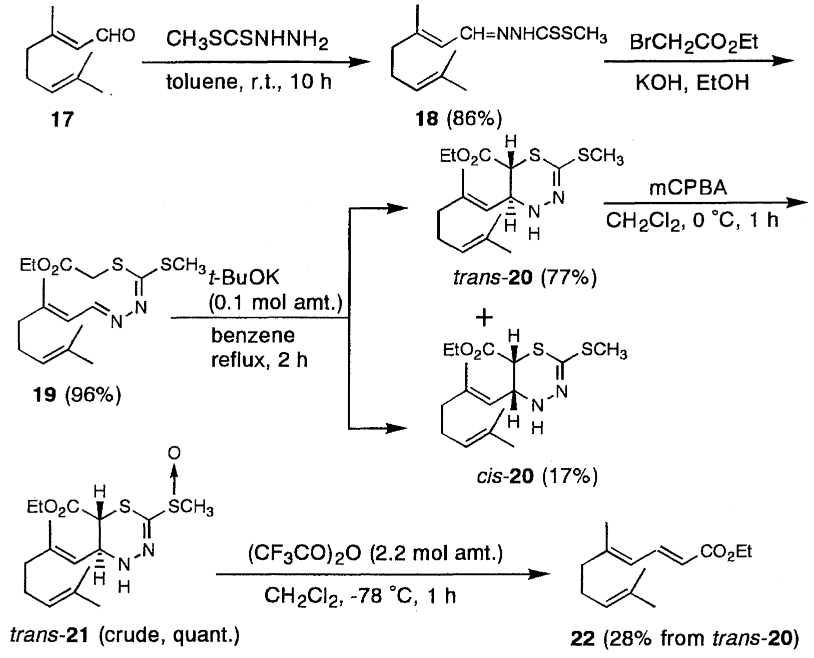
tion and the Pummerer-type ring fission of 2-methylsulfinyl-5,6-dihydro-4*H*-1,3,4-thiadiazines. Further attempts to trap the reaction intermediates **E** as well as the application of the sequence to the synthesis of natural products are in progress in our laboratory.

Experimental

Instruments. The melting points were determined with a Büchi 535 micromelting-point apparatus. ^{1}H NMR spectra were recorded on a Hitachi R-22 (90 MHz) or a Bruker AC-400 (400 MHz) spectrometer. The chemical shifts of the ^{1}H NMR spectra are given in δ relative to internal tetramethylsilane (TMS). ^{13}C NMR spectra were also recorded on a Bruker AC-400 (100 MHz). Mass spectra were recorded on a Hitachi RMU-6M mass spectrometer or a Hitachi M-2000 mass spectrometer with electron-impact ionization at 20 or 70 eV using a direct inlet system. IR spectra were recorded for a thin film (neat) or KBr disks on a JASCO FT/IR-7300 spectrometer. Elemental analyses were performed using a Yanagimoto MT-3 CHN Analyzer.

Materials. Column chromatography was performed using Merck Silica Gel 60 (Cat. No. 7734 and 9385-5B) without any pretreatment. Dichloromethane and chloroform were dried over P_4O_{10}, and were freshly distilled before use. Benzene, toluene, hexane, decalin, ethanol, DBU, and triethylamine were dried over CaH_2 and were freshly distilled before use. THF, diethyl ether, and DME were pretreated with sodium metal, dried over $LiAlH_4$, and freshly distilled before use. All of the substrates and reagents including benzaldehyde, isobutyraldehyde, cinnamaldehyde, cyclohexanone, acetophenone, hydrazine monohydrate, carbon disulfide, iodomethane, KOH, ethyl bromoacetate, chloroacetone, α-bromoacetophenone, α-bromoacetonitrile, *t*-BuOK, NaH, DBU, *m*-chloroperbenzoic acid (mCPBA), diethyl ether–boron trifluoride (1/1) ($Et_2O{\cdot}BF_3$), trifluoroacetic anhydride ($(CF_3CO)_2O$), trifluoromethanesulfonic anhydride ($(CF_3SO_2)_2O$), geraniol, and manganese dioxide were commercially available reagent grade and were used without any pretreatment.

Preparation of Methyl Dithiocarbazate. A slight modification of a literature procedure was employed.[1] To an ethanolic solution (100 ml) of dimethyl trithiocarbonate[10] (26.8g, 0.194



Scheme 6.

mol) was added an ethanolic solution (20 ml) of hydrazine monohydrate (10.7g, 0.214 mmol) at 0 °C; the reaction mixture was stirred for 3 h at 0 °C. An excess amount of water was then added to quench the reaction. The resulting mixture was extracted with benzene and the extract was washed with brine. The organic layer was dried over anhydrous Na_2SO_4. Removal of the solvent and separation of the residue by column chromatography on silica gel using dichloromethane–hexane as the eluent afforded a crude solid, which was recrystallized from chloroform to afford methyl dithiocarbazate (26.8 g, 91%) as colorless needles.[1,2j] Methyl dithiocarbazate ($CH_3SCSNHNH_2$): Colorless needles, mp 78.5—79.5 °C (decomp) (lit,[1] 79 °C (decomp)); MS (*m/z*) 122 (M^+; bp), 91 (60%), 74 (69%); IR (KBr) 3265, 3158, 2980, 1601, 1510, 1008, 947 cm^{-1}; ^1H NMR ($CDCl_3$) major : minor = 2 : 1,[11] major isomer $\delta = 2.66$ (3H, br.s), 4.40—5.00 (2H, m), 8.10—8.70 (1H, m), minor isomer $\delta = 2.63$ (3H, br.s), 4.00—4.30 (2H, m), 8.70—9.20 (1H, m); ^{13}C NMR ($CDCl_3$) $\delta = 17.5$ (q), 199.7 (s).

Typical Procedure for the Preparation of *S*-Methyl Alkylidenehydrazinecarbodithioates 1—4 (Method A). An ethanolic solution of hydrazine monohydrate (35.3 g, 1.10 mol) was treated with an aqueous solution of KOH (72.6 g, 1.10 mol (85%)), carbon disulfide (83.8 g, 1.10 mol), and iodomethane (156.1 g, 1.10 mol); the reaction mixture was stirred at 0 °C for 1 h. To the resulting mixture was added an ethanolic solution of an aldehyde or a ketone (1.00 mol), and the reaction mixture was stirred at 0 °C to room temperature for 3 h. The reaction was quenched with an excess amount of water, and the reaction mixture was extracted with dichloromethane. The organic layer was first washed with water and then dried over anhydrous Na_2SO_4. Removal of the solvent gave a crude yellow solid, which was purified using column chromatography on silica gel to obtain *S*-methyl alkylidenehydrazinecarbodithioates (**1**—**4**) in modest yields.

Typical Procedure for the Preparation of *S*-Methyl Alkylidenehydrazinecarbodithioates 1—4 (Method B). A toluene solution (20 ml) of an aldehyde or a ketone (1 mmol) was treated with 1.1 molar amount of methyl dithiocarbazate; the reaction mixture was stirred at 0 °C to room temperature overnight. The reaction was quenched with an excess amount of water, and the reaction mixture was extracted with chloroform. The organic layer was first washed with water and then dried over anhydrous Na_2SO_4. Removal of the solvent gave a residue which was separated by column chromatography on silica gel using dichloromethane–hexane as the eluent to afford *S*-methyl alkylidenehydrazinecarbodithioates **1**—**4** in modest yields.

Physical Data of 1—4. 1 (R^1=Ph, R^2=H): Colorless prisms, mp 159.5—160.5 °C (decomp) (lit,[1] 157.5 °C); MS (*m/z*) 210 (M^+; 29%), 162 (65%), 104 (79%), 77 (bp); IR (KBr) 3050, 1475, 1285, 1095 cm^{-1}; ^1H NMR ($CDCl_3$) δ=2.67 (3H, s), 7.35—7.45 (3H, m), 7.68—7.75 (2H, m), 7.95 (1H, s), 11.05—11.15 (1H, m); ^{13}C NMR ($CDCl_3$) δ=17.7 (q), 127.8 (d), 128.8 (d), 131.0 (d), 132.9 (s), 145.6 (d), 200.4 (s). Found: C, 51.39; H, 4.88; N, 13.17%. Calcd for $C_9H_{10}N_2S_2$: C, 51.40; H, 4.79; N, 13.32%.

2 (R^1=*i*-Pr, R^2=H): Colorless prisms, mp 51.5—52.0 °C (decomp); MS (*m/z*) 176 (M^+; 25%), 133 (bp), 43 (36%); IR (KBr) 3110, 1625, 1495, 1305, 1070 cm^{-1}; ^1H NMR ($CDCl_3$) major : minor = 8 : 1, major isomer $\delta = 1.14$ (6H, d, $J = 6.8$ Hz), 2.52—2.65 (1H, m), 2.61 (3H, s), 7.34 (1H, d, $J = 5.0$ Hz), 10.90—11.10 (1H, m), minor isomer $\delta = 0.96$ (6H, d, $J = 6.7$ Hz), 1.80—2.00 (1H, m), 2.50 (3H, s), 5.16 (1H, d, $J = 6.5$ Hz), 10.90—11.10 (1H, m); ^{13}C NMR ($CDCl_3$) $\delta = 15.7$ (q), 17.5 (q), 18.5 (q), 19.3 (q), 31.4 (d), 34.4 (d), 155.4 (d), 199.9 (s). Found: C, 40.80; H, 6.91; N, 15.84%. Calcd for $C_6H_{12}N_2S_2$: C, 40.88; H, 6.86; N, 15.89%.

