cm^{-1}; ^1H NMR ($CDCl_3$) 2.4–3.4 (AB, 8 H), 3.65 (s, 3 H), 5.80 (s, 1 H). Anal. Calcd for $C_9H_{12}O_3$: C, 64.3; H, 7.1. Found: C, 64.1; H, 7.0.

1,4-Bis(carboxymethyl)cyclohexa-1,3-diene (10). Diester 8 (2.24 g, 0.01 mol) was refluxed for 1 h in methanol (60 mL) containing potassium hydroxide (2.0 g). Solvent was then removed in vacuo, and the resulting viscous oil was dissolved in water. Acidification with dilute HCl precipitated white crystals of diene 10 (1.90 g, 97%): mp 184–188 °C; IR (Nujol) 1690, 1330, 1230, 1142, 920, 770 cm^{-1}; ^1H NMR [$(CD_3)_2CO$] δ 2.26 (s, 4 H), 3.07 (s, 4 H), 5.70 (s, 2 H); UV (CH_3OH) 262 nm. Anal. Calcd for $C_{10}H_{12}O_4$: C, 61.2; H, 6.1. Found: C, 60.9; H, 6.3.

Preparation of Bis(benzothiazolinium) Derivative 11. Oxalyl chloride (1.30 g, 10 mmol) was added dropwise with stirring to a solution of diacid 10 (1.0 g, 5 mmol) in dry chloroform under nitrogen. The solution was held at 50 °C for 2 h, and then solvent was removed in vacuo to yield 1.23 g of the diacid chloride as a viscous oil [IR (film) 1800 (C=O) cm^{-1}]. This oil was dissolved in dry chloroform (20 mL) and added dropwise to a solution of *N*-methyl-*o*-aminothiophenol[10] (1.4 g, 10 mmol) in dry chloroform (20 mL). The solution was stirred at room temperature for 12 h under nitrogen and then a solution of excess triphenylcarbenium tetrafluoroborate in acetonitrile was added to precipitate dication 11 as a buff powder. Recrystallization from acetic acid/water gave 1.41 g [48% based on diacid 10] as buff crystals: mp >290 °C; ^1H NMR (CF_3COOH) δ 2.10 (s, 4 H), 3.93 (s, 4 H), 3.98 (s, 6 H), 5.88 (s, 2 H), 7.30–7.80 (m, 8 H). Anal. Calcd for $C_{24}H_{24}N_2S_2B_2F_8$: C, 49.8; H, 4.2; N, 4.8. Found: C, 50.1; H, 4.0; N, 5.2.

Preparation of Bis(benzothiazoline) Derivative 12. To a suspension of dication 11 (578 mg, 1.0 mmol) in acetonitrile (15 mL) was added an excess of triethylamine. The mixture was stirred at room temperature for 12 h. Evaporation of the solvent yielded a brown solid which was purified by column chromatography on alumina with diethyl ether as eluent. Compound 12 (320 mg, 80%) was obtained as orange crystals: mp 212–213 °C; ^1H NMR [$(CD_3)_2SO$] δ 2.31 (s, 4 H), 5.50 (s, 2 H), 5.80 (s, 2 H), 7.12–7.80 (m, 8 H). Anal. Calcd for $C_{24}H_{22}N_2S_2$: C, 71.6; H, 5.5; N, 7.0. Found: C, 71.3; H, 5.9; N, 7.2.

Registry No. 8, 91158-09-7; 9, 91158-10-0; 10, 91158-11-1; 10 (diacid chloride), 91158-14-4; 11, 91158-12-2; 12, 91158-13-3; $Ph_3P{=}CHCO_2Me$, 2605-67-6; 1,4-cyclohexanedione, 637-88-7; *N*-methyl-*o*-aminophenol, 21749-63-3.

