Synthesis and Characterization of 4-Aryl-5-(1-aryl-2-methyl-2-nitropropyl)-1,2,3-selenadiazoles

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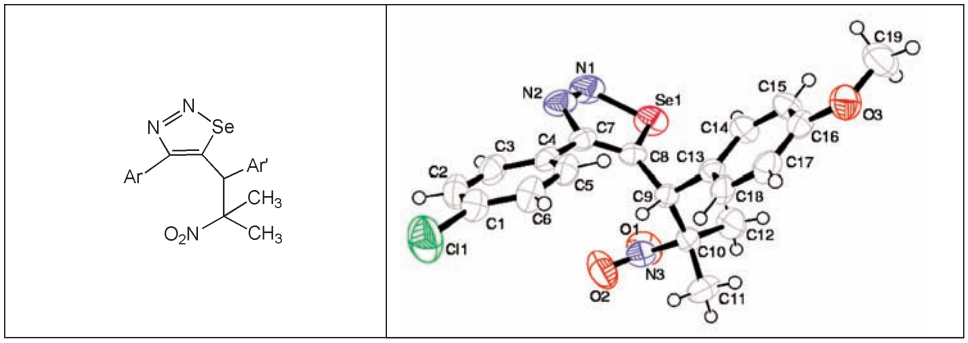
Received June 27, 2005



The synthesis of a new set of selenadiazoles, 4-aryl-5-(1-aryl-2-methyl-2-nitropropyl)-1,2,3-selenadiazoles (**4**) derived from 2-[4-methyl-4-nitro-1,3-diarylpentylidene]-1-hydrazinecarboxamide (**3**) has been reported. THF has been found to be the solvent of choice for this reaction. Structural features of **3** and **4** have been analyzed by NMR and X-ray techniques.

J. Heterocyclic Chem., **43**, 149 (2006).

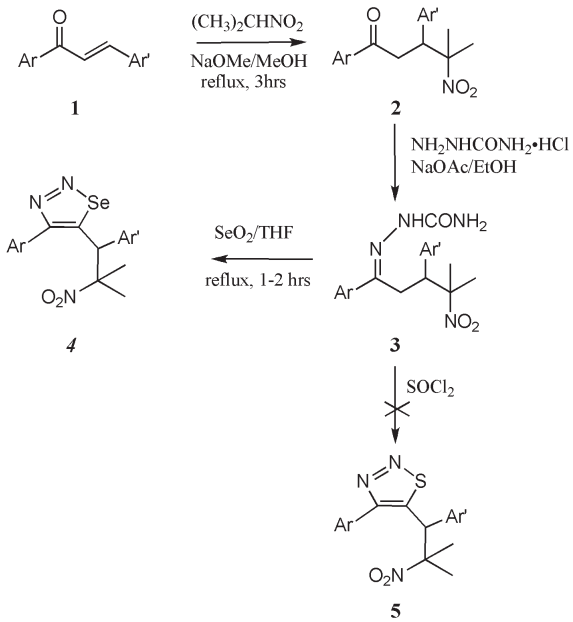
Introduction.

Synthesis of heterocyclic compounds containing selenium are of recent interest as 1,2,3-selenadiazoles are versatile intermediates for the preparation of alkynes and other selenium compounds [1]. They have attracted much attention for their biological characteristics [2]. The complexing ability of certain 1,2,3-selenadiazoles has been illustrated [3]. Recently, different N-substituted hydrazones are found to yield selenadiazole on selenium dioxide treatment [4], though conventionally the semicarbazones are used as the precursors [5]. Nitro groups are found responsible for potential biological activity in several molecules. For example, naturally occurring nitro compounds like chloramphenicol, 2-nitroimidazole, and aureothin exhibit a broad antibiotic activity and certain alkyl nitro compounds exhibit antitumor activity [6]. This prompted us to synthesize selenadiazole ring with a nitro group in the side chain. Thus, in continuation of our study on the chemistry of selenium heterocyclic compounds [7], we now report the synthesis and characterization of 4-aryl-5-(1-aryl-2-methyl-2-nitropropyl)-1,2,3-selenadiazoles.

Results and Discussion.

The adduct obtained by the addition of 2-nitropropane to chalcone, **1** [8] has its diastereotopic methylenic protons appearing nearly 0.4 ppm away from each other (3.57 δ, dd, 16.8, 10.8 Hz and 3.18 δ, dd, 16.8, 3.3 Hz for **2e**). The methine proton (4.07 δ, dd, 10.8, 3.3 Hz) appears downfield to these protons. When converted to its semicarbazone, in the major *E* isomer, these protons undergo dramatic shift in their position loosing the clarity in the

Scheme 1



	Ar	Ar'
a	C_6H_5	C_6H_5
b	C_6H_5	*p*-Me-C_6H_4
c	C_6H_5	*p*-OMe-C_6H_4
d	*p*-Cl-C_6H_4	*p*-Me-C_6H_4
e	*p*-Cl-C_6H_4	*p*-OMe-C_6H_4
f	*p*-Cl-C_6H_4	*p*-Cl-C_6H_4
g	*p*-Me-C_6H_4	*p*-Me-C_6H_4
h	*p*-Me-C_6H_4	*p*-OMe-C_6H_4
i	4-Biphenyl	*p*-OMe-C_6H_4
j	2-Naphthyl	2-furyl

coupling pattern. The difference between the non equivalent methylenic protons is now increased by 0.8 ppm, the methine proton suffering a deshielding of about 0.5 ppm. The coupling pattern is not well defined due to an ABX spin system and hence the correct geometry and conformation for these semicarbazones can not be obtained from the ^{1}H NMR data. Hence, to ascertain the preferred geometry, X-ray analysis of one of the semicarbazones (**3f**) was carried out, though what is found in solid state need not always corresponds to that in the solution. The results are presented in Table 1 and the ORTEP and packing diagrams are shown in Figure 1 and Figure 2 respectively [9]. This study clearly confirms the *E* orientation around C=N bond and the preference for the gauche arrangement between the aryl group and iminocarbon around the α and β-carbons. This is in accordance with the solid state conformations of related semicarbazones **6** and **7** (Figure 3), studied by us earlier [10]. It is interesting to notice that in the solid state, the hydrogen on the NH and not the NH_2 group of one molecule is involved in hydrogen bonding with the carbonyl oxygen of the other molecule thus forming a closed dimer (N2–H2 = 0.86 Å, H2–O1 = 2.066 Å, N2–O1 = 2.901 Å and N2–H2–O1 = 163.75°; symmetry code: -x, -y+1, -z+1) as noticed in **6** in contrast to **7**. One of the hydrogen on the NH_2 group is involved in intermolecular hydrogen bonding with the oxygen of the NO_2 group of the third molecule (N1–H1B = 0.86 Å, H1B–O2 = 2.428 Å, N1–O2 = 3.029 Å and N1–H1B–O2 = 127.42°; symmetry code: x+1, y, z) (Figure 2). The minor *Z*-isomer of the semicarbazone exhibits a well-defined AMX pattern, unlike the *E*-isomer. The ^{1}H NMR spectrum recorded for **3a** as mixture of *E* and *Z*-isomers indicates that one of the α-protons of the *Z* isomer is shielded to 3.1 ppm compared

