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Toxicological and pesticidal studies on novel bioactive sulfonamide imine organotin(IV) complexes

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Toxicological, pesticidal and stereochemical aspects of organotin(IV) complexes with a sulfonamide imine ligand having an N∩N donor system are described with the support of elemental analysis, IR, UV, ^{1}H NMR, ^{13}C NMR and ^{119}Sn NMR spectroscopy. The spectral data suggest that the ligand acts in a monobasic bidentate manner coordinating through the nitrogen atom. The complexes have been characterized on the basis of molecular weight determinations, conductivity measurements, and magnetic measurements. The isolated products are coloured solids, soluble in dimethylsulfoxide, dimethylformamide (DMF) and methanol. All the complexes are monomeric in nature, as indicated by their molecular weight determinations. Conductivity measurements in dry DMF show them to be non-electrolytes. From the analyses of these studies the donor sites of the ligand are located and the geometries of the donor environment around the tin(IV) acceptor centres proposed. The ligand and its metal complexes are tested *in vitro* against a number of pathogenic fungal and bacterial strains and the findings are discussed. Emphasis has been given to the nematicidal properties.

KEYWORDS: nematicides; pesticides; fungicides; bactericides; sulfonamide imine

INTRODUCTION

Extensive studies have been made on diorganotindihalide complexes of N∩N chelating ligands owing to the possible link between the Sn–N bond length and the antitumour activity of such compounds.[1–5] Recently, Gielen[6] presented a very good account of organotin compounds and their therapeutic potential. The review gave an account of selected classes of compounds, such as tetraorganodicarboxylatodistannoxanes and related diorganotin dicarboxylates, and of triorganotin carboxylates. In view of that, we recently reported a series of tri- and di-organotin chloride complexes of 2-acetylnaphthalene-sulfapyridine. Organotin compounds having the formula R_nSnX_{4-n} have been found to possess significant biological activity and are used as fungicides,[7,8] bactericides, and antitumour[9] agents. Several reports have appeared on the complexes of di- and tri-organotin halides with various nitrogen-, oxygen- and sulfur-containing ligands. Many drugs are ingested from Schiff bases before they are assimilated in the body. Probably, Schiff base formation facilitates the absorption of the drug.[10–13] Encouraged by these findings and our interest in the field of organotin complexes, a ligand and its tin complexes have been prepared and characterized. The ligand and its corresponding metal complexes have also been screened against several pathogens, and a comparative account of its activities and structure–activity relationship have been incorporated in the present results. The ligand used is shown in Fig. 1.

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EXPERIMENTAL

The chemicals and solvents used were dried and purified by standard methods and moisture was excluded from the glass apparatus using $CaCl_2$ guard tubes.

Preparation of the ligand

Sulfonamide imine was prepared by the condensation of 2-acetylnaphthalene with sulfapyridine in 1 : 1 molar ratio in alcohol. The reaction mixture was refluxed in ethanol (50 ml) for about 5 h on a water bath. On cooling, crystals of the imine separated out; these were washed with ethanol, dried

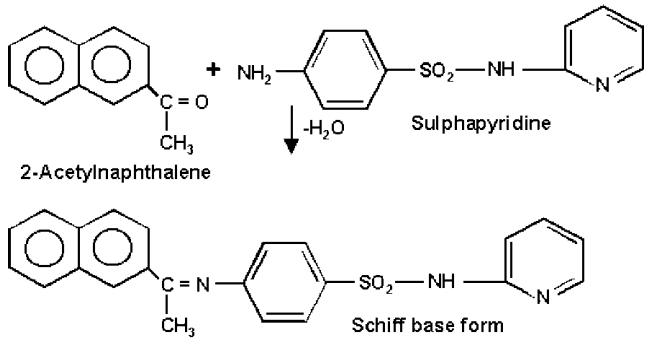

Figure 1. The ligand used, and its Schiff base form.

and recrystallized with acetone and dried *in vacuo*. These were characterized and analysed before use.

Preparation of tin(IV) complexes

To a weighed amount of R_2SnCl_2 and R_3SnCl (R = Ph or Me) in dry methanol was added the sodium salt of the sulfonamide imine ligand (prepared by treating the ligand with sodium metal in dry methanol) in 1:1 and 1:2 molar ratios. The contents were refluxed for 15–16 h, filtered to remove sodium chloride, and the excess of the solvent was removed *in vacuo*. This process of refluxing and filtration was repeated two to three times until all of the sodium chloride was precipitated and separated out. The resulting complexes were washed with *n*-hexane and finally dried *in vacuo*. All the complexes were crystallized in methanol and cyclohexane solution (1:1, v/v). Their synthetic and analytical data are reported in Table 1.