3 (R^1=R^2=–(CH_2)$_5$–): Colorless prisms, mp 100.0—101.0 °C (decomp); MS (*m/z*) 202 (M^+; 36%); IR (KBr) 3400, 3100, 2925, 1635, 1480, 1058 cm^{-1}; ^1H NMR ($CDCl_3$) δ = 1.60—1.85 (6H, m), 2.28—2.45 (4H, m), 2.62 (3H, s), 10.05—10.20 (1H, m); ^{13}C NMR ($CDCl_3$) $\delta = 17.5$ (q), 25.3 (t), 25.9 (t), 26.9 (t), 27.1 (t), 35.1 (t), 159.5 (s), 200.0 (s). Found: C, 47.67; H, 7.13; N, 13.94%. Calcd for $C_8H_{14}N_2S_2$: C, 47.49; H, 6.97; N, 13.84%.

4 (R^1=Ph, R^2=Me): Pale yellow prisms, mp 146.5—147.0 °C (decomp); MS (*m/z*) 224 (M^+; 6%), 176 (bp), 118 (69%), 77 (65%); IR (KBr) 3176, 2915, 1473, 1337, 1276, 1103, 1057 cm^{-1}; ^1H NMR ($CDCl_3$) major : minor = 2 : 1, major isomer δ = 2.27 (3H, s), 2.64 (3H, s), 7.30—7.55 (3H, m), 7.70—7.90 (2H, m), 10.05—10.15 (1H, m), minor isomer $\delta = 2.31$ (3H, s), 2.66 (3H, s), 7.30—7.55 (3H, m), 7.70—7.90 (2H, m), 9.95—10.05 (1H, m); ^{13}C NMR (CDCl$_3$) $\delta = 13.1$ (q), 17.8 (q), 126.5 (d), 128.5 (d), 130.2 (d), 136.8 (s), 149.0 (s), 201.5 (s). Found: C, 53.25; H, 5.47; N, 12.68%. Calcd for $C_{10}H_{12}N_2S_2$: C, 53.54; H, 5.39; N, 12.49%.

Typical Procedure for the Preparation of 5. An ethanolic solution (10 ml) of *S*-methyl alkylidenehydrazinecarbodithioate (1.00 mmol) was treated with KOH (73 mg, 1.10 mmol (85%)) in ethanol (30 ml) or NaH (44 mg, 1.10 mmol (60% dispersion in mineral oil)) in dry THF (30 ml), respectively, and alkylating agent (ethyl bromoacetate, chloroacetone, α-bromoacetophenone, or α-bromoacetonitrile, 1.10 mmol), and the reaction mixture was stirred at 0 °C to room temperature overnight. After the reaction was quenched with an excess amount of water, the reaction mixture was extracted with dichloromethane. The organic layer was first washed with water and then dried over anhydrous Na_2SO_4. Removal of the solvent gave a residue which was separated by column chromatography on silica gel using dichloromethane-hexane as the eluent to afford **5** in modest yields.

Physical Data of 5. 5a (R^1=Ph, R^2=H, R^3=CO$_2$Et)): Pale yellow needles, mp 68.0—68.5 °C (decomp); MS (*m/z*) 296 (M$^+$; 60%), 104 (bp); IR (KBr) 1740, 1600 cm^{-1}; ^{1}H NMR (CDCl$_3$) major : minor = 3 : 1, major isomer $\delta = 1.30$ (3H, t, $J = 7.2$ Hz), 2.55 (3H, s), 3.93 (2H, s), 4.23 (2H, q, $J = 7.2$ Hz), 7.35—7.45 (3H, m), 7.70—7.85 (2H, m), 8.28 (1H, s), minor isomer $\delta = 1.30$ (3H, t, $J = 7.2$ Hz), 2.58 (3H, s), 3.86 (2H, s), 4.24 (2H, q, $J = 7.2$ Hz), 7.35—7.45 (3H, m), 7.70—7.85 (2H, m), 8.36 (1H, s); ^{13}C NMR (CDCl$_3$) $\delta = 14.0$ (q), 14.1 (q), 14.2 (q), 15.6 (q), 33.5 (t), 34.5 (t), 61.7 (t), 61.9 (t), 128.3 (d), 128.4 (d), 128.6 (d), 130.77 (d), 130.82 (d), 134.2 (s), 157.7 (d), 157.9 (d), 165.3 (s), 165.6 (s), 168.45 (s), 168.54 (s). Found: C, 52.79; H, 5.45; N, 9.35%. Calcd for $C_{13}H_{16}N_2O_2S_2$: C, 52.68; H, 5.44; N, 9.45%.

5b (R^1=Ph, R^2=H, R^3=COCH$_3$): Pale yellow oil; MS (*m/z*) 266 (M$^+$; 71%), 104 (bp); IR (neat) 1738, 1605, 1490 cm^{-1}; ^{1}H NMR (CDCl$_3$) major : minor = 10 : 1, major isomer $\delta = 2.34$ (3H, s), 2.55 (3H, s), 3.94 (2H, s), 7.35—7.45 (3H, m), 7.73—7.83 (2H, m), 8.26 (1H, s), minor isomer $\delta = 2.32$ (3H, s), 2.56 (3H, s), 3.89 (2H, s), 7.35—7.45 (3H, m), 7.73—7.83 (2H, m), 8.36 (1H, s); ^{13}C NMR (CDCl$_3$) $\delta = 14.0$ (q), 15.5 (q), 28.5 (q), 28.8 (q), 41.8 (t), 42.0 (t), 128.2 (d), 128.3 (d), 128.6 (d), 130.8 (d), 134.0 (s), 134.1 (s), 157.6 (d), 157.8 (d), 164.9 (s), 165.9 (s), 202.1 (s), 202.2 (s). Found: C, 54.53; H, 5.30; N, 10.25%. Calcd for $C_{12}H_{14}N_2OS_2$: C, 54.11; H, 5.30; N, 10.52%.

5c (R^1=Ph, R^2=H, R^3=COPh): Pale yellow needles, mp 81.0—82.0 °C (decomp); MS (*m/z*) 328 (M$^+$; 41%), 222 (68%), 104 (bp); IR (KBr) 3124, 1682, 1477 cm^{-1}; ^{1}H NMR (CDCl$_3$) major : minor=4 : 1, major isomer $\delta = 2.57$ (3H, s), 4.66 (2H, s), 7.35—7.55 (8H,m), 7.55—7.65 (1H, m), 7.78—7.82 (1H, m), 8.05 (1H, br.d, $J = 7.4$ Hz), 8.07 (1H, s), minor isomer $\delta = 2.44$ (3H, s), 4.59 (2H, s), 7.35—7.55 (8H,m), 7.55—7.65 (1H, m), 7.78—7.82 (1H, m), 8.00 (1H, br.d, $J = 7.4$ Hz), 8.36 (1H, s); ^{13}C NMR (CDCl$_3$) $\delta = 14.1$ (q), 15.7 (q), 38.7 (t), 39.5 (t), 128.2 (d), 128.36 (d), 128.45 (d), 130.7 (d), 130.8 (d), 133.5 (d), 133.7 (d), 134.18 (d), 134.21 (d), 135.5 (s), 136.1 (s), 157.6 (d), 157.7 (d), 166.1 (s), 167.2 (s), 192.9 (s), 193.5 (s). Found: C, 62.19; H, 4.80; N, 8.43%. Calcd for $C_{17}H_{16}N_2OS_2$: C, 62.17; H, 4.91; N, 8.53%.

5d (R^1=Ph, R^2=H, R^3=CN): Pale yellow needles, mp 67.5—68.0 °C (decomp); MS (*m/z*) 249 (M$^+$; 10%), 146 (56%), 104 (bp); IR (KBr) 2981, 2251, 1606, 1503 cm^{-1}; ^{1}H NMR (CDCl$_3$) major : minor = 2 : 1, major isomer $\delta = 2.51$ (3H, s), 3.92 (2H, s), 7.35—7.50 (3H, m), 7.70—7.85 (2H, m), 8.39 (1H, s), minor isomer $\delta = 2.64$ (3H, s), 3.80 (2H, s), 7.35—7.50 (3H, m), 7.70—7.85 (2H, m), 8.39 (1H, s); ^{13}C NMR (CDCl$_3$) $\delta = 13.8$ (q), 15.8 (q), 16.5 (t), 17.2 (t), 115.8 (s), 115.9 (s), 128.4 (d), 128.66 (d), 128.72 (d), 128.8 (d), 131.1 (d), 131.2 (d), 133.7 (s), 133.9 (s), 158.6 (d), 159.1 (d), 162.6 (s), 163.1 (s). Found: C, 53.11; H, 4.35; N, 17.11%. Calcd for $C_{11}H_{11}N_3S_2$: C, 52.98; H, 4.45; N, 16.85%.

5e (R^1=*i*-Pr, R^2=H, R^3=CO$_2$Et): Colorless oil; MS (*m/z*) 262 (M$^+$; 63%), 43 (bp); IR (neat) 1745, 1630 cm^{-1}; ^{1}H NMR (CDCl$_3$) major : minor = 3 : 2, major isomer $\delta = 1.12$ (6H, d, $J = 6.8$ Hz), 1.27 (3H, t, $J = 7.0$ Hz), 2.50 (3H, s), 2.52—2.65 (1H, m), 3.85 (2H, s), 4.20 (2H, q, $J = 7.0$ Hz), 7.55 (1H, d, $J = 5.5$ Hz), minor isomer $\delta = 1.15$ (6H, d, $J = 6.8$ Hz), 1.30 (3H, t, $J = 7.0$ Hz), 2.50 (3H, s), 2.52—2.65 (1H, m), 3.81 (2H, s), 4.22 (2H, q, $J = 7.0$ Hz), 7.63 (1H, d, $J = 5.4$ Hz); ^{13}C NMR (CDCl$_3$) $\delta = 13.8$ (q), 13.97 (q), 14.03 (q), 19.5 (q), 31.5 (d), 31.6 (d), 33.3 (t), 34.2 (t), 61.5 (t), 61.7 (t), 162.8 (s), 162.9 (s), 166.7 (d), 166.9 (d), 168.37 (s), 168.44 (s). Found: C, 45.51; H, 7.01; N, 10.71%. Calcd for $C_{10}H_{18}N_2O_2S_2$: C, 45.77; H, 6.91; N, 10.68%.