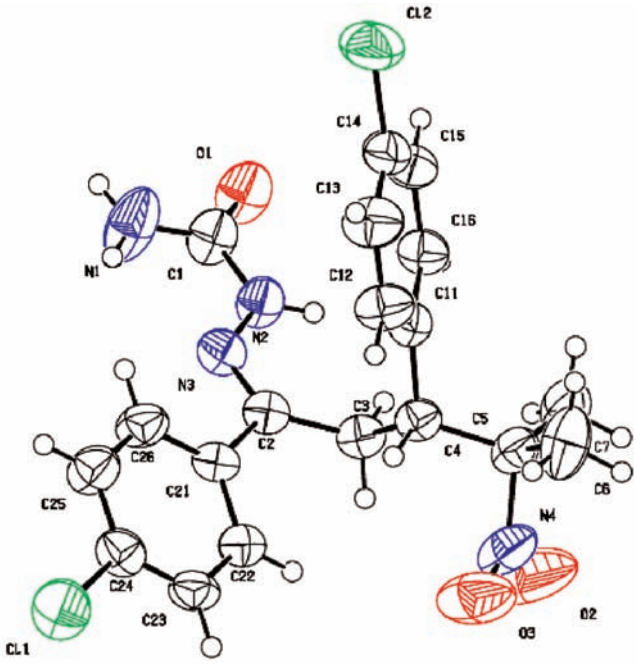


Figure 1. ORTEP diagram of 2-[(*E*)-1,3-bis(4-chlorophenyl)-4-methyl-4-nitropentylidene]-1-hydrazinecarboxamide (**3f**).

Table 1

Crystal Data and Structural Refinement for **3f** and **4e**

Parameters	**3f**	**4e**
Empirical formula	$C_{19}H_{20}Cl_2N_4O_3$	$C_{19}H_{18}ClN_3O_3Se$
Formula weight	423.29	450.77
Temperature	293(2) K	293(2) K
Wavelength	0.71073 Å	0.71073 Å
Crystal system, Space group	Triniclinic, P-1	Monoclinic, P21/c
Unit cell dimensions	a = 8.873 Å; α = 82.78 deg; b = 10.626 Å; β = 80.14 deg; c = 11.388 Å; γ = 88.08 deg.	a = 11.570 Å; α = 90 deg; b = 9.653 Å; β = 99.74 deg; c = 17.781 Å; γ = 90 deg.
Z, Volume	2, 1049.5(7) A^3	4, 1957.3(14) A^3
Density (calculated)	1.340 Mg/m^3	1.530 Mg/m^3
Absorption coefficient	0.336 mm^{-1}	2.079 mm^{-1}
F(000)	440	912
Crystal size	0.22 x 0.19 x 0.15 mm	0.25 x 0.18 x 0.14 mm
Theta range for data collection	2.33 to 24.98 deg.	2.32 to 24.99 deg.
Index ranges	-1≤h≤10, -12≤k≤12, -13≤l≤13	0≤h≤13, -1≤k≤11, -21≤l≤20
Reflections collected	4473	4078
Independent reflections	3691 [R(int) = 0.0184]	3433 [R(int) = 0.0416]
Absorption correction	Psi-scans	Psi-scans
Refinement method	Full-matrix least-squares on F^2	Full-matrix least-squares on F^2
Data / restraints / parameters	3691 / 0 / 255	3433 / 0 / 247
Goodness-of-fit on F^2	1.016	1.006
Final R indices [I>2sigma(I)]	R_1 = 0.0445, wR_2 = 0.1117	R_1 = 0.0430, wR_2 = 0.1028
R indices (all data)	R_1 = 0.1026, wR_2 = 0.1365	R_1 = 0.1068, wR_2 = 0.1251
Largest diff. peak and hole	0.343 and -0.277 $e.A^{-3}$	0.494 and -0.449 $e.A^{-3}$

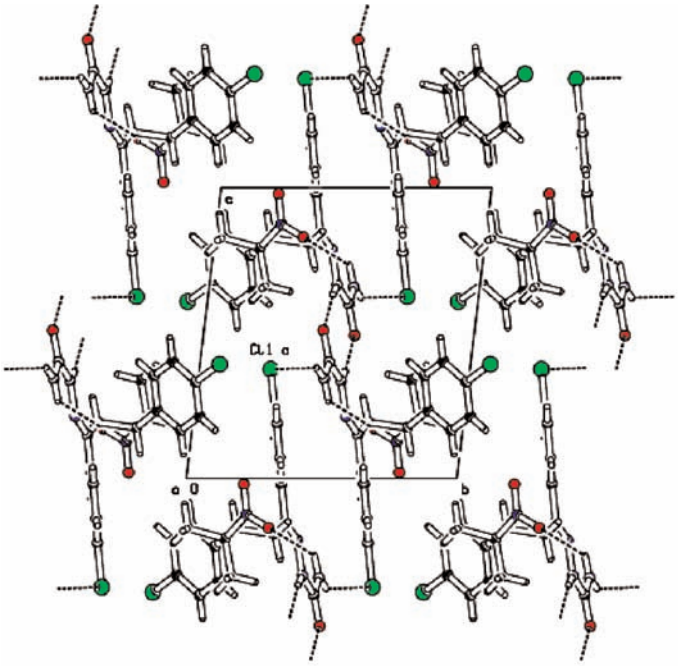
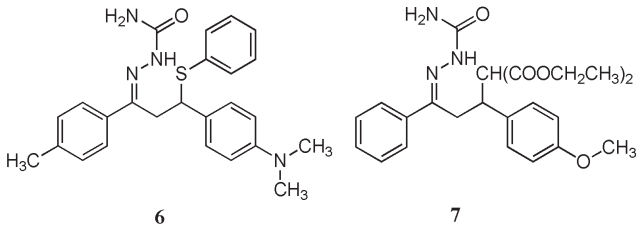


Figure 2. Packing diagram of 2-[(*E*)-1,3-bis(4-chlorophenyl)-4-methyl-4-nitropentylidene]-1-hydrazinecarboxamide (**3f**).

to *E* isomer, while the β-proton is deshielded slightly. Considerable difference in the chemical shift of α-carbons of these two stereoisomers has been noticed (27.3 ppm for *E*-isomer and 37.3 ppm for *Z*-isomer), though there is not much difference in the chemical shifts of other carbons of these isomers.