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The Bromination of 2-Phenyl-2*H*-indazole. Formation and Structure Determination of Mono-, Di-, and Tribromo-2-phenyl-2*H*-indazoles[1]

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Electrophilic substitution of azoles[4] is a complex reaction where reaction conditions considerably modify product orientation. The situation is even more complex for benzazoles as is illustrated by the results of electrophilic aromatic substitution reactions of 1*H*-indazole.[5-8] Bromination of 1*H*-indazole in dilute acid gives 3,5-dibromo-1*H*-indazole,[9] sulfonation affords 1*H*-indazole-7-sulfonic acid,[10] and nitration in sulfuric acid gives 5-nitro-1*H*-indazole,[11] whereas from the nitration in acetic acid/acetic anhydride a mixture of 3-nitro- and 3,5-dinitro-1*H*-indazole,[2] is obtained. Moreover substituents quite often exercise effects different from their effects on electrophilic aromatic substitution in benzene. A typical example being the ortho nitration of 6-nitro-1*H*-indazole to 5,6-dinitro-1*H*-indazole.[2,12,13]

Scheme I

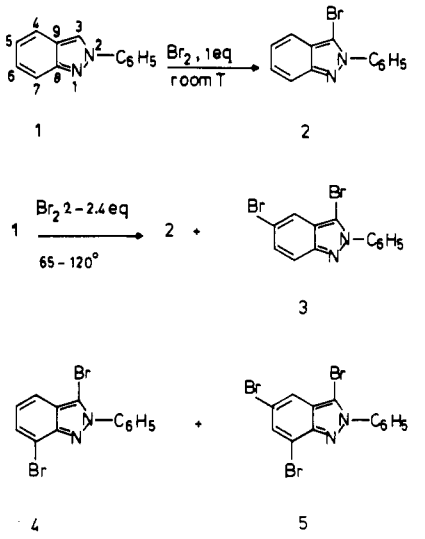

Table I. Bromination Procedures[a] and Yields (relative mole %)[e]

	1			2
	1.0 equiv Br_2[b] 20 °C	2.4 equiv Br_2[c] 120 °C	2.0 equiv Br_2[c] 65 °C	1.0 equiv Br_2[d] 120 °C
2	100	33	52	47
3		39	27	32
4		24	18	19
5		4	3	2
total rel %	100	100	100	100
actual yield %	88.6	86.8	91.7	75.2

[a] A 1–2 N Br_2 solution in acetic acid was slowly dropped into a solution of 1 g of 1 or 2 in 25 mL of acetic acid. [b] Addition time, 3.5 h. [c] Addition time, 12 h. [d] Addition time, 8 h. [e] Separated by column chromatography (see Experimental Section).

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(13) (a) In contrast to what is described in ref 5 and 8 nitration of 6-nitro-1*H*-indazole gives 5,6-dinitro-1*H*-indazole whereas nitration of 5-nitro-1*H*-indazole affords 5,7-dinitro-1*H*-indazole; see ref 2 and 12. (b) When indazole has an unsubstituted NH group there is the possibility of tautomerism and to our knowledge 1*H*- and 2*H*-tautomers have never been isolated as separate compounds, although they may enter chemical reactions predominantly in one form. An indication that the exchange of the NH proton is so fast that the "tautomeric mixture" behaves magnetically as a single compound is evident from the proton magnetic resonance spectra of these indazoles exhibiting a one-proton signal for H-3. For indazoles designated either as 1*H*- or 2*H*-indazoles the existence and therefore the participation in reactions of the other tautomer is understood.

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Table II. ^{1}H Chemical Shift Data (300 MHz) and Coupling Constants of Bromo-2-phenyl-2*H*-indazoles 2–5[a,b]

	H-4	H-5	H-6	H-7	phenyl	J4-5	J4-6	J4-7	J5-6	J5-7	J6-7
2	7.59 dt	7.19 octet	7.37 octet	7.74 dt	7.67–7.70 7.52–7.56 m	8.5	1.1	0.9	6.6	0.7	8.8
3	7.75 dd		7.39 dd	7.61 dd	7.63–7.67 7.52–7.58 m		1.8	0.5			9.2
4	7.65 d	7.0 dd	7.64 d		7.48–7.56 m	8.4			7.3		
5	7.74 d		7.69 d		7.65–7.68 7.54–7.63 m		1.5				

[a] In ppm relative to Me_4Si; the solvent was $CDCl_3$. [b] For structures see Scheme I.