5f (R^1=R^2=–(CH$_2$)$_5$–, R^3=CO$_2$Et): Orange oil; MS (*m/z*) 288 (M$^+$; 45%), 96 (bp); IR (neat) 1745, 1620, 1020 cm^{-1}; ^{1}H NMR (CDCl$_3$) major : minor = 2 : 1, major isomer $\delta = 1.27$ (3H, t, $J = 7.0$ Hz), 1.55—1.95 (7H, m), 2.30—2.65 (3H, m), 2.50 (3H, s), 3.82 (2H, s), 4.17 (2H, q, $J = 7.0$ Hz), minor isomer $\delta = 1.30$ (3H, t, $J = 7.0$ Hz), 1.55—1.95 (7H, m), 2.30—2.65 (3H, m), 2.50 (3H, s), 3.80 (2H, s), 4.22 (2H, q, $J = 7.0$ Hz); ^{13}C NMR (CDCl$_3$) $\delta = 13.7$ (q), 14.0 (q), 15.3 (q), 24.8 (t), 25.8 (t), 26.38 (t), 26.43 (t), 26.9 (t), 27.3 (t), 27.4 (t), 28.4 (t), 33.2 (t), 34.2 (t), 35.2 (t), 41.8 (t), 61.5 (t), 61.7 (t), 158.8 (s), 159.5 (s), 168.5 (s), 168.6 (s), 169.9 (s), 170.1 (s). Found: C, 49.82; H, 6.99; N, 9.57%. Calcd for $C_{12}H_{20}N_2O_2S_2$: C, 49.97; H, 7.00; N, 9.71%.

5g (R^1=Ph, R^2=CH$_3$, R^3=CO$_2$Et): Pale yellow needles, mp 57.5—58.5 °C (decomp); MS (*m/z*) 310 (M$^+$; 43%), 264 (56%), 118 (bp); IR (KBr) 2990, 1740, 1600 cm^{-1}; ^{1}H, NMR (CDCl$_3$) major : minor = 5 : 4, major isomer $\delta = 1.28$ (3H, t, $J = 7.0$ Hz), 2.36 (3H, s), 3.90 (2H, br.s), 4.21 (2H, q, $J = 7.0$ Hz), 7.35—7.42 (3H, m), 7.85—7.90 (2H, m), minor isomer $\delta = 1.28$ (3H, t, $J = 7.0$ Hz), 2.53 (3H, s), 3.90 (2H, br.s), 4.21 (2H, q, $J = 7.0$ Hz), 7.35—7.42 (3H, m), 7.85—7.90 (2H, m); ^{13}C NMR (CDCl$_3$) $\delta = 13.8$ (q), 14.0 (q), 14.6 (q), 14.7 (q), 15.6 (q), 33.3 (t), 34.5 (t), 61.6 (t), 61.8 (t), 126.76 (d), 126.82 (d), 128.2 (d), 129.78 (d), 129.81 (d), 137.9 (s), 138.0 (s), 161.6 (s), 162.6 (s), 168.4 (s), 168.6 (s). Found: C, 53.93; H, 5.94; N, 9.39%. Calcd for $C_{14}H_{18}N_2O_2S_2$: C, 54.17; H, 5.84; N, 9.02%.

Typical Procedure for the Ring-Closure of 5. A dry THF or benzene solution (100 ml) of *N*-alkylidene-*N*′-bis(alkylthio)methylenehydrazines (**5**, 1.00 mmol) was treated with NaH (4 mg, 0.100 mmol (60% suspension in mineral oil)) or *t*-BuOK (11 mg, 0.100 mmol); the reaction mixture was then heated at the ambient temperature for several hours under a N_2 atmosphere. After the reaction was quenched with 10% aqueous hydrochloric acid, the reaction mixture was extracted with dichloromethane. The organic layer was washed with an aqueous $NaHCO_3$ solution and water, and the organic layer was dried over anhydrous Na_2SO_4. Removal of the solvent gave a residue which was column chromatographed on silica gel with dichloromethane–hexane as the eluent to afford *cis*-**6** and *trans*-**6**.

Physical Data of 6. *cis*-6a (R^1=Ph, R^2=H, R^3=CO$_2$Et): Colorless needles, mp 125.0—125.5 °C; MS (*m/z*) 296 (M$^+$; 10%), 104 (bp); IR (KBr) 3340, 1735 cm^{-1}; ^{1}H NMR (CDCl$_3$) $\delta = 1.04$ (3H, t, $J = 7.2$ Hz), 2.44 (3H, s), 3.95—4.05 (2H, m), 4.14 (1H, d, $J = 3.2$ Hz), 4.52 (1H, d, $J = 3.2$ Hz), 5.95—6.25 (1H, m), 7.25—7.45 (5H, m); ^{13}C NMR (CDCl$_3$) $\delta = 13.7$ (q), 15.8 (q), 47.7 (d), 54.4 (d), 61.4 (t), 126.8 (d), 128.6 (d), 128.7 (d), 131.8 (s), 137.8 (s), 168.3 (s). Found: C, 52.65; H, 5.44; N, 9.28%. Calcd for $C_{13}H_{16}N_2O_2S_2$: C, 52.68; H, 5.44; N, 9.45%.

***trans*-6a (R^1=Ph, R^2=H, R^3=CO$_2$Et):** Colorless needles, mp 90.0—90.5 °C; MS (*m/z*) 296 (M$^+$; 25%), 104 (bp); IR (KBr) 3280, 1740 cm^{-1}; ^{1}H NMR (CDCl$_3$) δ = 1.03 (3H, t, J = 7.2 Hz), 2.40 (3H, s), 3.90—4.15 (2H, m), 4.15 (1H, d, J = 9.1 Hz), 4.40 (1H, d, J = 9.1 Hz), 5.70—6.05 (1H, m), 7.25—7.45 (5H, m); ^{13}C NMR (CDCl$_3$) δ = 13.6 (q), 15.4 (q), 50.5 (d), 57.1 (d), 61.5 (t), 127.9 (d), 128.7 (d), 128.7 (d), 137.5 (s), 138.7 (s), 167.7 (s). Found: C, 52.61; H, 5.52; N, 9.44%. Calcd for $C_{13}H_{16}N_2O_2S_2$: C, 52.68; H, 5.44; N, 9.45%.

***trans*-6b (R^1=Ph, R^2=H, R^3=COCH$_3$):** Colorless needles, mp 109.8—110.3 °C; MS (*m/z*) 266 (M$^+$; 43%), 104 (bp); IR (KBr) 3300, 1720, 1580 cm^{-1}; ^{1}H NMR (CDCl$_3$) δ = 2.00 (3H, s), 2.44 (3H, s), 4.18 (1H, br.d, J = 8.2 Hz), 4.42 (1H, d, J = 8.2 Hz), 5.85—5.95 (1H, m), 7.25—7.40 (5H, m); ^{13}C NMR (CDCl$_3$) δ = 15.5 (q), 28.7 (q), 56.5 (d), 56.6. (d), 127.7 (d), 128.9 (d), 129.0 (d), 137.4 (s), 138.0 (s), 201.5 (s). Found: C, 53.95; H, 5.27; N, 10.55%. Calcd for $C_{12}H_{14}N_2OS_2$: C, 54.11; H, 5.30, N, 10.52%. A trace amount of *cis*-**6b** was also observed by ^{1}H NMR measurement of the crude ring-closure product of **5b**. *cis*-**6b** (R^1 = Ph, R^2 = H, R^3 = COCH$_3$): ^{1}H NMR (CDCl$_3$) δ = 2.27 (3H, s), 2.47 (3H, s), 4.06 (1H, d, J = 3.0 Hz), 4.45 (1H, d, J = 3.0 Hz), 5.80—6.10 (1H, m), 7.20—7.50 (5H, m).

***trans*-6c (R^1=Ph, R^2=H, R^3=COPh):** Yellow prisms, mp 166.5—167.0 °C; MS (*m/z*) 328 (M$^+$; 14%), 105 (bp); IR (KBr) 3342, 2931, 1684, 1448 cm^{-1}; ^{1}H NMR (CDCl$_3$) δ = 2.44 (3H, s), 4.46 (1H, d, J = 8.5 Hz), 5.33 (1H, d, J = 8.5 Hz), 5.85—5.90 (1H, m), 7.20—7.35 (3H, m), 7.35—7.45 (4H, m), 7.53 (1H, br.t, J = 7.4 Hz), 7.80 (2H, br.d, J = 7.4 Hz); ^{13}C NMR (CDCl$_3$) δ = 15.7 (q), 51.1 (br.s), 56.8 (d), 128.2 (d), 128.5 (d), 128.7 (d), 128.78 (d), 128.82 (d), 134.0 (d), 134.8 (s), 138.2 (s), 138.9 (s), 192.4 (s). Found: C, 61.70; H, 4.84; N, 8.53%. Calcd for $C_{17}H_{16}N_2OS_2$: C, 62.17; H, 4.91; N, 8.53%.

6d (R^1=Ph, R^2=H, R^3=CN, a mixture of *trans* and *cis* isomers): Colorless needles, mp 124.5—125.0 °C; MS (*m/z*) 249 (M$^+$; 71%), 104 (bp); IR (KBr) 3318, 2953, 2248, 1605, 1575, 1493 cm^{-1}; ^{1}H NMR (CDCl$_3$) *trans* : *cis* = 60 : 40, *trans* isomer δ = 2.449 (3H, s), 4.12 (1H, br.d, J = 9.0 Hz), 4.47 (1H, d, J = 9.0 Hz), 5.95—6.05 (1H, m), 7.35—7.55 (5H, m), *cis* isomer δ = 2.447 (3H, s), 4.13 (1H, br.d, J = 2.3 Hz), 4.41 (1H, d, J = 2.3 Hz), 5.95—6.05 (1H, m), 7.35—7.55 (5H, m); ^{13}C NMR (CDCl$_3$) δ = 15.7 (q), 36.4 (d), 37.0 (d), 55.5 (d), 57.2 (d), 115.4 (s), 115.9 (s), 127.2 (d), 127.5 (d), 129.3 (d), 129.4 (d), 129.7 (d), 129.8 (d), 132.5 (s), 135.8 (s), 136.0 (s), 136.8 (s). Found: C, 53.06; H, 4.54; N, 16.70%. Calcd for $C_{11}H_{11}N_3S_2$: C, 52.98; H, 4.45; N, 16.85%.