Semicarbazones (**3**) were then subjected to selenium dioxide treatment in different solvents. In acetic acid, nearly the whole semicarbazone undergoes conversion but only 20 % of the semicarbazone gets converted to selenadiazole (**4**), while the remaining gets hydrolysed to the parent ketone (**1**). In dimethylformamide, the reaction mixture still contains traces of semicarbazone even after 2 hours, but the extent of selenadiazole formation over ketone is more here with a ratio of 1.0 to 1.5 (45 %). However tetrahydrofuran is found to be an excellent solvent as, under reflux condition, hydrolysis of the semicarbazone to



6 **7**

Figure 3. Semicarbazones of phenylthio and diethyl malonate adducts of chalcone.

the ketone did not take place and around 60 % of selenadiazole (**4**) has been isolated.

The semicarbazones were then subjected to thinoyl chloride treatment in the hope of getting the respective thiadiazoles (**5**). Unfortunately the reaction did not proceed in the expected line giving only the parent ketone in quantitative yield.

All the selenadiazoles (**4a-4j**) synthesized were characterized by spectral techniques. The mass spectra of all the compounds (except **4j**) lack the molecular ion peak. A very weak fragment ion corresponding to M-108 has been noticed in all the cases and the base peak in these compounds corresponds to the fragment M-196 due to the loss of SeN_2 and subsequently $C_3H_6NO_2$ units. Another prominent fragment at M-154 by the loss of SeN_3O_2 has been noticed in all the compounds with considerable intensity (~ 25 %). Compound **4j** does not show any of the above peaks indicating different pattern of fragment in this case. Complete characterization of a representative selenadiazole, 4-(4-chlorophenyl)-5-[1-(4-methoxyphenyl)-2-methyl-2-nitropropyl]-1,2,3-selenadiazole (**4e**, Figure 4), is discussed here in detail. The ^{1}H NMR spectrum of **4e** exhibits two singlets each accounting for three protons at 1.55 and 1.56 ppm due to the diastereotopic nature of the methyl groups and the former signal correlates with the signal at 25.7 ppm in C,H-COSY and the latter with that at 23.4 ppm. There is a three proton singlet at 3.80 ppm due to the methoxy group. This signal has a C,H-COSY contour with a signal at 55.3 ppm and hence the latter is assigned to C-10. As the signal at 3.80 ppm shows HMBC

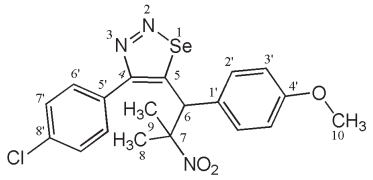


Figure 4. 4-(4-Chlorophenyl)-5-[1-(4-methoxyphenyl)-2-methyl-2-nitropropyl]-1,2,3-Selenadiazole.

contour with the signal at 159.5 ppm, the latter is assigned to C-4', which in turn makes HMBC contour with the signal at 7.07 ppm. Hence the signal at 7.07 is due to H-2'. From the C,H-COSY contour of this signal, C-2' is assigned to be 131.1. The H-3' and C-3' are assigned to the signals at 6.87 ppm and 114.5 ppm, respectively which is confirmed from H, H-COSY and C,H-COSY spectra. The proton H-3' makes an HMBC contour with the signal at 126.6 ppm which is now assigned to C-1'. The one hydrogen singlet at 5.25 ppm can easily be assigned to H-6 and from the C,H-COSY spectrum, C-6 is assigned to the signal at 55.1 ppm. The proton H-6 shows seven HMBC contours, of which the signals at 126.6, 131.1, 25.7 and 23.4

have already been assigned, and now the carbons C-7, C-4 and C-5 are assigned to the signal at 91.1, 161.4 and 155.7 ppm respectively. The assigned signals for C-4 and C-5 are confirmed by the fact that C-5 shows only one HMBC contour with H-6, while C-4 makes HMBC contour with H-6 and another aromatic proton signal at 7.36 ppm, which is now assigned to H-6'. From H,H-COSY and C,H-COSY experiments, it is very easy to assign signals at 7.50 ppm, 131.3 ppm, 129.1 ppm to H-7', C-6' and C-7'. As H-7' has a strong HMBC relation with the signal at 130.3 ppm and a relatively weak contour with the signal at 135.5 ppm, the former can be assigned to C-5' and the latter to C-8'.

The single crystal X-ray analysis for this compound (**4e)** confirms the above structural assignment [11]. The results are summarized in Table 1 and the ORTEP diagram is shown in Figure 5**.** In the crystal state, the aryl substitutent at the 4th position of the selenadiazole ring is slightly out of plane to the heterocyclic ring.

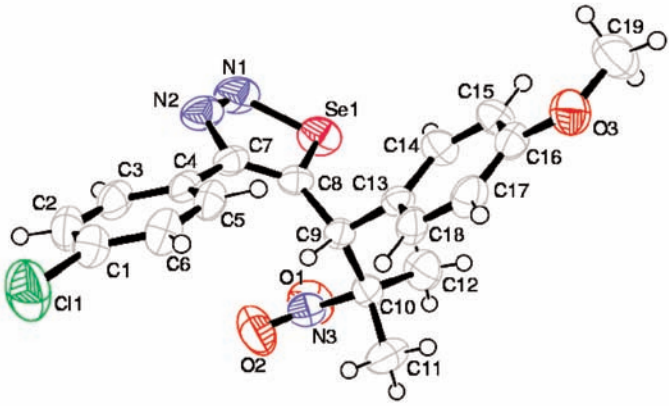


Figure 5. ORTEP diagram of 4-(4-chlorophenyl)-5-[1-(4-methoxyphenyl)-2-methyl-2-nitropropyl]-1,2,3-selenadiazole (**4e**).