Analytical methods and physical measurements

Nitrogen was estimated by Kjeldahl's method. Tin was determined gravimetrically as SnO_2 and molecular weights were determined by the Rast camphor method. IR spectra were recorded as KBr discs on a Perkin–Elmer 577 grating spectrophotometer in the range 4000–200 cm^{-1}. The ^1H NMR and ^{119}Sn NMR spectra were recorded on a Bruker AM 270 spectrometer. All chemical shifts are reported in parts per million (ppm) relative to tetramethylsilane (TMS) as an internal standard in dimethylsulfoxide-d_6 (DMSO-d_6).

Toxicity

In order to evaluate the fungicidal, bactericidal and nematicidal activities, experiments were performed using the radial growth method, paper disc method and step-by-step method. The values of the percentage inhibition in growth of the fungi, the diameter of the inhibition zone of bacteria and the hatching percentage of nematodes were calculated.

RESULTS AND DISCUSSION

Reactions of organotin(IV) halides with monobasic bidentate ligand in 1:1 and 1:2 molar ratios in methanol may be represented by the following equations:

$$R_2SnCl_2 + N^{\cap}NNa \longrightarrow R_2SnCl(N^{\cap}N) + NaCl$$

$$R_2SnCl_2 + 2N^{\cap}NNa \longrightarrow R_2Sn(N^{\cap}N)_2 + 2NaCl$$

$$Ph_3SnCl + N^{\cap}NNa \longrightarrow Ph_3Sn(N^{\cap}N) + NaCl$$

where $N^{\cap}N$ is the donor system of the sulfonamide imine ligand (R = Me or Ph).

All the complexes are soluble in most of the common organic and coordinating solvents. The monomeric nature of these coloured solids is confirmed by their molecular weights. The molar conductances of 10^{-3} M solutions of the compounds in anhydrous dimethylformamide (DMF) lie in the range (10–23 Ω^{-1} cm^2 mol^{-1}) which shows their non-electrolytic nature.

UV spectra

The UV–VIS absorption spectral data of the ligand and its tin complexes are listed in Table 2. The spectrum of the ligand shows a broad band at 360 nm that can be assigned to the n–π^* transitions of the azomethine group, which undergoes a blue shift in the metal complexes due to the polarization within the >C═N chromophore caused by the metal–ligand interaction.[14] The electronic spectrum of the base also exhibits another two bands at around 240 nm and 280 nm. These are possibly due to π–π^* transitions within the benzene ring and the >C═N band of the azomethine group respectively. These two bands remain unchanged in the corresponding complexes.

IR spectra

The IR spectrum of the free ligand displays absorption bands at 3130–3420 cm^{-1}, 1635cm^{-1} and 1610 cm^{-1} assigned to ν(N–H),[15] ν(C═N) and δ(N–H)[16] respectively. In the spectra of the metal complexes, these NH bands are absent-indicating deprotonation of the NH group followed by coordination.

Several significant changes with respect to the ligand are observed in the corresponding metal complexes. A sharp band at 1635 cm^{-1} due to ν(>C═N) is shifted to lower frequency (*ca* 15 cm^{-1}) in the complexes, indicating the coordination of the ligand through nitrogen atom of the azomethine group. Two medium to sharp intensity bands observed in the far IR region of the tin complexes[15,17] at around 402–411 cm^{-1} and 352–364 cm^{-1} are assigned to ν(Sn–N) and ν(Sn–Cl) modes respectively, which are not observed in the spectrum of the ligand. One strong to medium intensity band appeared in the spectra of the complexes in the region 1230–1180 cm^{-1} and can be assigned to Sn–CH_3 stretching vibrations. The presence of only one Sn–C stretching frequency at 556 cm^{-1} suggests that 1:2 complexes of tin exist in the trans form. Medium to sharp intensity bands are observed at 595 and 525 cm^{-1}, and these