***trans*-6e (R^1=*i*-Pr, R^2=H, R^3=CO$_2$Et):** Colorless oil; MS (*m/z*) 262 (M$^+$; 48%), 219 (bp); IR (neat) 3340, 1740 cm^{-1}; ^{1}H NMR (CDCl$_3$) δ = 1.00 (3H, d, J = 6.0 Hz), 1.04 (3H, d, J = 6.0 Hz), 1.29 (3H, t, J = 7.0 Hz), 2.02 (1H, octet, J = 7.0 Hz), 2.41 (3H, s), 3.08 (1H, br.dd, J = 7.0, 6.5 Hz), 4.08 (1H, d, J = 6.5 Hz), 4.22 (2H, q, J = 7.0 Hz), 5.85—5.95 (1H, m); ^{13}C NMR (CDCl$_3$) δ = 13.9 (q), 14.0 (q), 15.6 (q), 15.8 (q), 17.8 (q), 19.0 (d), 19.2 (d), 19.9 (d), 29.1 (d), 29.2 (d), 43.6 (d), 46.7 (d), 56.8 (d), 57.6 (d), 61.4 (t), 61.8 (t), 131.6 (s), 137.1 (s), 168.7 (s), 169.4 (s). Found: C, 45.91; H, 7.02; N, 10.82%. Calcd for $C_{10}H_{18}N_2O_2S_2$: C, 45.77; H, 6.91; N, 10.68%. A trace amount of *cis*-**6e** (R^1 = *i*-Pr, R^2 = H, R^3 = COOEt) was observed by ^{1}H NMR measurement of the crude ring-closure product of **5e**. *cis*-**6e** (R^1 = *i*-Pr, R^2 = H, R^3 = COOEt): ^{1}H NMR (CDCl$_3$) δ = 1.04 (3H, d, J = 6.0 Hz), 1.09 (3H, d, J = 6.0 Hz), 1.28 (3H, t, J = 7.0 Hz), 1.67—1.75 (1H, m), 2.41 (3H, s), 3.01 (1H, dd, J = 9.4, 2.6 Hz), 4.07 (1H, d, J = 2.6 Hz), 4.22 (2H, q, J = 7.0 Hz), 5.85—5.95 (1H, m).

6f (R^1=R^2=–(CH$_2$)$_5$–, R^3=CO$_2$Et): Colorless prisms, 94.5—95.0 °C (decomp); MS (*m/z*) 288 (M$^+$; 92%), 96 (bp); IR (KBr) 3320, 1750, 1155 cm^{-1}; ^{1}H NMR (CDCl$_3$) δ = 1.28 (3H, t, J = 7.0 Hz), 1.35—1.45 (2H, m), 1.45—1.75 (8H, m), 2.42 (3H, s), 3.75 (1H, s), 4.15—4.25 (2H, m), 5.75—5.95 (1H, m); ^{13}C NMR (CDCl$_3$) δ = 14.1 (q), 16.4 (q), 21.2 (t), 25.2 (t), 33.3 (t), 34.6 (t), 48.1 (s), 49.4 (d), 61.4 (t), 129.6 (s), 169.3 (s). Found: C, 49.79; H, 7.15; N, 9.80%. Calcd for $C_{12}H_{20}N_2O_2S_2$: C, 49.97; H, 7.00; N, 9.71%.

Typical Procedure for the Preparation of 7. After a dichloromethane or chloroform solution (25 ml) of 2-methylthio-5,6-dihydro-4*H*-1,3,4-thiadiazines (**6**, 1.00 mmol) was treated with mCPBA (237 mg (80%), 1.10 mmol) at 0 °C in the presence of powdered NaHCO$_3$ (420 mg, 5.00 mmol), the reaction mixture was stirred for 1 h at 0 °C. The reaction was quenched with an aqueous Na$_2$SO$_3$ solution, and the reaction mixture was extracted with dichloromethane. The organic layer was washed with an aqueous NaHCO$_3$ solution and with water, and the organic layer was dried over anhydrous Na$_2$SO$_4$. Removal of the solvent gave a residue which was column chromatographed on silica gel using chloroform as the eluent to afford *trans*- or *cis*-**7** in high yields as colorless solid.

Physical Data of 7. ***trans*-7a (R^1=Ph, R^2=H, R^3=CO$_2$Et):** Pale yellow needles, mp 146.5—147.0 °C (decomp); MS (*m/z*) 312 (M$^+$; 77%), 296 (M$^+$ – O; 31%), 249 (66%), 104 (bp); IR (KBr) 3280, 3030, 2960, 1745, 1180, 1020 cm^{-1}; ^{1}H NMR (CDCl$_3$) major : minor = 5 : 4, major isomer δ = 1.07 (3H, t, J = 7.2 Hz), 2.80 (3H, s), 3.96—4.15 (2H, m), 4.18 (1H, d, J = 7.2 Hz), 4.38 (1H, d, J = 7.2 Hz), 6.30—6.40 (1H, m), 7.25—7.35 (2H, m), 7.35—7.45 (3H, m), minor isomer δ = 1.11 (3H, t, J = 7.2 Hz), 2.83 (3H, s), 3.96—4.15 (2H, m), 4.15 (1H, d, J = 6.6 Hz), 4.55 (1H, d, J = 6.6 Hz), 6.45—6.55 (1H, m), 7.25—7.35 (2H, m), 7.35—7.45 (3H, m); ^{13}C NMR (CDCl$_3$) δ = 13.7 (q), 13.8 (q), 40.4 (br.q), 45.1 (br.d), 46.1 (br.d), 56.0 (d), 56.4 (d), 62.1 (t), 127.3 (d), 127.8 (d), 128.9 (d), 129.1 (d), 136.8 (br.s), 137.9 (br.s), 167.5 (s), 167.8 (s). Found: C, 49.74; H, 5.27; N, 9.00%. Calcd for $C_{13}H_{16}N_2O_3S_2$: C, 49.98; H, 5.16; N, 8.97%.

***cis*-7a (R^1=Ph, R^2=H, R^3=CO$_2$Et):** Pale yellow needles, mp 127.0—130.0 °C (decomp); MS (*m/z*) 312 (M$^+$; bp), 296 (M$^+$ – O; 22%), 249 (97%); IR (KBr) 3298, 1733, 1477 cm^{-1}; ^{1}H NMR (CDCl$_3$) major : minor = 5 : 4, major isomer δ = 1.08 (3H, t, J = 7.2 Hz), 2.81 (3H, s), 3.95—4.10 (2H, m), 4.16 (1H, dd, J = 3.2, 1.0 Hz), 4.68 (1H, d, J = 3.2 Hz), 6.80—6.90 (1H, m), 7.20—7.35 (2H, m), 7.35—7.45 (2H, m), minor isomer δ = 1.04 (3H, t, J = 7.2 Hz), 2.74 (3H, s), 3.95—4.10 (2H, m), 4.13 (1H, dd, J = 3.3, 1.3 Hz), 4.64 (1H, d, J = 3.3 Hz), 6.80—6.90 (1H, m), 7.20—7.35 (2H, m), 7.35—7.45 (3H, m); ^{13}C NMR (CDCl$_3$) δ = 13.7 (q), 40.2 (q), 40.3 (q), 41.4 (d), 43.2 (d), 54.5 (d), 54.8 (d), 61.4 (dd), 61.6 (dd), 126.7 (d), 126.9 (d), 128.8 (d), 128.9 (d), 129.0 (d), 136.7 (s), 136.8 (s), 137.1 (s), 137.4 (s), 167.4 (s), 167.8 (s). Found: C, 49.96; H, 5.13; N, 9.27%. Calcd for $C_{13}H_{16}N_2O_3S_2$: C, 49.98; H, 5.16; N, 8.97%.

***trans*-7b (R^1=Ph, R^2=H, R^3=COCH$_3$):** Pale yellow needles, mp 148.0—148.5 °C (decomp); MS (*m/z*) 282 (M$^+$; 22%), 266 (M$^+$ – O; 19%), 177 (92%), 43 (bp); IR (KBr) 3283, 1711, 1031 cm^{-1}; ^{1}H NMR (CDCl$_3$) major : minor = 9 : 8, major isomer δ = 2.14 (3H, s), 2.77 (3H, s), 4.08 (1H, d, J = 5.5 Hz), 4.52—4.58 (1H, m), 6.55—6.62 (1H, m), 7.20—7.28 (2H, m), 7.30—7.40 (3H, m), minor isomer δ = 2.14 (3H, s), 2.79 (3H, s), 4.12 (1H, d, J = 6.0 Hz), 4.52—4.58 (1H, m), 6.48—6.55 (1H, m), 7.20—7.28 (2H, m), 7.30—7.40 (3H, m); ^{13}C NMR (CDCl$_3$) δ = 28.9 (q), 29.1 (q), 40.1

(q), 40.3 (q), 49.8 (d), 51.2 (d), 55.5 (d), 55.9 (d), 126.9 (d), 127.20 (d), 127.25 (d), 128.9 (d), 129.0 (d), 129.1 (d), 138.1 (s), 138.4 (s), 138.7 (s), 139.5 (s), 201.1 (s), 201.5 (s). Found: C, 50.60; H, 4.97; N, 9.99%. Calcd for $C_{12}H_{14}N_2O_2S_2$: C, 51.04; H, 5.00; N, 9.92%.