EXPERIMENTAL

Melting points are uncorrected. ^{1}H NMR and ^{13}C NMR spectra were recorded on a Bruker 300 MHz instrument in $CDCl_3$ using TMS as internal standard. Chemical shifts are given in parts per million (δ-scale) and coupling constants are given in Hertz. GC/MS spectra were recorded on a Thermo Finnigan gas chromatograph (RTX-5 capillary column) with a Finnigan mass spectrometer operating on the electron impact mode (70 eV). IR spectra were recorded on a JASCO FT-IR instrument using KBr pellets. The single crystal X-ray data were collected on a Nonius MACH3 kappa diffractometer with MoK_α radiation (λ = 0.71073 Å). The structure was solved by direct methods from SHELXS-86 and refined by full matrix least squares on F^2 by SHELXL-93. Crystallographic data (excluding structure factors) for the structure in this paper have been deposited with the Cambridge Crystallographic Data Centre as supplementary publication number CCDC 273007 and CCDC 273723 for **3f** and **4e** respectively. Copies of the data can be obtained, free of charge, by contacting The Cambridge Crystallographic Data Centre, 12, Union Road, Cambridge CB2 1EZ, UK (email: data_request@ccdc.cam.ac.uk; fax: +44 1223 336033).

General Procedure for the Preparation of 4-Methyl-4-nitro-1,3-diaryl-1-pentanone (**2a-i**) and 3-(2-Furyl)-4-methyl-1-(2-naphthyl)-4-nitro-1-pentanone (**2j**).

The adducts, 4-methyl-4-nitro-1,3-diaryl-1-pentanone, have all been prepared by reported procedure [8]. A solution of 2-nitropropane and substituted chalcones in ethanol was refluxed on a water bath in presence of catalytic amount of sodium ethoxide for about five hours and the reaction mixture was cooled. The crystals obtained were washed with ethanol and dried.

General Procedure for the Preparation of 2-[4-Methyl-4-nitro-1,3-diarylpentylidene]-1-hydrazine Carboxamide (**3a-j**).

To a warm solution of 0.01 mole of the appropriate ketone in 30 mL of ethanol, a solution of equimolar amount (0.07 mole) of semicarbazide hydrochloride and anhydrous sodium acetate in 20 mL of water was added and refluxed for 4 hours. The solution was cooled and poured onto crushed ice and extracted with chloroform. The solvent was evaporated and the product was recrystallised from ethanol.

2-[4-Methyl-4-nitro-1,3-diphenylpentylidene]-1-hydrazine Carboxamide (**3a**).

This compound was obtained as colourless crystals (ethanol), yield 85 % (*E*:*Z* = 64:36), mp 152 ºC; ir (potassium bromide): 3465, 2928, 1687, 1579, 1535, 1458 cm^{-1}; ^{1}H NMR (of *E* and *Z* mixture): δ 1.39 (s, 3H), 1.42 (s, 3H), 1.70 (s, 3H), 1.91 (s, 3H), 2.74 (disturbed doublet, J = 10.5 Hz, 1H, *E*-isomer), 2.80 (dd, J = 15.3, 3.3 Hz, 1H, *Z*-isomer), 3.10 (dd, J = 15.3, 12 Hz, 1H, *Z*-isomer), 3.66 (dd, J = 12, 3.3 Hz, 1H, *Z*-isomer), 3.54-3.61 (m, 2H, *E*-isomer), 5.09 (bs, 2H), 6.03 (bs, 2H), 6.87-6.91 (m, 2H), 6.99-7.03 (m, 2H), 7.12-7.24 (m, 6H), 7.29-7.33 (m, 6H), 7.37-7.40 (m, 4H) 9.73 (s, 2H); ^{13}C NMR*: 21.4, 21.5, 26.0, 26.2, 27.3 (*E*-isomer), 37.3 (*Z*-isomer), 50.6, 51.1, 91.5, 91.8, 126.6, 126.7, 127.9, 128.0, 128.2, 128.4, 128.8, 129.3, 129.5, 129.6, 129.7, 132.4, 136.0, 136.8, 137.3, 147.9, 148.3, 156.7, 158.4 (one aromatic carbon resonance is merged with another).

Anal. Calcd. for $C_{19}H_{22}N_4O_3$: C, 64.39; H, 6.26; N, 15.81. Found: C, 64.52; H, 6.30; N, 15.71.

2-[(*E*)-4-Methyl-3-(4-methylphenyl)-4-nitro-1-phenylpentylidene]-1-hydrazine Carboxamide (**3b**).

This compound was obtained as colourless crystals (ethanol), yield 44 %, mp 170 ºC; ir (potassium bromide): 3467, 2929, 1674, 1576, 1533, 1464 cm^{-1}; ^{1}H NMR: δ 1.40 (s, 3H), 1.72 (s, 3H), 2.27 (s, 3H), 2.74 (disturbed doublet, J = 10.5 Hz, 1H), 3.50-3.62 (m, 2H), 5.09 (bs, 1H), 6.03 (bs, 1H), 6.91 (d, J = 8.1 Hz, 2H), 6.99 (d, J = 8.1 Hz, 2H), 7.23 - 7.27 (m, 2H), 7.29 - 7.34 (m, 3H), 9.56 (s, 1H); ^{13}C NMR: 21.1, 21.4, 26.4, 27.4, 50.7, 91.9, 126.7, 128.3, 128.8, 129.0, 129.1, 132.9, 137.3, 137.8, 148.2, 158.3.

Anal. Calcd. for $C_{20}H_{24}N_4O_3$: C, 65.20; H, 6.57; N, 15.21. Found: C, 65.28; H, 6.65; N, 15.29.

2-[(*E*)-3-(4-Methoxyphenyl)-4-methyl-4-nitro-1-phenylpentylidene]-1-hydrazine Carboxamide (**3c**).

This compound was obtained as colourless crystals (ethanol), yield 38 %, mp 151 ºC; ir (potassium bromide): 3467, 2937, 1676, 1570, 1533, 1464 cm^{-1}; ^{1}H NMR: δ 1.41 (s, 3H), 1.72 (s,

3H), 2.72 (disturbed doublet, J = 10.8 Hz, 1H), 3.57-3.59 (m, 2H), 3.74 (s, 3H), 5.10 (bs, 1H), 6.11 (bs, 1H), 6.72 (d, J = 8.7 Hz, 2H), 7.95 (d, J = 8.7 Hz, 2H), 7.23 - 7.27 (m, 2H), 7.30 - 7.35 (m, 3H), 9.81 (s, 1H); ^{13}C NMR: 21.3, 26.2, 27.3, 50.4, 55.1, 91.9, 113.6, 126.6, 127.9, 128.3, 128.8, 130.3, 137.3, 148.3, 158.5, 159.1.

Anal. Calcd. for $C_{20}H_{24}N_4O_4$: C, 62.49; H, 6.29; N, 14.57. Found: C, 62.45; H, 6.33; N, 14.62.

2-[(*E*)-1-(4-Chlorophenyl)-4-methyl-3-(4-methylphenyl)-4-nitropentylidene]-1-hydrazine Carboxamide (**3d**).