Table 1. Synthetic and analytical data of the ligand and its metal complexes

Compound	Colour, m.p. (°C)	Yield (%)	Analysis, found (Calc.) (%)						
			Sn	N	S	C	H	Cl	Mol.Wt
LH $C_{23}H_{19}N_3SO_2$	White, 162–164	72	—	10.38 (10.46)	7.87 (7.98)	68.69 (68.80)	4.71 (4.76)	—	371 (401.49)
$Me_2SnCl(L)$ $C_{25}H_{24}N_3SnO_2SCl$	Yellowish, 154–156	81	20.24 (20.29)	7.09 (7.18)	5.38 (5.48)	51.01 (51.35)	4.09 (4.13)	5.89 (6.06)	553 (584.70)
$Me_2Sn(L)_2$ $C_{48}H_{42}N_6SnO_4S_2$	Cream, 144–146	78	12.47 (12.49)	8.75 (8.84)	6.63 (6.75)	60.60 (60.70)	4.42 (4.45)	—	908 (949.73)
$Ph_2SnCl(L)$ $C_{35}H_{28}N_3SnO_2SCl$	Sandy, 171–173	79	16.70 (16.74)	5.85 (5.92)	4.45 (4.52)	59.00 (59.30)	3.92 (3.98)	4.86 (5.00)	684 (708.84)
$Ph_2Sn(L)_2$ $C_{58}H_{46}N_6SnO_4S_2$	Brownish, 110–112	75	11.00 (11.05)	7.76 (7.82)	5.91 (5.97)	64.55 (64.87)	4.28 (4.31)	—	1031 (1073.87)
$Ph_3Sn(L)$ $C_{41}H_{33}N_3SnO_2S$	White, 94–96	70	15.76 (15.81)	5.51 (5.59)	4.19 (4.27)	65.28 (65.61)	4.39 (4.43)	—	721 (750.49)

Table 2. Important UV—VIS spectral data of the ligand and its metal complexes

Group	Ligand[a]	$Me_2SnCl(L)$	$Me_2Sn(L)_2$	$Ph_2SnCl(L)$	$Ph_2Sn(L)_2$	$Ph_3Sn(L)$
$n-\pi^*$ λ_{max}/nm >C=N	360	350	352	340	346	342
$\pi-\pi^*$ λ_{max}/nm C_6H_5 ring	240	240	240	240	240	240
$\pi-\pi^*$ λ_{max}/nm >C=N	280	280	280	280	280	280

[a] Ligand = 2-acetylnaphthalene sulfapyridine.

may be assigned to the asymmetric and symmetric modes of Sn–C stretching vibrations.

For the trimethyltin complexes there is one band observed at 560 cm^{-1} due to the Sn–C stretching frequency, suggesting a planar arrangement of the M–Me moiety that is the two-atom donor from the ligand occupying the cis–axial–equatorial positions. The proposed structure is also supported by the comparatively low $\delta(^{119}Sn)$ value of the triphenyltin complex. A new band observed at *ca* 275 cm^{-1} may be assigned to ν(Sn–Ph). The most important IR absorption frequencies, along with the relative assignments of the ligand and its metal complexes, are summarized in Table 3.

^{1}H NMR spectra

The ^{1}H NMR spectra of the ligand and its corresponding metal complexes were recorded in DMSO-d_6. The chemical shift values relative to the TMS peak are listed in Table 4. The ^{1}H NMR spectrum of the ligand also exhibits NH protons at δ 10.65 ppm; this disappears in the complexes, showing the involvement of adjacent nitrogen in bonding with the tin atom. A proton signal is observed at δ 2.11 ppm due to –C (CH_3)=N–, and this moves down field (δ 2.21–2.14 ppm) in the complexes in comparison with its original positions in the ligand due to coordination of >C=N to the metal atom. The ligand shows a complex multiplet in the region δ 8.96–7.56 ppm for the aromatic protons and this is observed in the region δ 9.25–7.52 ppm in the spectra of the organotin(IV) complexes. This shift also supports the coordination through the nitrogen atom. The additional singlets in the region δ 1.03–1.12 ppm and the multiplet in the region δ 8.77–7.70 ppm are due to CH_3Sn and C_6H_5Sn groups respectively. The C–Sn–C angles have been calculated as 126°and 132° using the equation θ(C-Sn-C) = 0.0161 $[^2J(Sn-H)]^2 - 1.32[^2J(Sn-H)] + 133.4$.[18,19]