The situation becomes considerably more complex for *N*-phenyl-substituted indazoles where, in principle, electrophilic substitution can occur in both indazole rings as well as in the phenyl ring. Because we had a need for a number of brominated indazoles of known structure as reference compounds we decided to investigate the bromination of 2-phenyl-2*H*-indazole (**1**).[14]

Bromination of 2-phenyl-2*H*-indazole (**1**) in acetic acid solution at room temperature by the slow addition of 1 equiv of Br_2 in acetic acid afforded mainly 3-bromo-2-phenyl-2*H*-indazole (**2**). Treatment, however, at higher temperatures with 2–2.4 equiv of Br_2 gave mixtures of **2** and the dibromo derivatives **3** and **4** (see Scheme I) in addition to 3,5,7-tribromo-2-phenyl-2*H*-indazole (**5**), which were separated by column chromatography (see Table I). Bromination of **2** in boiling acetic acid with 1 equiv of Br_2 also gave a mixture of **2–5**. In both instances a substantial amount of **2** is not brominated further and only small amounts of **5**, the tribromo indazole, are formed whereas the absence of bromination of the phenyl ring is striking.

The structure assignments of **2–5** were based on their ^{1}H and ^{13}C NMR spectra and their mass spectra. In addition to the molecular ions observed in their mass spectra as expected for **2–5** the presence of the *m/e* 77 ion in all three mass spectra unequivocally shows that the phenyl group is unbrominated. This is corroborated by the ^{1}H NMR spectra (see Table II).

The characteristic resonance for a 3-proton in indazoles[2,3,16] is absent in the ^{1}H NMR spectra of **2–5** and thus the 3-position is the one first brominated. Furthermore, the ^{1}H NMR spectrum of the tribromo compound **5** shows resonances for two indazole hydrogens in meta positions and therefore **5** is either 3,5,7- or 3,4,6-tribromo-2-phenyl-2*H*-indazole. In the gated decoupled ^{13}C NMR spectra[17,18] of **2–5** only the spectrum of **5** has a distinct singlet peak for C-9 indicating the absence of three-bond carbon hydrogen coupling for C-9 and such a configuration agrees only with a substitution pattern for **5** as depicted with bromine atoms in positions 3, 5, and 7.

Assuming that **5** is the product of further bromination of the two dibromo 2-phenyl-2*H*-indazoles **3** and **4**, the compound with resonances for three adjacent indazole hydrogens in the ^{1}H NMR spectrum therefore is 3,7-dibromo-2-phenyl-2*H*-indazole (**4**) and the other dibromo compound with two ortho coupled indazole protons consequently must be 3,5-dibromo-2-phenyl-2*H*-indazole (**3**).

Table III. ^{13}C Chemical Shift Data (75 MHz)[a–c] for *N*-Phenylindazoles 1[d] and 6[e] and Bromo-2-phenyl-2*H*-indazoles 2–5[d]

	C-3	C-4	C-5	C-6	C-7	C-8	C-9
1	126.9	120.5	120.5	122.6	118.1	149.9	122.9
6	135.4	121.5	121.3	127.1	110.4	138.7	125.3
2	106.2	119.8	123.1	127.7	118.3	149.3	123.1
3	105.4	121.8	116.5	131.3	120.0	147.6	124.1
4	107.6	119.3	123.5	130.3	111.5	147.6	123.5
5	106.9	121.4	115.7	133.3	112.9	146.5	124.2

[a] In ppm relative to Me_4Si. [b] The solvent was $CDCl_3$. [c] The ^{13}C chemical shifts of the carbon atoms of the phenyl group are in the range of 121.1–126.4 (C-2), 126.6–129.8 (C-4), 129.1–129.7 (C-3), and 138.8–140.7 (C-1). [d] For structures see Scheme I. [e] 6 = 1-phenyl-1*H*-indazole.

For comparison the ^{13}C chemical shift data of **1–5** and also of 1-phenyl-1*H*-indazole **6** are collected in Table III. Comparison of the ^{13}C chemical shifts for C-3 and C-8 in **1** and **6** reveals an upfield shift for the carbon atom adjacent to the pyrrolic N and a downfield shift for the carbon atom adjacent to the pyridinic N. This finding is in agreement with results in ref 3 and 17.