This compound was obtained as colourless crystals (ethanol), yield 42 %, mp 157 ºC; ir (potassium bromide): 3473, 2920, 1676, 1570, 1531, 1461 cm^{-1}; ^{1}H NMR: δ 1.39 (s, 3H), 1.72 (s, 3H), 2.26 (s, 3H), 2.65 (dd, J = 12.9, 2.1 Hz, 1H), 3.57-3.76 (m, 2H), 5.34 (bs, 1H), 6.03 (bs, 1H), 6.92 (d, J = 8.1 Hz, 2H), 6.99 (d, J = 8.1 Hz, 2H), 7.18 (d, J = 8.4 Hz, 2H), 7.28 (d, J = 8.4 Hz, 2H), 10.03 (s, 1H); ^{13}C NMR: 20.9, 21.0, 26.5, 27.2, 50.7, 91.9, 127.9, 128.4, 129.0, 129.2, 132.7, 134.7, 135.7, 137.8, 147.1, 158.5.

Anal. Calcd. for $C_{20}H_{23}ClN_4O_3$: C, 59.63; H, 5.75; N, 13.91. Found: C, 59.75; H, 5.81; N, 13.88.

2-[(*E*)-1-(4-Chlorophenyl)-3-(4-methoxyphenyl)-4-methyl-4-nitropentylidene]-1-hydrazine Carboxamide (**3e**).

This compound was obtained as colourless crystals (ethanol), yield 61 %, mp 186 ºC; ir (potassium bromide): 3471, 2927, 1685, 1579, 1535, 1460 cm^{-1}; ^{1}H NMR: δ 1.39 (s, 3H), 1.72 (s, 3H), 3.74 (s, 3H), 2.65 (dd, J = 12.9, 1.5 Hz, 1H), 3.52-3.66 (m, 2H), 5.25 (bs, 1H), 6.06 (bs, 1H), 6.72 (d, J = 8.7 Hz, 2H), 6.95 (d, J = 8.7 Hz, 2H), 7.18 (d, J = 8.7 Hz, 2H), 7.29 (d, J = 8.7 Hz, 2H), 10.07 (s, 1H); ^{13}C NMR: 21.0, 26.5, 27.2, 50.4, 55.1, 91.9, 113.6, 127.7, 127.9, 128.5, 130.4, 134.7, 135.8, 147.2, 158.5, 159.2.

Anal. Calcd. for $C_{20}H_{23}ClN_4O_4$: C, 57.35; H, 5.53; N, 13.38. Found: C, 57.44; H, 5.50; N, 13.45.

2-[(*E*)-1,3-Bis(4-chlorophenyl)-4-methyl-4-nitropentylidene]-1-hydrazine Carboxamide (**3f**).

This compound was obtained as colourless crystals (ethanol), yield 40 %, mp 187-188 ºC; ir (potassium bromide): 3485, 2933, 1687, 1577, 1533, 1459 cm^{-1}; ^{1}H NMR (DMSO): δ 1.41 (s, 3H), 1.73 (s, 3H), 2.67 (broad d, J = 12.6 Hz,1H), 3.57-3.77 (m, 2H), 5.81 - 6.19 (bs, 2H), 7.03 (d, J = 8.1 Hz, 2H), 7.17 (d, J = 8.1 Hz, 2H), 7.24 (d, J = 8.4 Hz, 2H), 7.31 (d, J = 8.4 Hz, 2H), 10.24 (s, 1H); ^{13}C NMR (DMSO): 21.0, 25.2, 26.2, 50.1, 91.1, 127.4, 127.7, 127.9, 130.2, 133.2, 133.9, 134.1, 135.2, 145.1, 157.8.

Anal. Calcd. for $C_{19}H_{20}Cl_2N_4O_3$: C, 53.91; H, 4.76; N, 13.24. Found: C, 53.98; H, 4.80; N, 13.32.

2-[(*E*)-4-Methyl-1,3-bis(4-methylphenyl)-4-nitropentylidene]-1-hydrazine Carboxamide (**3g**).

This compound was obtained as colourless crystals (ethanol), yield 59 %, mp 202 ºC; ir (potassium bromide): 3471, 2927, 1682, 1580, 1537, 1456 cm^{-1}; ^{1}H NMR: δ 1.40 (s, 3H), 1.72 (s, 3H), 2.27 (s, 3H), 2.37 (s, 3H), 2.71 (dd, J = 10.5, 1.5 Hz, 1H), 3.50-3.61 (m, 2H), 5.15 (bs, 1H), 6.05 (bs, 1H), 6.93 (d, J = 8.1 Hz, 2H), 7.00 (d, J = 8.1 Hz, 2H), 7.12 (d, J = 8.4 Hz, 2H), 7.17 (d, J = 8.4 Hz, 2H), 9.64 (s, 1H); ^{13}C NMR*: 21.0, 21.2, 21.5, 26.2, 27.3, 50.9, 91.9, 126.5, 128.9, 129.1, 133.0, 134.4, 137.7, 138.9, 148.3, 158.4 (one aromatic carbon resonance is merged with another).

Anal. Calcd. for $C_{21}H_{26}N_4O_3$: C, 65.95; H, 6.85; N, 14.65. Found: C, 66.02; H, 6.90; N, 14.72.

2-[(*E*)-3-(4-Methoxyphenyl)-4-methyl-1-(4-methylphenyl)-4-nitropentylidene]-1-hydrazine Carboxamide (**3h**).

This compound was obtained as colourless crystals (ethanol), yield 47 %, mp 203 ºC; ir (potassium bromide): 3469, 2929, 1685, 1579, 1535, 1458 cm^{-1}; ^{1}H NMR: δ 1.40 (s, 3H), 1.71 (s, 3H), 2.37 (s, 3H), 3.74 (s, 3H), 2.70 (disturbed doublet, J = 10.5 Hz, 1H), 3.48-3.59 (m, 2H), 5.13 (bs, 1H), 6.07 (bs, 1H), 6.72 (d, J = 8.7 Hz, 2H), 6.96 (d, J = 8.7 Hz, 2H), 7.12 (d, J = 8.4 Hz, 2H), 7.16 (d, J = 8.4 Hz, 2H), 9.66 (s, 1H); ^{13}C NMR: 21.2, 21.4, 26.2, 27.4, 50.5, 55.1, 91.9, 116.6, 126.5, 128.0, 129.0, 130.3, 134.5, 138.9, 148.3, 158.4, 159.2.