***trans*-7c (R^1=Ph, R^2=H, R^3=COPh):** Colorless needles, mp 212.0—213.0 °C (decomp); MS (*m/z*) 344 (M^+; 4%), 328 (M^+-O; 3%), 105 (bp); IR (KBr) 3262, 2959, 1676, 1001 cm^{-1}; ^1H NMR ($CDCl_3$) major : minor = 3 : 1, major isomer $\delta = 2.69$ (3H, s), 4.76 (1H, dd, $J = 5.4$, 2.4 Hz), 4.94 (1H, d, $J = 5.4$ Hz), 6.58—6.65 (1H, m), 7.25—7.50 (7H, m), 7.57 (1H, br.d, $J = 8.5$ Hz), 7.86 (2H, br.d, $J = 8.5$ Hz), minor isomer $\delta = 2.84$ (3H, s), 4.64 (1H, dd, $J = 7.0$, 1.2 Hz), 5.05 (1H, d, $J = 7.0$ Hz), 6.38—6.42 (1H, m), 7.25—7.50 (7H, m), 7.55 (1H, br.t, $J = 8.5$ Hz), 7.82 (2H, br.d, $J = 8.5$ Hz); ^{13}C NMR ($CDCl_3$) $\delta = 40.4$ (q), 40.5 (q), 44.6 (d), 46.2 (d), 55.9 (d), 56.4 (d), 127.6 (d), 128.0 (d), 128.6 (d), 128.79 (d), 128.84 (d), 128.9 (d), 129.0 (d), 134.1 (d), 134.5 (s), 134.8 (s), 137.7 (s), 139.1 (s), 139.3 (s), 192.6 (s), 193.1 (s). Found: C, 59.44; H, 4.59; N, 8.06%. Calcd for $C_{17}H_{16}N_2O_2S_2$: C, 59.28; H, 4.68; N, 8.13%.

7d (R^1=Ph, R^2=H, R^3=CN, a mixture of isomers): Pale yellow needles, mp 172.0—172.8 °C (decomp); MS (*m/z*) 265 (M^+; 78%), 249 (M^+-O; 24%), 202 (56%), 104 (bp); IR (KBr) 3301, 2969, 2241, 1472, 1023 cm^{-1}; ^1HNMR ($CDCl_3$) major : medium : minor = 5 : 4 : 1, major isomer $\delta = 2.81$ (3H, s), 4.29 (1H, t, $J = 2.0$ Hz), 4.62 (1H, d, $J = 2.0$ Hz), 6.60—6.65 (1H, m), 7.30—7.35 (2H, m), 7.40—7.55 (3H, m), medium isomer $\delta = 2.80$ (3H, s), 4.35 (1H, d, $J = 7.0$ Hz), 4.47 (1H, br.d, $J = 7.0$ Hz), 6.65—6.70 (1H, m), 7.30—7.35 (2H, m), 7.40—7.55 (3H, m), minor isomer $\delta = 2.83$ (3H, s), 4.27 (1H, br.d, $J = 5.5$ Hz), 4.74—4.77 (1H, m), 6.95—6.98 (1H, m), 7.25—7.30 (2H, m), 7.40—7.55 (3H, m); ^{13}CNMR ($CDCl_3$) $\delta = 30.5$ (d), 32.8 (d), 40.67 (q), 40.73 (q), 40.80 (q), 55.8 (d), 56.1 (d), 56.6 (d), 115.2 (s), 115.3 (s), 115.7 (s), 126.8 (d), 127.1 (d), 127.2 (d), 129.3 (d), 129.45 (d), 129.55 (d), 130.0 (s), 130.3 (d), 135.0 (s), 135.5 (s), 137.2 (s), 138.1 (s), 140.7 (s). Found: C, 49.55; H, 4.13; N, 15.96%. Calcd for $C_{11}H_{11}N_3OS_2$: C, 49.79; H, 4.18; N, 15.84%.

***trans*-7e (R^1=*i*-Pr, R^2=H, R^3=CO_2Et):** Pale yellow prisms, mp 141.0—142.8 °C (decomp); MS (*m/z*) 278 (M^+; bp), 262 (M^+-O; 10%), 235 (72%), 100 (73%); IR (KBr) 3243, 2967, 1737, 1026 cm^{-1}; ^1HNMR ($CDCl_3$) major : minor=5 : 4, major isomer $\delta = 1.04$ (3H, d, $J = 6.8$ Hz), 1.07 (3H, d, $J = 6.8$ Hz), 1.28 (3H, t, $J = 7.0$ Hz), 1.90—2.05 (1H, m), 2.79 (3H, s), 3.24 (1H, dd, $J = 9.0$, 4.0 Hz), 4.11 (1H, d, $J = 4.0$ Hz), 4.15—4.25 (2H, m), 6.55—6.70 (1H, m), minor isomer $\delta = 0.96$—1.32 (6H, m), 1.01 (3H, d, $J = 6.7$ Hz), 1.07 (3H, d, $J = 6.8$ Hz), 1.29 (3H, t, $J = 7.0$ Hz), 1.90—2.05 (1H, m), 2.81 (3H, s), 3.27 (1H, dd, $J = 8.1$, 4.0 Hz), 4.07 (1H, d, $J = 4.0$ Hz), 4.15—4.25 (2H, q, $J = 7.0$ Hz), 6.55—6.70 (1H, m); ^{13}CNMR ($CDCl_3$) $\delta = 13.97$ (q), 14.04 (q), 18.3 (q), 18.5 (q), 18.81 (q), 18.85 (q), 30.5 (d), 31.6 (d), 39.8 (d), 40.0 (q), 40.4 (q), 41.3 (d), 56.8 (d), 57.3 (d), 62.1 (t), 62.3 (t), 137.6 (s), 138.7 (s), 168.9 (s), 169.1 (s). Found: C, 43.53; H, 6.65; N, 10.12%. Calcd for $C_{10}H_{18}N_2O_3S_2$: C, 43.14; H, 6.52; N, 10.06%.

7f (R^1=R^2=–$(CH_2)_5$–, R^3=CO_2Et): Pale yellow needles, 169.0—170.5 °C (decomp); MS (*m/z*) 305 (M^++1; bp), 304 (M^+; 52%), 288 (M^+-O; 13%), 139 (86%); IR (KBr) 3260, 2915, 1732, 1140, 1020 cm^{-1}; ^1HNMR ($CDCl_3$) major : minor = 3 : 2, major isomer $\delta = 1.26$ (3H, t, $J = 7.1$ Hz), 1.40—1.85 (10H, m), 2.79 (3H, s), 3.83 (1H, br.s), 4.19 (2H, q, $J = 7.1$ Hz), 6.31—6.38 (1H, m), minor isomer $\delta = 1.27$ (3H, t, $J = 7.1$ Hz), 1.40—1.85 (10H, m), 2.75 (3H, s), 3.85 (1H, br.s), 4.19 (2H, q, $J = 7.1$ Hz), 6.39—6.42 (1H, m); ^{13}C NMR ($CDCl_3$) $\delta = 14.0$ (q), 14.1 (q), 20.99 (t), 21.04 (t), 21.2 (t), 21.3 (t), 24.99 (t), 25.02 (t), 33.7 (t), 34.1 (t), 35.8 (t), 36.7 (t), 40.2 (q), 40.8 (q), 43.1 (d), 44.7 (d), 50.0 (s), 50.1 (s), 61.5 (t), 61.7 (t), 135.3 (s), 135.6 (s), 168.3 (s), 168.7 (s). Found: C, 47.38; H, 6.73; N, 8.98%. Calcd for $C_{12}H_{20}N_2O_3S_2$: C, 47.34; H, 6.62; N, 9.20%.

Thermal Reaction of 2-Methylthio-5,6-dihydro-4*H*-1,3,4-thiadiazine (*trans*-6a). A decalin solution (10 ml) of 2-methylthio-5,6-dihydro-4*H*-1,3,4-thiadiazine (*trans*-**6a**, 1.00 g, 3.37 mmol) was heated at 200 °C for 48 h in a sealed tube. The reaction mixture was first cooled to room temperature and then subjected to column chromatography on silica gel to afford ethyl cinnamate (**8a**, 75 mg, 13%) as a colorless oil along with recovery of the substrate (*trans*-**6a**, 655 mg, 66%).

Thermal Reaction of 2-Methylsulfinyl-5,6-dihydro-4*H*-1,3,4-thiadiazine (*trans*-7a). A decalin solution (10 ml) of 2-methylsulfinyl-5,6-dihydro-4*H*-1,3,4-thiadiazine (*trans*-**7a**, 500 mg, 1.60 mmol) was heated at 120 °C for 26 h. The reaction mixture was first cooled to room temperature and then subjected to column chromatography on silica gel to afford ethyl cinnamate (**8a**, 84 mg, 30%) as a colorless oil along with the deoxygenated product (*trans*-**6a**, 237 mg, 50%).

Thermal Reaction of 2-Methylsulfinyl-5,6-dihydro-4*H*-1,3,4-thiadiazine (*trans*-7a) in the Presence of $Et_2O\cdot BF_3$. A benzene solution (10 ml) of 2-methylsulfinyl-5,6-dihydro-4*H*-1,3,4-thiadiazine (*trans*-**7a**, 500 mg, 1.60 mmol) and $Et_2O\cdot BF_3$ (227 mg, 1.60 mmol) was heated at refluxing temperature for 6 h. After the reaction was quenched with an aqueous $NaHCO_3$ solution, the reaction mixture was extracted with dichloromethane. The organic layer was first washed with water and then dried over anhydrous Na_2SO_4. Removal of the solvent gave a residue which was separated by column chromatography on silica gel using chloroform as the eluent to afford ethyl cinnamate (**8a**, 51 mg, 18%) as a colorless oil along with the deoxygenated product (*trans*-**6a**, 171 mg, 36%).