Finally, it is noteworthy that only the indazole ring of **1** is brominated and that no bromination is observed in the phenyl ring. Remarkable also is the predominant bromination, at room temperature, of the 3-position in the indazole ring, in contrast to the bromination of the parent 1*H*-indazole, which in dilute acid gives 3,5-dibromo-1*H*-indazole[5,6,9] without discrimination at room temperature between these two positions.

Experimental Section

The *N*-phenylindazoles **1** and **6** were synthesized according to literature procedures.[20,21] All melting points are uncorrected. Analyses were performed by Mikroanalytisches Labor Pascher, Bonn, BRD. Mass spectra were taken on an AEI type MS-902 instrument at ambient temperature.

NMR Spectra. High-resolution NMR spectra were recorded on a Bruker WM-300 spectrometer operating in the Fourier transform mode. Data acumulation and processing were carried out on a Aspect-2000 computer. Proton spectra were recorded at 300 MHz using a spectral window of 3000 Hz at 16K data points. Carbon-13 spectra were measured at 75 MHz using a spectral window of 18000 Hz at 16K data points. The latter spectra were zero-filled up to 64K data points before Fourier transformation in order to obtain a satisfactory digital resolution. Various techniques were employed to assign the carbon-13 spectra: (a) proton noise decoupling, (b) proton gated noise decoupling with the decoupler switched off during the acquisition (this method yields a proton-coupled carbon-13 spectrum with increased intensities because of the nuclear Overhauser effect). ^{1}H and ^{13}C

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NMR data are collected in Tables II and III.

3-Bromo-2-phenyl-2*H*-indazole (2). During 3–5 h and at room temperature a solution of 1.7 g of bromine in 50 mL of acetic acid was added to a solution of 2 g of 1 in 50 mL of acetic acid. The resulting light yellow colored solution was stirred for an hour and the reaction mixture was allowed to stand at room temperature for another 20 h. The almost colorless mixture, containing colorless needles was treated with 10 mL of water and the so formed solution was gradually added to 500 mL of chilled water (ice–salt bath) under continuous stirring. Crystallization from the milky solutions was induced by seeding. After 3 h of stirring the colorless crystals were collected on a Hirsch funnel, washed with water, and vacuum dried over $CaCl_2$: yield 2.49 g (89%); mp 64–75 °C. Crystallization of 1 g of 2 from 12 mL of ethanol/water 2:1 gave crystals with mp 75.5–77 °C. Additional crystallization did not raise the melting point further. Anal. Calcd for $C_{13}BrH_9N_2$: C, 57.16; H, 3.32; Br, 29.26. Found: C, 56.91; H, 3.40; Br, 29.7.

Bromination of 1 and 2 at 65 and 120 °C. Analogous to the preparation of 2 at room temperature a 1–2 N solution of bromine in acetic acid was gradually dropped into a solution of 1 g of 1 or 2 in 25 mL of acetic acid. For the entire reaction time the reaction mixture was heated either at 65 or at 120 °C. See Table I for reaction times and yields. For the separation of products the short column chromatography technique of Hunt and Rigby[22] was used on silica gel 60 H (Merck) according to Stahl with toluene as solvent for elution.

3,5-Dibromo-2-phenyl-2*H*-indazole (3): white needles, mp 154–155 °C (from toluene/petroleum ether 80–100 and ethanol successively). Anal. Calcd for $C_{13}Br_2H_8N_2$: C, 44.35; H, 2.29; Br, 45.40. Found: C, 44.11; H, 2.31; Br, 45.7.

3,7-Dibromo-2-phenyl-2*H*-indazole (4): white crystals, mp 110.5–111.5 °C (from toluene/petroleum ether 40–60 and ethanol successively). Anal. Calcd for $C_{13}Br_2H_8N_2$: C, 44.35; H, 2.29; Br, 45.40. Found: C, 44.11; H, 2.40; Br, 46.0.