Anal. Calcd. for $C_{21}H_{26}N_4O_4$: C, 63.30; H, 6.58; N, 14.06. Found: C, 63.37; H, 6.64; N, 14.10.

2-[(*E*)-1-[1,1'-Biphenyl]-4-yl-3-(4-methoxyphenyl)-4-methyl-4-nitropentylidene]-1-hydrazine Carboxamide (**3i**).

This compound was obtained as colourless crystals (ethanol), yield 43 %, mp 186 ºC; ir (potassium bromide): 3525, 2927, 1676, 1560, 1537, 1466 cm^{-1}; ^{1}H NMR (DMSO): δ 1.42 (s, 3H), 1.72 (s, 3H), 2.71 (disturbed doublet, J = 11.4 Hz, 1H), 3.58-3.66 (m, 2H), 3.73 (s, 3H), 5.95 (bs, 2H), 6.71 (d, J = 8.1 Hz, 2H), 6.99 (d, J = 8.1 Hz, 2H), 7.35 - 7.48 (m, 5H), 7.56 (d, J = 7.8 Hz, 2H), 7.63 (d, J = 7.8 Hz, 2H), 9.72 (s, 1H); ^{13}C NMR (DMSO): 20.9, 25.0, 26.2, 49.8, 54.3, 91.4, 112.7, 125.9, 126.1, 126.3, 126.8, 127.2, 128.1, 129.7, 135.6, 139.4, 140.2, 145.9, 157.4, 158.3.

Anal. Calcd. for $C_{26}H_{28}N_4O_4$: C, 67.81; H, 6.13; N, 12.17. Found: C, 67.76; H, 6.19; N, 12.25.

2-[(*E*)-3-(2-Furyl)-4-methyl-1-(2-naphthyl)-4-nitropentylidene]-1-hydrazine Carboxamide (**3j**).

This compound was obtained as colourless crystals (ethanol), yield 52 %, mp 195 ºC; ir (potassium bromide): 3467, 2927, 1685, 1531, 1452 cm^{-1}; ^{1}H NMR: δ 1.40 (s, 3H), 1.79 (s, 3H), 2.88 (disturbed doublet, J = 10.5 Hz, 1H), 3.74-3.80 (m, 2H), 5.30 (bs, 1H), 6.12 (bs, 1H), 7.06 – 7.08 (m, 2H), 7.16 - 7.20 (m, 2H), 7.42 - 7.52 (m, 2H), 7.70 - 7.82 (m, 4H), 10.06 (s, 1H); ^{13}C NMR*: 21.2, 26.6, 27.3, 51.4, 91.9, 124.2, 126.2, 126.3, 126.6, 127.5, 127.9, 128.1, 128.3, 128.5, 129.4, 132.9, 133.4, 134.4, 136.2, 147.9, 158.6 (one aromatic carbon resonance is merged with another).

Anal. Calcd. for $C_{21}H_{22}N_4O_4$: C, 63.95; H, 5.62; N, 14.20. Found: C, 63.76; H, 5.82; N, 14.47.

General Procedure for the Synthesis of 5-(2,2-Dimethyl-1-arylpropyl)-4-aryl-1,2,3-selenadiazoles (**4a-j**).

A solution of 0.005 mole of the appropriate semicarbazone and 0.05 mole of powdered selenium dioxide in dry THF was gently heated on a water bath for two hours. The selenium deposited on cooling was removed by filtration, and the filtrate was poured into crushed ice, extracted with chloroform, and purified by column chromatography using silica gel (60-120 mesh) with 97:3 petroleum ether: ethyl acetate as eluent to give the selenadiazoles (**4a-j),** which were recrystallised from ethyl alcohol.

5-(2-Methyl-2-nitro-1-phenylpropyl)-4-phenyl-1,2,3-selenadiazole (**4a**).

This compound was obtained as colourless crystals (ethanol), reaction time 2 hrs, yield 62 %, mp 86-87 ºC; ir

(potassium bromide): 2994, 2927, 1541, 1452, 1338 cm^{-1}; ^1H NMR: δ 1.55 (s, 6H), 5.36 (s, 1H), 7.14-7.17 (m, 2H), 7.32-7.35 (m, 3H), 7.40-7.43 (m, 2H), 7.51-7.54 (m, 3H); ^{13}C NMR: 23.8, 25.5, 55.8, 91.0, 128.4, 128.8, 129.0, 129.3, 129.9, 130.0, 131.7, 135.1, 155.0, 162.9; ms: m/z 249 (1%), 232 (24%), 217 (26%), 202 (21%), 191 (100%), 189 (33%), 91 (56%), 77 (25%).

Anal. Calcd. for $C_{18}H_{17}N_3O_2Se$: C, 55.96; H, 4.44; N, 10.88. Found: C, 56.16; H, 4.64; N, 11.02.

5-[2-Methyl-1-(4-methylphenyl)-2-nitropropyl]-4-phenyl-1,2,3-selenadiazole (**4b**).

This compound was obtained as colourless crystals (ethanol), reaction time 2 hrs, yield 65 %, mp 96 ºC; ir (potassium bromide): 2989, 2927, 1541, 1456, 1342 cm^{-1}; ^1H NMR: δ 1.54 (s, 3H), 1.55 (s, 3H), 2.33 (s, 3H), 5.32 (s, 1H), 7.04 (d, J = 8.4 Hz, 2H), 7.14 (d, J = 8.4 Hz, 2H), 7.41-7.45 (m, 2H), 7.51-7.54 (m, 3H); ^{13}C NMR: 21.0, 23.9, 25.3, 55.4, 91.1, 128.8, 129.2, 129.7, 129.8, 130.0, 131.8, 132.0, 138.4, 155.2, 162.7; ms: m/z 263 (1%), 246 (23%), 231 (12%), 215 (15%), 205 (100%), 202 (23%), 189 (10%), 91 (15%), 77 (14%).

Anal. Calcd. for $C_{19}H_{19}N_3O_2Se$: C, 57.00; H, 4.78; N, 10.50. Found: C, 57.21; H, 4.82; N, 10.63.

5-[1-(4-Methoxyphenyl)-2-methyl-2-nitropropyl]-4-phenyl-1,2,3-selenadiazole (**4c**).