^{13}C NMR spectra

The ^{13}C NMR spectral data for all compounds were recorded in DMSO-d_6. The shifting of the signals due to carbon attached to the azomethine nitrogen in the spectra of the complexes

Table 3. Important IR absorption bands (cm^{-1}) of the ligand and its metal complexes[a]

Compound	ν(NH)	ν(C=N)	δ(N–H)	ν(M←N)	ν(M–Cl)
Ligand	3130–3420 m	1635 vs	1610 w	—	—
$Me_2SnCl(L)$	—	1625 vs	—	406 w	352 m
$Me_2Sn(L)_2$	—	1627 vs	—	411 w	—
$Ph_2SnCl(L)$	—	1625 vs	—	402 w	364 m
$Ph_2Sn(L)_2$	—	1620 vs	—	403 w	—
$Ph_3Sn(L)$	—	1622 vs	—	404 w	—

[a] m = medium; vs = very strong; w = weak.

Table 4. ^{1}H NMR and ^{119}Sn NMR spectral data of the ligand and its complexes (δ, ppm)

Compound	CH_3	M–CH_3/C_6H_5[a]	NH	Aromatic protons[a]	^{2}J(Sn–H) (Hz)	C–Sn–C angle[b] (°)	^{119}Sn
Ligand	2.11 (s, 3H)	—	10.65 (br, 1H)	8.96–7.56(m)			
$Me_2SnCl(L)$	2.21 (s, 3H)	1.12s	—	9.12–7.52(m)	76	126	−151.11
$Me_2Sn(L)_2$	2.18 (s, 6H)	1.03s	—	9.25–7.90(m)	81	132	−363.86
$Ph_2SnCl(L)$	2.18 (s, 3H)	8.70–7.75(m)*	—	8.70–7.75(m)*	—	—	−122.78
$Ph_2Sn(L)_2$	2.16 (s, 6H)	8.74–7.95(m)*	—	8.74–7.95(m)*	—	—	−331.42
$Ph_3Sn(L)$	2.14 (s, 3H)	8.77–7.70(m)*	—	8.77–7.70(m)*	—	—	−149.76

[a] (m)* merged together.
[b] Formula: θ(C–Sn–C) = 0.0161 $[^2J(Sn-H)]^2 - 1.32[^2J(Sn-H)] + 133.4$.

from δ 149.46–157.41 ppm further supports the involvement of this group in complexation. The different aromatic carbon atoms in the ligand from δ 124.68 to 147.79 ppm appeared in the complexes in the region δ 122.98–151.78 ppm (Table 5). The θ(C–Sn–C) angle values in these derivatives have been estimated as 127.1°, 133.7°, 124.2°, 131.9° and 123.5° using the equation $^{1}J(^{119}\text{Sn}, ^{13}\text{C}) = 11.4\theta(\text{C–Sn–C}) - 875$.[20] For organo methyltin(IV) complexes, values very near to 126° and 132° were calculated from ^{2}J(Sn–H) coupling constant.

^{119}Sn NMR spectra

In the ^{119}Sn NMR spectra of organotin(IV) complexes, the signals of any series of organotin compounds factors resulting in an increase in electron density (shielding) of the tin atom would shift the $\delta(^{119}\text{Sn})$ to higher field. Quantitatively, $\delta(^{119}\text{Sn})$ values depend on the coordination number.[21] on the nature of the ligand, and on the ligand bite.[22] Structurally, a more informative property of ^{119}Sn chemical shifts is the growing upfield shift of $\delta(^{119}\text{Sn})$ with increasing coordination number of the tin atom from four to five or six. Sharp signals at *ca* δ −122.78 and −151.11 ppm due to $Ph_2SnCl(L)$ and $Me_2SnCl(L)$ and δ −331.42 and −363.86 ppm due to $Ph_2Sn(L)_2$ and $Me_2Sn(L)_2$ in ^{19}Sn NMR spectra strongly support the penta- and hexa-coordination around the tin atom.

On the basis of the results discussed, so far including the analytical and spectral data, a suitable pentacoordinated trigonal bipyramidal geometry has been suggested for the 1 : 1 tri- and di-organometal derivatives and a hexacoordinated octahedral geometry for the 1 : 2 diorganometal derivatives (Fig. 2).