Thermal Reaction of 2-Methylsulfinyl-5,6-dihydro-4*H*-1,3,4-thiadiazine (*trans*-7a) in the Presence of Chlorotrimethylsilane. After a dichloromethane solution (10 ml) of 2-methylsulfinyl-5,6-dihydro-4*H*-1,3,4-thiadiazine (*trans*-**7a**, 120 mg, 0.384 mmol) was treated with an excess amount of chlorotrimethylsilane (417 mg, 3.84 mmol) at 0 °C, the reaction mixture was stirred at 0 °C for 3 h. The reaction was quenched with an aqueous $NaHCO_3$ solution, and the reaction mixture was extracted with dichloromethane. The organic layer was first washed with water and then dried over anhydrous Na_2SO_4. Removal of the solvent gave a residue, which was separated by column chromatography on silica gel using chloroform as the eluent to afford ethyl cinnamate (**8a**, 10 mg, 15%) as a colorless oil along with the deoxygenated product (*trans*-**6a**, 69 mg, 46%).

Typical Procedure for the Reaction of 2-Methylsulfinyl-5,6-dihydro-4*H*-1,3,4-thiadiazines with Trifluoroacetic Anhydride or Trifluoromethanesulfonic Anhydride. After a dichloromethane solution (5 ml) of trifluoroacetic anhydride (420 mg, 2.20 mmol) or trifluoromethanesulfonic anhydride (621 mg, 2.20 mmol) was added dropwise to a dichloromethane solution (20 ml) of 2-methylsulfinyl-5,6-dihydro-4*H*-1,3,4-thiadiazines (**7**, 1.00 mmol) at −78 °C, the reaction mixture was stirred for 0.5 h at −78 °C. The reaction was quenched with an aqueous $NaHCO_3$ solution, and the reaction mixture was extracted with dichloromethane. The organic layer was first washed with water and then dried over anhydrous Na_2SO_4. Removal of the solvent gave a residue which was separated by column chromatography on silica gel using chloroform as the eluent to afford olefinic compounds (**8**), pyrazole derivative **9**, and several unidentified by-products.

Reaction of 2-Methylsulfinyl-5,6-dihydro-4*H*-1,3,4-thiadi-

azine (*trans*-7a) with Trifluoroacetic Anhydride in the Presence of an Excess Amount of Triethylamine and Methanol. After a dichloromethane solution (5 ml) of trifluoroacetic anhydride (340 mg, 1.62 mmol) was added dropwise to a dichloromethane solution (30 ml) of 2-methylsulfinyl-5,6-dihydro-4*H*-1,3,4-thiadiazine (*trans*-**7a**, 230 mg, 0.736 mmol) and an excess amount of triethylamine (373 mg, 3.68 mmol) and methanol (118 mg, 3.68 mmol) at −78 °C, the reaction mixture was stirred for 30 min at 0 °C. The reaction was quenched with an aqueous $NaHCO_3$ solution, and the reaction mixture was extracted with dichloromethane. The organic layer was first washed with water and then dried over anhydrous Na_2SO_4. Removal of the solvent gave a complex mixture which was separated by column chromatography on silica gel using chloroform as eluent to afford orthoester **10a** (31 mg, 14%, yellow oil) along with the recovered sulfoxide **7a** (141 mg, 61%), ethyl cinnamate (**8a**, 17 mg, 13%), and a trace amount of pyrazole derivative **9a**.

Physical Data of 9. **9a (R^1=Ph, R^3=CO_2Et):** Colorless needles, mp 131.0—132.0 °C (lit,[2j] 131.0—132.0 °C); MS (*m/z*) 262 (M^+; bp); IR (KBr) 3200, 2970, 1725, 1670 cm^{-1}; ^1HNMR ($CDCl_3$) $\delta = 1.16$ (3H, t, $J = 7.0$ Hz), 2.40 (3H, s), 4.16 (2H, q, $J = 7.0$ Hz), 7.12—7.60 (6H, m). Found: C, 59.08; H, 5.27; N, 10.61%. Calcd for $C_{13}H_{14}N_2O_2S$: C, 58.48; H, 5.38; N, 10.68%.

Physical Data of 10. **10a (R^1=Ph, R^2=H, R^3=CO_2Et):** Pale yellow oil; MS (*m/z*) 298 (M^+; 32%), 91 (bp); IR (neat) 2950, 1720, 1590, 1440, 1240, 690 cm^{-1}; ^1HNMR ($CDCl_3$) $\delta = 1.39$ (3H, t, J=7.0 Hz), 2.11 (3H, s), 3.28 (3H, s), 4.34 (2H, q, J=7.0 Hz), 6.15 (1H, s), 7.25—7.88 (5H, m), 7.94 (1H, s). Found: C, 56.01; H, 6.14%. Calcd for $C_{14}H_{18}O_3S_2$: C, 56.35; H, 6.08%.

Preparation of *S*-Methyl Cinnamylidenehydrazinecarbodithioate 12. An ethanolic solution (100 ml) of hydrazine monohydrate (10.4 g, 208 mmol) was treated stepwise with an aqueous KOH solution (11.7 g, 208 mmol, in 10 ml water), carbon disulfide (15.8 g, 208 mmol), iodomethane (29.5 g, 208 mmol), and cinnamaldehyde (25.00 g, 189 mmol) at 0 °C, and the reaction mixture was stirred at 0 °C for 1 h. After solidification of the reaction mixture, a large amount of water was added to quench the reaction; the resulting mixture was subjected to suction filtration. The crude solid was recrystallized from EtOH to give *S*-methyl cinnamylidenehydrazinecarbodithioate (38.4 g, 86%) as pale yellow needles.

12: Pale yellow needles, mp 163.5—165.0 °C (decomp); MS (*m/z*) 236 (M^+, 30%), 130 (bp); IR (KBr) 3080, 1625, 1038 cm^{-1}; ^1HNMR ($CDCl_3$) $\delta = 2.66$ (3H, s), 6.92 (1H, dd, $J = 16.0$, 8.3 Hz), 6.99 (1H, d, $J = 16.0$ Hz), 7.30—7.40 (3H, m), 7.45—7.55 (2H, m), 7.79 (1H, d, J=8.3 Hz). 10.50—11.00 (1H, m); ^{13}CNMR ($CDCl_3$) $\delta = 17.0$ (q), 123.9 (m), 127.3 (d), 128.9 (d), 129.5 (d), 135.5 (s), 142.2 (m), 147.8 (d), 199.5 (s). Found: C, 55.96; H, 5.15; N, 12.12%. Calcd for $C_{11}H_{12}N_2S_2$: C, 55.90; H, 5.12; N, 11.85%.

Preparation of *N*-Bis(alkylthio)methylene-*N*′-cinnamylidenehydrazinecarbodithioate (13). After a DME solution (10 ml) of *S*-methyl cinnamylidenehydrazinecarbodithioate (**12**, 1.05 g, 4.42 mmol) was treated stepwise with an aqueous KOH solution (273 mg, 4.86 mmol, in 1 ml water) and ethyl bromoacetate (812 mg, 4.86 mmol) at 0 °C, the reaction mixture was stirred at 0 °C for 1 h. The reaction was then quenched with an excess amount of water and the reaction mixture was subjected to the usual workup according to the preparation of **5** to afford *N*-bis(alkylthio)methylene-*N*′-cinnamylidenehydrazinecarbodithioate (**13**, 1.16 g, 81%) as pale yellow oil.

13: Pale yellow oil; MS (*m/z*) 322 (M^+; 14%), 235 (85%), 103 (bp); IR (neat) 2980, 1745, 1624, 1025 cm^{-1}; ^1HNMR ($CDCl_3$) major : minor = 5 : 3, major isomer $\delta = 1.28$ (3H, t, $J = 7.2$ Hz), 2.54 (3H, s), 3.90 (2H, s), 4.22 (2H, q, $J = 7.2$ Hz), 6.98 (1H, d, $J = 16.0$ Hz), 7.07 (1H, dd, $J = 16.0$, 9.3 Hz), 7.27—7.40 (3H, m), 7.46—7.52 (2H, m), 8.10 (1H, d, J=9.3 Hz), minor isomer $\delta = 1.28$ (3H, t, J=7.2 Hz), 2.55 (3H, s), 3.84 (2H, s), 4.22 (2H, q, J=7.2 Hz), 7.00 (1H, d, $J = 16.0$ Hz), 7.08 (1H, dd, $J = 16.0$, 9.2 Hz), 7.27—7.40 (3H, m), 7.46—7.52 (2H, m), 8.17 (1H, d, $J = 9.2$ Hz); ^{13}CNMR ($CDCl_3$) $\delta = 13.8$ (q), 13.9 (q), 14.0 (q), 14.1 (q), 15.5 (q), 33.5 (t), 34.4 (t), 61.6 (t), 61.8 (t), 125.4 (m), 127.2 (d), 127.8 (d), 128.2 (d), 128.7 (d), 129.1 (d), 135.8 (s), 135.9 (s), 142.0 (m), 142.1 (m), 159.9 (d), 160.1 (d), 164.4 (s), 164.8 (s), 168.3 (s), 168.4 (s). Found: C, 55.84; H, 5.68; N, 8.63%. Calcd for $C_{15}H_{18}N_2O_2S_2$: C, 55.87; H, 5.63; N, 8.68%.

Base-induced Ring Closure of *N*-Bis(alkylthio)methylene-*N*′-cinnamylidenehydrazinecarbodithioate (13). After a benzene solution (50 ml) of *N*-bis(alkylthio)-*N*′-cinnamylidenehydrazinecarbodithioate (**13**, 310 mg, 0.932 mmol) was treated with NaH (25 mg, 1.03 mmol), the solution was heated at 80 °C for 30 min. The reaction was quenched with an excess amount of water and the reaction mixture was subjected to the usual workup according to the preparation of **6** to afford *trans*-**14** (115 mg, 37%) and *cis*-**14** (99 mg, 32%) as pale yellow oil along with the recovered substrate (**13**, 87 mg, 28%).