3,5,7-Tribromo-2-phenyl-2*H*-indazole (5): white crystals, mp 208–209 °C (from toluene and acetonitrile successively). Anal. Calcd for $C_{13}Br_3H_7N_2$: C, 36.23; H, 1.64; Br, 55.63. Found: C, 36.15; H, 1.74; Br, 56.1.

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Registry No. 1, 3682-71-1; 2, 91002-55-0; 3, 91002-56-1; 4, 91002-57-2; 5, 91002-58-3.

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New Synthetic Methods for γ-Geraniol, Boll Weevil Pheromone, and α-Damascone Employing 2-(Hydroxymethyl)-4-(phenylthio)-1-butene as a Building Block

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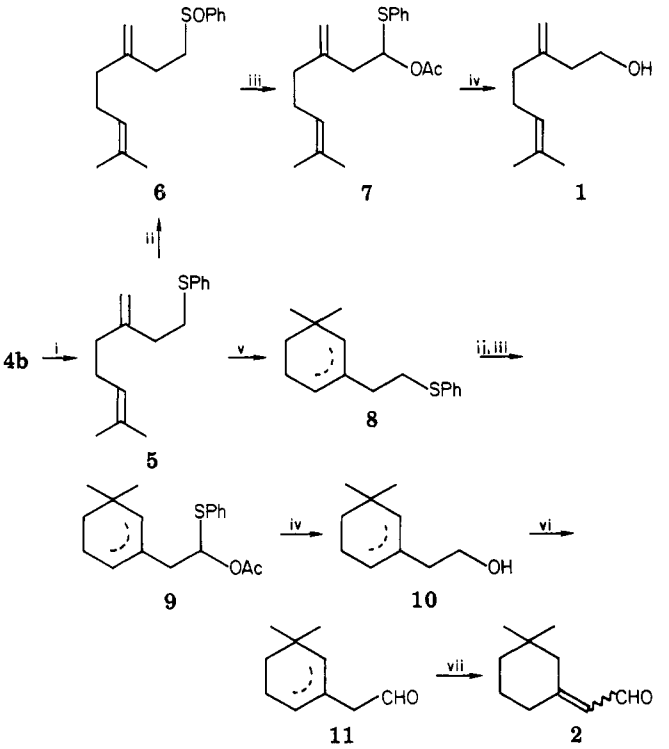
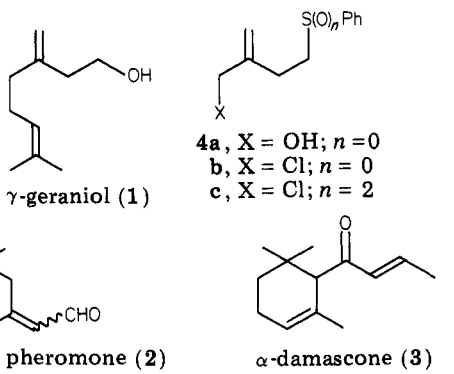
Previously, we have reported a convenient synthetic method for 2-(hydroxymethyl)-4-(phenylthio)-1-butene (**4a**) from ethyl acetoacetate and 2-(phenylthio)-1-bromoethane.[1] The versatility of the functionalities in **4a** has led us to novel syntheses of several terpenoids such as myrcene, citral, squalane, isophytol, β-ionone, irones, β-farnesene, β-sinensal, and dendrolasin.[2] Further, conjugated polyenes and methyl retinoate also have been successfully synthesized by employing **4a**.[3]

In this paper, we describe a new synthetic method for γ-geraniol (**1**), the cyclohexyl constituent of the boll weevil pheromone (**2**), and α-damascone (**3**). γ-Geraniol has been postulated as the biosynthetic precursor for grandisol and **2**,[4] while α-damascone is a black tea aroma constituent having a powerful fragrance.[5]

Scheme I[a]



[a] (i) $(CH_3)_2C{=}CHCH_2MgCl$, CuI, α,α′-dipyridyl, THF; (ii) H_2O_2, dioxane; (iii) Ac_2O catalyst $(CF_3CO)_2O$; (iv) $NaBH_4$–EtOH; (v) HCO_2H; (vi) PDC, CH_2Cl_2; (vii) MeONa–MeOH.



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