This compound was obtained as colourless crystals (ethanol), reaction time 2 hrs, yield 69 %, mp 82-83 ºC; ir (potassium bromide): 2989, 2933, 1541, 1460, 1346 cm^{-1}; ^1H NMR: δ 1.54 (s, 3H), 1.55 (s, 3H), 3.79 (s, 3H), 5.30 (s, 1H), 6.86 (d, J = 9.0 Hz, 2H), 7.07 (d, J = 9.0 Hz, 2H), 7.41-7.44 (m, 2H), 7.51-7.54 (m, 3H); ^{13}C NMR: 23.8, 25.3, 55.0, 55.3, 91.1, 114.3, 126.8, 128.8, 129.2, 129.9, 131.0, 131.8, 155.3, 159.4, 162.6; ms: m/z 309 (0.1%), 279 (0.1%), 262 (13%), 247 (5%), 232 (2%), 221 (100%), 202 (5%), 189 (4%), 91 (5%), 77 (4%).

Anal. Calcd. for $C_{19}H_{19}N_3O_3Se$: C, 54.81; H, 4.60; N, 10.09. Found: C, 54.78; H, 4.65; N, 10.15.

4-(4-Chlorophenyl)-5-[2-methyl-1-(4-methylphenyl)-2-nitropropyl]-1,2,3-selenadiazole (**4d**).

This compound was obtained as colourless crystals (ethanol), reaction time 2 hrs, yield 67 %, mp 133-134 ºC; ir (potassium bromide): 2990, 2931, 1537, 1458, 1342 cm^{-1}; ^1H NMR: δ 1.55 (s, 3H), 1.57 (s, 3H), 2.33 (s, 3H), 5.27 (s, 1H), 7.04 (d, J = 8.1 Hz, 2H), 7.16 (d, J = 8.1 Hz, 2H), 7.36 (d, J = 8.4 Hz, 2H), 7.50 (d, J = 8.4 Hz, 2H); ^{13}C NMR*: 21.0, 23.3, 25.8, 55.5, 91.0, 129.1, 129.8, 130.2, 131.4, 131.7, 135.4, 138.5, 155.6, 161.5; ms: m/z 328 (0.1%), 296(0.4%), 281 (25%), 239 (100%), 215 (27%), 202 (34%), 189 (11%), 91 (11%), 77 (12%) (one aromatic carbon resonance is merged with another).

Anal. Calcd. for $C_{19}H_{18}ClN_3O_2Se$: C, 59.49; H, 4.17; N, 9.66. Found: C, 59.54; H, 4.25; N, 9.75.

4-(4-Chlorophenyl)-5-[1-(4-methoxyphenyl)-2-methyl-2-nitropropyl]-1,2,3-selenadiazole (**4e**).

This compound was obtained as colourless crystals (ethanol), reaction time 2 hrs, yield 73 %, mp 121-122 ºC; ir (potassium bromide): 2987, 2930, 1539, 1460, 1346 cm^{-1}; ^1H NMR: δ 1.55 (s, 3H), 1.56 (s, 3H), 3.80 (s, 3H), 5.25 (s, 1H), 6.87 (d, J = 8.7 Hz, 2H), 7.07 (d, J = 8.7 Hz, 2H), 7.36 (d, J = 8.7 Hz, 2H), 7.50 (d, J = 8.7 Hz, 2H); ^{13}C NMR: 23.4, 25.7, 55.1, 55.3, 91.1, 114.5, 126.6, 129.1, 130.3, 131.1, 131.3, 135.5, 155.7, 159.5, 161.4; ms: m/z 344 (0.1%), 296 (13%), 281 (3%). 255 (100%), 239 (4%), 212 (6%), 202 (7%), 189 (4%), 91 (2%), 77 (2%).

Anal. Calcd. for $C_{19}H_{18}ClN_3O_3Se$: C, 50.62; H, 4.02; N, 9.32. Found: C, 50.69; H, 4.10; N, 9.41.

4-(4-Chlorophenyl)-5-[1-(4-chlorophenyl)-2-methyl-2-nitropropyl]-1,2,3-selenadiazole (**4f**).

This compound was obtained as colourless crystals (ethanol), reaction time 2 hrs, yield 71 %, mp 148-149 ºC; ir (potassium bromide): 2981, 2933, 1541, 1340, 1086 cm^{-1}; ^1H NMR: δ 1.56 (s, 3H), 1.57 (s, 3H), 5.27 (s, 1H), 7.08 (d, J = 8.4 Hz, 2H), 7.31-7.35 (m, 4H), 7.51 (d, J = 8.4 Hz, 2H); ^{13}C NMR: 23.6, 25.6, 55.2, 90.7, 129.2, 129.4, 130.0, 131.2, 131.3, 133.3, 134.8, 135.7, 154.8, 161.7; ms: m/z 347 (0.1%), 302 (62%), 282 (17%), 266 (31%), 259 (100%), 223 (31%), 215 (88%), 189 (61%), 94 (36%), 77. (8%).

Anal. Calcd. for $C_{18}H_{15}Cl_2N_3O_2Se$: C, 47.49; H, 3.32; N, 9.23. Found: C, 47.55; H, 3.38; N, 9.32.

5-[2-Methyl-1-(4-methylphenyl)-2-nitropropyl]-4-(4-methylphenyl)-1,2,3-selenadiazole (**4g**).

This compound was obtained as colourless crystals (ethanol), reaction time 2 hrs, yield 64 %, mp 94-95 ºC; ir (potassium bromide): 2919, 1541, 1342, 1024 cm^{-1}; ^1H NMR: δ 1.53 (s, 3H), 1.55 (s, 3H), 2.33 (s, 3H), 2.47 (s, 3H), 5.33 (s, 1H), 7.05 (d, J = 7.8 Hz, 2H), 7.15 (d, J = 7.8 Hz, 2H), 7.32 (s, 4H); ^{13}C NMR: 21.0, 21.4, 24.0, 25.2, 55.4, 91.1, 128.8, 129.5, 129.7, 129.8, 129.9, 132.1, 138.3, 139.2, 154.8, 162.9; ms: m/z 260 (16%), 245 (14%), 230 (11%), 219 (100%), 202 (22%), 185 (20%), 91 (17%), 77 (12%).

Anal. Calcd. for $C_{20}H_{21}N_3O_2Se$: C, 57.97; H, 5.11; N, 10.14. Found: C, 58.04; H, 5.18; N, 10.22.

5-[1-(4-Methoxyphenyl)-2-methyl-2-nitropropyl]-4-(4-methylphenyl)-1,2,3-selenadiazole (**4h**).