***trans*-14:** Pale yellow oil; MS (*m/z*) 322 (M^+; 62%), 234 (52%), 176 (53%), 130 (bp); IR (neat) 3320, 2975, 2920, 1742, 1290, 1160, 970, 747, 692 cm^{-1}; ^1HNMR ($CDCl_3$) $\delta = 1.20$ (3H, t, J=7.0 Hz), 2.43 (3H, s), 3.88 (1H, br.t, J=8.0, 7.5 Hz), 4.15 (2H, q, J=7.0 Hz), 4,16 (1H, d, J=7.5 Hz), 5.75—5.90 (1H, m), 6.07 (1H, dd, J=16.5, 8.0 Hz), 6.65 (1H, d, J=16.5 Hz), 7.10—7.50 (5H, m). Found: C, 55.94; H, 5.68; N, 8.56%. Calcd for $C_{15}H_{18}N_2O_2S_2$: C, 55.87; H, 5.63; N, 8.68%.

***cis*-14:** Pale yellow oil; MS (*m/z*) 322 (M^+; 9%), 288 ($M^+ - H_2S$; bp); IR (neat) 3325, 2980, 2920, 1740, 1280, 1160, 990, 748, 692 cm^{-1}; ^1HNMR ($CDCl_3$) $\delta = 1.25$ (3H, t, $J = 7.0$ Hz), 2.44 (3H, s), 4.20 (1H, dd, $J = 7.5$, 3.0 Hz), 4.22 (2H, q, $J = 7.0$ Hz), 4,32 (1H, d, $J = 3.0$ Hz), 5.80—6.05 (1H, m), 6.20 (1H, dd, $J = 15.5$, 7.5 Hz), 6.63 (1H, d, $J = 15.5$ Hz), 7.10—7.50 (5H, m). Found: C, 55.87; H, 5.69; N, 8.78%. Calcd for $C_{15}H_{18}N_2O_2S_2$: C, 55.87; H, 5.63; N, 8.68%.

mCPBA Oxidation of *trans*-14 and the Subsequent Trifluoroacetic Anhydride-Induced Ring Fission of Sulfoxide 15. After a dichloromethane solution (25 ml) of 2-methylthio-5,6-dihydro-4*H*-1,3,4-thiadiazines (*trans*-**14**, 520 mg, 1.61 mmol) was treated with mCPBA (382 mg (80%), 1.77 mmol) at 0 °C in the presence of powdered $NaHCO_3$ (743 mg, 8.85 mmol), the reaction mixture was stirred for 1 h at 0 °C. The reaction was quenched with an aqueous Na_2SO_3 solution, and the reaction mixture was subjected to the usual workup according to the preparation of **7** to afford an isomeric mixture of 2-methylsulfinyl-5,6-dihydro-4*H*-1,3,4-thiadiazine (**15**, 516 mg, 95%) as a pale-red solid. A dichloromethane solution (5 ml) of trifluoromethanesulfonic anhydride (191 mg, 0.680 mmol) was then added to a dichloromethane solution (20 ml) of **15** (104 mg, 0.307 mmol) at −78 °C, and the reaction mixture was stirred for 30 min. After the reaction was quenched with an aqueous $NaHCO_3$ solution, the reaction mixture was subjected to the usual workup according to the preparation of **8** to afford ethyl 5-phenyl-(2*E*,4*E*)-2,4-pentadienoate (**16**, 20 mg, 32% from *trans*-**14**) as pale yellow oil besides several unidentified by-products.

***trans*-15:** Pale yellow oil; MS (*m/z*) 338 (M^+; 7%), 322 ($M^+ - O$; 22%), 275 (22%), 232 (92%), 187 (bp); IR (neat) 3278, 2985, 1733, 1054 cm^{-1}; ^1HNMR ($CDCl_3$) major : minor = 5 : 4, major isomer $\delta = 1.25$ (3H, t, $J = 7.0$ Hz), 2.93 (3H, s), minor isomer $\delta = 1.29$ (3H, t, $J = 7.0$ Hz), 2.93 (3H, s).

16: Colorless oil (lit,[12] mp 25—26 °C); MS (m/z) 202 (M^+; 94%), 129 (bp); IR (neat) 2982, 1711, 1626, 1134 cm^{-1}; ^{1}H NMR (CDCl$_3$) $\delta = 1.28$ (3H, t, $J = 7.0$ Hz), 4.22 (2H, q, $J = 7.0$ Hz), 6.00 (1H, d, $J = 15.0$ Hz), 6.70—7.60 (7H, m), 7.55 (1H, d, $J = 15.0$ Hz).

Preparation of *S*-Methyl Geranylidenehydrazinecarbodithioate (18). After a toluene solution (100 ml) of geranial (**17**, 5.19 g, 34.1 mmol), derived quantitatively by the oxidation of geraniol using manganese dioxide, was treated with methyl dithiocarbazate (4.14 g, 37.5 mmol) at 0 °C, the reaction mixture was stirred at 0 °C for 10 h. After removing the solvent, the residue was subjected to column chromatography on silica gel to afford yellow solid. The crude solid was recrystallized from hexane-dichloromethane to give *S*-methyl geranylidenehydrazinecarbodithioate (**18**, 7.52 g, 86%) as pale yellow needles.

18: Pale yellow needles, mp 92.5—93.5 °C; MS (m/z) 256 (M^+, 9%), 188 (43%), 41 (bp); IR (KBr) 3130, 2980, 2905, 1642, 1520, 1328, 1310 cm^{-1}; ^{1}H NMR (CDCl$_3$) major : minor = 10 : 1, major isomer $\delta = 1.61$ (3H, br.s), 1.69 (3H, br.s), 1.91 (3H, d, $J = 0.8$ Hz), 2.10—2.30 (4H, m), 2.62 (3H, s), 5.05—5.12 (1H, m), 6.04 (1H, br.d, $J = 9.7$ Hz), 8.00 (1H, d, $J = 9.7$ Hz), 11.13—11.20 (1H, m). minor isomer $\delta = 1.63$ (3H, br.s), 1.70 (3H, br.s), 1.95 (3H, d, $J = 0.8$ Hz), 2.10—2.30 (4H, m), 2.64 (3H, s), 5.05—5.12 (1H, m), 6.16 (1H, br.d, $J = 9.7$ Hz), 7.97 (1H, d, $J = 9.7$ Hz), 11.13—11.20 (1H, m); ^{13}C NMR (CDCl$_3$) $\delta = 17.49$ (q), 17.54 (q), 17.6 (q), 25.6 (q), 26.0 (t), 40.3 (t), 120.6 (d), 123.0 (s), 132.4 (s), 145.9 (d), 152.8 (s), 198.6 (s). Found: C, 55.93; H, 8.02; N, 10.94%. Calcd for $C_{12}H_{20}N_2S_2$: C, 56.20; H, 7.86; N, 10.92%.

Preparation of *N*-Bis(alkylthio)methylne-*N*′-geranylidenehydrazinecarbodithioate (19). An ethanolic solution (50 ml) of *S*-methyl geranylidenehydrazinecarbodithioate (**18**, 2.51 g, 9.79 mmol) was treated with an aqueous KOH solution (604 mg, 10.8 mmol, in 5 ml water) and ethyl bromoacetate (1.80 g, 10.8 mmol) at 0 °C; the reaction mixture was then stirred at 0 °C for 30 min. The reaction was quenched with an excess amount of water and the reaction mixture was subjected to the usual workup according to the preparation of **5** to afford *N*- bis(alkylthio)methylene-*N*′-geranylidenehydrazinecarbodithioate (**19**, 3.22 g, 96%) as pale yellow oil.

19: Pale yellow oil; MS (m/z) 342 (M^+; 45%), 295 (79%), 262 (bp), 69 (94%); IR (neat) 2920, 1750, 1643, 1575, 1495 cm^{-1}; ^{1}H NMR (CDCl$_3$) major : minor = 5 : 3, major isomer $\delta = 1.29$ (3H, t, $J = 7.0$ Hz), 1.61 (3H, br.s), 1.68 (3H, br.s), 1.91 (3H, d, $J = 1.0$ Hz), 2.10—2.25 (4H, m), 2.52 (3H, s), 3.89 (2H, s), 4.21 (2H, q, $J = 7.0$ Hz), 5.05—5.12 (1H, m), 6.17 (1H, br.d, $J = 10.2$ Hz), 8.25 (1H, d, $J = 10.2$ Hz), minor isomer $\delta = 1.29$ (3H, t, $J = 7.0$ Hz), 1.60 (3H, br.s), 1.68 (3H, br.s), 1.93 (3H, d, $J = 1.0$ Hz), 2.10—2.25 (4H, m), 2.53 (3H, s), 3.82 (2H, s), 4.22 (2H, q, $J = 7.0$ Hz), 5.05—5.12 (1H, m), 6.19 (1H, br.d, $J = 10.1$ Hz), 8.32 (1H, d, $J = 10.1$ Hz); ^{13}C NMR (CDCl$_3$) $\delta = 13.9$ (q), 14.0 (q), 14.1 (q), 15.4 (q), 17.38 (q), 17.40 (q), 17.6 (q), 25.6 (q), 26.0 (t), 33.4 (t), 34.3 (t), 40.3 (t), 61.5 (t), 61.7 (t), 122.0 (d), 123.1 (s), 132.1 (s), 152.1 (s), 152.3 (s), 157.0 (d), 157.2 (d), 162.7 (s), 163.0 (s), 168.4 (s). Found: C, 56.29; H, 7.72; N, 8.38%. Calcd for $C_{16}H_{26}N_2O_2S_2$: C, 56.11; H, 7.65; N, 8.18%.

Base-Induced Ring Closure of *N*-Bis(alkylthio)methylene-*N*′-geranylidenehydrazonecarbodithioate (19). After a benzene solution (30 ml) of *N*-bis(alkylthio)methylene-*N*′-geranylidenehydrazonecarbodithioate (**19**, 950 mg, 2.77 mmol) was treated with *t*-BuOK (31 mg, 0.280 mmol), the solution was heated at refluxing temperature for 2 h. The reaction was quenched with an excess amount of water and the reaction mixture was subjected to the usual workup according to the preparation of **6** to afford *trans*-**20** (732 mg, 77%) and *cis*-**20** (160 mg, 17%) as pale-yellow oils.

***trans*-20:** Pale yellow oil; MS (m/z) 342 (M^+; bp), 295 (21%), 262 (21%), 69 (74%); IR (neat) 3290, 2960, 2910, 1748, 1440, 1368, 1280, 1155, 942 cm^{-1}; ^{1}H NMR (CDCl$_3$) $\delta = 1.24$ (3H, t, $J = 7.0$ Hz), 1.60 (3H, br.s), 1.68 (3H, br.s), 1.73 (3H, d, $J = 1.5$ Hz), 1.80—2.30 (4H, m), 2.42 (3H, s), 3.89 (1H, t, $J = 8.0$ Hz), 4.04 (2H, d, $J = 8.0$ Hz), 4.13 (2H, q, $J = 7.0$ Hz), 4.70—5.20 (2H, m), 5.47 (1H, m). Found: C, 55.87; H, 7.59; N, 8.08%. Calcd for $C_{16}H_{26}N_2O_2S_2$: C, 56.11; H, 7.65; N, 8.18%.

***cis*-20:** Pale yellow oil; MS (m/z) 342 (M^+; bp), 295 (26%), 262 (39%), 223 (29%), 69 (76%); IR (neat) 3330, 2970, 2915, 1745, 1445, 1370, 1280, 1155, 1025, 990, 950 cm^{-1}; ^{1}H NMR (CDCl$_3$) $\delta = 1.27$ (3H, t, $J = 7.0$ Hz), 1.59 (3H, br.s), 1.67 (3H, br.s), 1.73 (3H, d, $J = 1.5$ Hz), 1.90—2.30 (4H, m), 2.42 (3H, s), 4.06 (2H, d, $J = 4.0$ Hz), 4.14 (1H, dd, $J = 9.0$, 4.0 Hz), 4.20 (2H, q, $J = 7.0$ Hz), 5.04 (1H, br.s), 5.19 (1H, br.d, $J = 9.0$ Hz), 5.61 (1H, m). Found: C, 56.33; H, 7.69; N, 8.05%. Calcd for $C_{16}H_{26}N_2O_2S_2$: C, 56.11; H, 7.65; N, 8.18%.

mCPBA Oxidation of *trans*-20 and the Subsequent Trifluoroacetic Anhydride-Induced Ring Fission of Sulfoxide 21. After a dichloromethane solution (25 ml) of 2-methylthio-5,6-dihydro-4*H*-1,3,4- thiadiazine (*trans*-**20**, 500 mg, 1.46 mmol) was treated with mCPBA (346 mg (80%), 1.61 mmol) at 0 °C in the presence of powdered NaHCO$_3$ (613 mg, 7.30 mmol), the reaction mixture was stirred for 1 h at 0 °C. The reaction was quenched with an aqueous Na$_2$SO$_3$ solution, and the reaction mixture was subjected to the usual workup according to the preparation of **7** to afford an isomeric mixture of 2-methylsulfinyl-5,6-dihydro-4*H*-1,3,4-thiadiazine (trans-**21**, 497 mg, quant.) as colorless solid. A dichloromethane solution (5 ml) of trifluoroacetic anhydride (675 mg, 3.21 mmol) was then added to a dichloromethane solution (20 ml) of *trans*-**21** (497 mg) at −78 °C, and the reaction mixture was stirred for 1 h at −78 °C. After the reaction was quenched with an aqueous NaHCO$_3$ solution, the reaction mixture was subjected to the usual workup acceding to the preparation of **8** to afford ethyl 5,9-dimethyl-(2*E*,4*E*,8*E*)-2,4,8-decatrienoate (**22**, 91 mg, 28% from *trans*-**20**) as pale-yellow oil besides several unidentified by-products.

***trans*-21:** Pale yellow oil; MS (m/z) 358 (M^+; 24%), 342 ($M^+ - O$; 11%), 69 (bp); IR (neat) 3278, 2969, 2241, 1735, 1053 cm^{-1}; ^{1}H NMR (CDCl$_3$) major : minor=5 : 4, major isomer $\delta = 1.26$ (3H, t, $J = 7.0$ Hz), 1.60 (3H, br.s), 1.68 (3H, br.s), 1.75 (3H, d, $J = 1.0$ Hz), 2.00—2.30 (4H, m), 2.80 (3H, s), 3.83 (1H, t, $J = 7.7$ Hz), 4.05—4.30 (3H, m), 5.00—5.20 (2H, m), 6.05—6.15 (1H, m), minor isomer $\delta = 1.27$ (3H, t, $J = 7.0$ Hz), 1.62 (3H, br.s), 1.71 (3H, br.s), 1.78 (3H, br.d, $J = 1.0$ Hz), 2.00—2.30 (4H, m), 2.83 (3H, s), 3.84 (1H, dd, $J = 10.4$, 6.6 Hz), 4.05—4.30 (3H, m), 5.00—5.20 (2H, m), 5.95—6.05 (1H, m).

22: Colorless oil (lit,[13] 103—105 °C/0.5 mmHg, 1 mmHg = 133.322 Pa); MS (m/z) 222 (M^+; 32%), 69 (bp); IR (neat) 2910, 1727, 1638 cm^{-1}; ^{1}H NMR (CDCl$_3$) $\delta = 1.31$ (3H, t, $J = 7.0$ Hz), 1.61 (3H, br.s), 1.68 (3H, br.s), 1.89 (3H, br.s), 2.00—2.40 (4H, m), 4.18 (2H, q, $J = 7.0$ Hz), 4.80—5.20 (1H, m), 5.75 (1H, d, $J = 15.5$ Hz), 5.95 (1H, br.d, $J = 12.0$ Hz), 7.55 (1H, dd, $J = 15.5$, 12.0 Hz).

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References

1) M. Busch and M. Starke, *J. Prakt. Chem.*, **93**, 59 (1916).

2) a) R. Andreasch, *Monatsh. Chem.*, **27**, 1211 (1906); b) S.

M. Losanitch, *J. Chem. Soc.*, **119**, 763 (1921); c) P. K. Bose, *Q. J. Indian Chem. Soc.*, **3**, 197 (1926); d) J. Sandström, *Ark. Kemi.*, **7**, 249 (1952); e) J. Sandström, *Ark. Kemi.*, **4**, 297 (1952); f) R. A. Mathes, *J. Org. Chem.*, **17**, 877 (1952); g) R. Hull, *J. Chem. Soc.*, **1952**, 2959; h) H. Beyer, W. Lässig, and E. Bulka, *Chem. Ber.*, **87**, 1385 (1954); i) T. Sato and M. Ohta, *Yakugaku Zasshi*, **77**, 771 (1957); j) J. Sandström, *Acta Chem. Scand.*, **16**, 2395 (1962); k) D. L. Trepanier, W. Reifschneider, W. Shumaker, and D. S. Tharpe, *J. Org. Chem.*, **30**, 2228 (1965); l) D. L. Trepanier and P. E. Krieger, *J. Heterocycl. Chem.*, **4**, 254 (1967); m) Y. Usui and T. Yamano, *Yakugaku Zasshi*, **89**, 689 (1969); n) Y. Usui and T. Yamano, *Yakugaku Zasshi*, **89**, 699 (1969); o) J. Beger, C. Thilemann, and P. D. Thong, *J. Prakt. Chem.*, **321**, 959 (1979); p) S. Kubota, Y. Ueda, K. Fujikane, K. Toyooka, and M. Shibuya, *J. Org. Chem.*, **45**, 1473 (1980); q) S. H. Askari, S. F. Moss, and D. R. Taylor, *J. Chem. Soc., Perkin Trans. 1*, **1981**, 360; r) S. Kubota, K. Toyooka, J. Ikeda, N. Yamamoto, and M. Shibuya, *J. Chem. Soc., Perkin Trans. 1*, **1983**, 967; s) Y. Nakayama and Y. Sanemitsu, *J. Org. Chem.*, **49**, 1703 (1984); t) Y. Nakayama and Y. Sanemitsu, *Synthesis*, **1984**, 771; u) S. V. Usol'tseva, G. P. Andronnikova, S. L. Nikolaeva, A. T. Lebedev, and V. A. Shevyrin, *Khim. Gelerotsikl. Soedin.*, **1991**, 554; v) W. Hanefeld and M. Schlitzer, *Arch. Pharm.*, **326**, 249 (1993).

3) D. M. Evans, D. R. Taylor, and M. Myers, *J. Chem. Soc., Chem. Commun.*, **1984**, 1444.

4) F. Babudri, S. Florio, A. Reho, and G. Trapani, *J. Chem. Soc., Perkin Trans. 1*, **1984**, 1949, and the references cited therein.

5) K. Shimada, A. Otaki, M. Yanakawa, S. Mabuchi, N. Yamakado, T. Shimoguchi, K. Inoue, T. Kagawa, K. Shoji, and Y. Takikawa, *Chem. Lett.*, **1995**, 925.

6) O. De Lucchi, U. Miotti, and G. Modena, "Organic Reactions," ed by L. A. Paquette, (1991), Vol. 40, p. 157, and the references cited therein.

7) For example, the *J* value of H-5 and H-6 of *trans*-**6a** was 9 Hz. On the other hand, that of *cis*-**6a** was 3 Hz.

8) R. R. Schmidt, *Angew. Chem.*, **87**, 603 (1975), and the references cited therein.

9) W. D. Pfeiffer, E. Bulka, and R. Miethchen, *Z. Chem.*, **27**, 296 (1987), and the references cited therein.

10) E. Wertheim, *J. Am. Chem. Soc.*, **48**, 826 (1926).

11) S. Manogaran and D. N. Sathyanarayana, *Bull. Chem. Soc. Jpn.*, **55**, 2628 (1982), and the references cited therein.

12) K. V. Awers, *J. Prakt. Chem.*, **105**, 361 (1923).

13) K. Sasaki, *Bull. Chem. Soc. Jpn.*, **40**, 2968 (1967).