This compound was obtained as colourless crystals (ethanol), reaction time 2 hrs, yield 67 %, mp 141-142 ºC; ir (potassium bromide): 2979, 2927, 1537, 1462, 1342 cm^{-1}; ^1H NMR: δ 1.53 (s, 3H), 1.55 (s, 3H), 2.47 (s, 3H), 3.79 (s, 3H), 5.31 (s, 1H), 6.86 (d, J = 8.7 Hz, 2H), 7.08 (d, J = 8.7 Hz, 2H), 7.32 (s, 4H); ^{13}C NMR: 21.4, 24.0, 25.1, 55.1, 55.3, 91.2, 114.3, 127.0, 128.8, 129.5, 129.8, 131.1, 139.2, 154.9, 159.4, 162.7; ms: m/z 276 (12%), 261 (6%), 246 (3%), 235 (100%), 219 (2%), 202 (3%), 189 (6%), 91 (8%), 77 (8%).

Anal. Calcd. for $C_{20}H_{21}N_3O_3Se$: C, 55.82; H, 4.92; N, 9.76. Found: C, 55.89; H, 4.89; N, 9.84.

4-[1,1'-Biphenyl]-4-yl-5-[1-(4-methoxyphenyl)-2-methyl-2-nitropropyl]-1,2,3-selenadiazole (**4i**).

This compound was obtained as colourless crystals (ethanol), reaction time 2 hrs, yield 66 %, mp 128-130 ºC; ir (potassium bromide): 2993, 2927, 1541, 1473, 1338 cm^{-1}; ^1H NMR: δ 1.57 (s, 3H), 1.58 (s, 3H), 3.80 (s, 3H), 5.37 (s, 1H), 6.88 (d, J = 8.7 Hz, 2H), 7.11 (d, J = 8.7 Hz, 2H), 7.41 (tt, J = 8.1, 2.1 Hz, 1H), 7.49 (d, J = 8.1 Hz, 2H), 7.51 (d, J = 8.1 Hz, 2H), 7.71 (d, J = 8.7 Hz, 2H), 7.76 (d, J = 8.7 Hz, 2H); ^{13}C NMR: 23.8, 25.4, 55.1, 55.3, 91.2, 114.4, 126.9, 127.2, 127.5, 127.8, 128.9, 130.4, 130.7, 131.1, 140.3, 142.0, 155.2, 159.4, 162.4; ms: m/z 493 (0.1%), 385 (0.1%), 338 (28%), 323 (7%), 297 (100%), 252 (16%), 201 (10%), 77 (2%).

Anal. Calcd. for $C_{25}H_{23}N_3O_3Se$: C, 60.98; H, 4.71; N, 8.53. Found: C, 61.13; H, 4.49; N, 8.55.

5-[1-(2-Furyl)-2-methyl-2-nitropropyl]-4-(2-naphthyl)-1,2,3-selenadiazole (**4j**).

This compound was obtained as colourless crystals (ethanol), reaction time 2 hrs, yield 69 %, mp 118-119 ºC; ir (potassium bromide): 2981, 2923, 1531, 1342 cm^{-1}; ^1H NMR: δ 1.55 (s, 3H), 1.57 (s, 3H), 5.43 (s, 1H), 7.21 (d, J = 7.8 Hz, 2H), 7.37-7.42 (m, 2H), 7.55-7.63 (m, 2H), 7.83 (m, 2H), 7.96 (d, J = 8.4 Hz, 1H), 8.01 (d, J = 8.4 Hz, 1H); ^{13}C NMR: 24.2, 26.1, 56.4, 91.4, 127.1, 127.5, 127.6, 128.3, 128.7, 128.9, 129.1, 129.5, 129.6, 130.1, 130.6, 133.5, 133.8, 135.6, 155.4, 163.3; ms: m/z 282 (43%), 267 (30%), 252 (32%), 241 (100%), 239 (38%), 170.9 (28%).

Anal. Calcd. for $C_{20}H_{17}N_3O_3Se$: C, 56.34; H, 4.02; N, 9.86. Found: C, 56.41; H, 4.13; N, 9.81.

Acknowledgements.

The authors thank DST, New Delhi for assistance under the IRHPA program for the NMR facility. We thank UGC, New Delhi for assistance under the DRS program for the GC-MS facility and DST (FIST) New Delhi, for single crystal X-ray diffractometer facility. Financial support from CSIR, New Delhi to S Saravanan, SRF is gratefully acknowledged.

REFERENCES AND NOTES

[1a] W. Ando and N. Tokitoh, *Heteroat. Chem.,* 1 (1991); [b] P. Arsenyan, K. Oberte, O. Pudova, and E. Lukevics, *Chem. Heterocycl. Compds.*, **38**, 1437 (2002); [c] Y. Y. Morzherin, T. V. Glukhareva and V. A. Bakulev, *Chem. Heterocycl. Compds.,* **39,** 679 (2003); [d] M. Al-Smadi and S. Ratrout, *J. Heterocyclic Chem.*, **41**, 887 (2004).

[2a] C. Faria, M. Prizza, A. Gramba and G. I. Pifferri, *Eur. J. Med. Chem-Chem. Ther.,* **14**, 27 (1979); [b] I. Lalezari, A. Shafiee, J. Khorrami and A. Soltani, *J Pharm Sci.,* **67,** 1336 (1978); [c] M. M. Kandeel, S. El-Meligie, R. H. Omar, S. A. Roshdy and K. M. Youssef, *J. Pharm. Sci.,* **3**,197 (1994).

[3a] S. Ford, C. P. Morley and M. Di Vaira, *Chem. Commun.,*1305 (1998); [b] S. Ford, P. K. Khanna, C. P. Morley and M. Di Vaira, *J. Chem. Soc., Dalton Trans.,* 791 (1999).

[4] M. Al-Smadi and S. Ratrout, *Molecules,* **9**, 957 (2004).

[5] I. Lalezari, A. Shafiee and M. Yalpani, *J. Org. Chem.,* **38**, 338 (1973).

[6] J. Venulet and R. L. VanEtten, in The Chemistry of the Nitro and Nitroso Groups, Part 2, H. Feuer, ed, John Wiley & Sons, New York, NY, 1970, pp 201.

[7a] S. Muthusubramanian, K. Parvathi, and S. Sivasubramanian, *Indian J. Heterocycl. Chem.*, **6**, 227 (1977); [b] S Saravanan and S. Muthusubramanian, *Phosphorus, Sulfur Silicon Relat. Elem.*, **179**, 2411 (2004).

[8] M. C. Koletzel, *J. Am. Chem. Soc.*, **69**, 2271 (1947).

[9] Crystal data have been deposited to CCDC, number 273007.

[10a] S. Saravanan, S. Muthusubramanian and K. Polborn, *J. Mol. Struct.*, **748**, 165 (2005); [b] S. Saravanan and S. Muthusubramanian, *Acta Crystallogr. Sect. E: Struct. Rep. Online*, **E60**, o1895 (2004).

[11] Crystal data have been deposited to CCDC, number 273723.