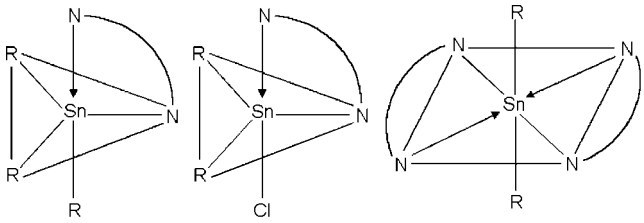

Figure 2. Geometrics of the organotin derivatives.

BIOCIDAL SCREENING

The base and its metal complexes have been screened for antibacterial and antifungal activities *in vitro*. Two standard drugs, Bavistin and Streptomycin, were used to compare the results of antifungal and antibacterial activities respectively.

Antifungal activity: radial growth method

The radial growth technique[23] was used to check the activity against fungi. The medium used was potato dextrose agar (PDA) medium. The compounds were mixed directly with the medium in DMF in different concentrations (25, 50 and 100 ppm). The spores of fungi were placed on the medium with the help of an inoculum needle. The Petri dishes were then wrapped in polyethylene bags containing some drops of alcohol and were placed in an incubator at 30 ± 2 °C. Controls were also prepared. Three replicates were used and linear growth of the fungus was obtained by measuring the fungal colony diameter after 5 days. The average linear growth in all replicates was recorded and the amount of growth inhibition was calculated by the following equation.[24]

$$\text{Inhibition}(\%) = \frac{(C - T) \times 100}{C}$$

Table 5. ^{13}C NMR data (δ, ppm) of ligand and its complexes

Compound	Azomethine C atom	Sn–Me	Aromatic carbon	$^{1}J(^{119}\text{Sn}, ^{13}\text{C})$ (Hz)	$^{2}J(^{119}\text{Sn}, ^{13}\text{C})$ (Hz)	$^{3}J(^{119}\text{Sn}, ^{13}\text{C})$ (Hz)	Estimated C–Sn–C angle°
Ligand	158.16	—	124.68, 126.14, 127.43, 128.84, 142.68, 147.79	—	—	—	—
$Me_2SnCl(L)$	151.98	16.70	125.97, 126.46, 132.72, 138.04, 144.64, 151.71	575	—	—	127.1
$Me_2Sn(L)_2$	149.46	18.96	127.42, 128.04, 131.09, 132.02, 135.76, 145.74	650	—	—	133.7
$Ph_2SnCl(L)$	155.74	—	124.21, 125.43, 126.98, 128.01, 129.96, 130.92, 131.74, 135.94, 140.79	542	41.0	131.9	124.2
$Ph_2Sn(L)_2$	155.01	—	126.12, 128.91, 129.75, 130.98, 133.10, 134.72, 137.30, 141.96	629	90.3	145.0	131.9
$Ph_3Sn(L)$	157.41	—	122.98, 123.46, 126.04, 129.76, 131.47, 132.86, 136.78, 142.92, 144.79	533	39.0	129.7	123.5

[a] The C–Sn–C angle may be calculated from these coupling constants using the relationship: $^{1}J(^{119}\text{Sn}, ^{13}\text{C}) = 11.4\theta$ (C–Sn–C) −875.

where *C* and *T* are the average diameters of the fungal colony in the control plate and the test plate respectively.

Antibacterial activity: paper disc method

In this technique, sterilized hot nutrient agar and 5 mm diameter Whatman No. 1 paper discs were used. The agar medium was poured into the Petri plates. After solidification, the plates were stored in an inverted position so that there was condensation of water in the upper lid. The bacterial suspension spread uniformly on the solidified nutrient agar. The solutions of test compounds in methanol, in 500 and 1000 ppm concentrations, were prepared by dipping discs in a solution of the test sample placed on seeded plates. The Petri plates having these discs on the seeded agar were kept at a low temperature for 2 to 4 h to allow for the diffusion of chemicals before being incubated at a suitable optimum temperature ($28 \pm 2\,^{\circ}C$) for 24 h, after which the inhibition zone around each disc was measured.

The synthesized ligand and its organotin complexes were evaluated for *in vitro* growth inhibitory activity against phytopathogenic fungi (i.e. *Fusarium oxysporum, Aspergillus niger, Macrophomina phaseolina* and *Alternaria alternata*) and bacteria (i.e. *Escherichia coli, Klebsiella aerogenous, Pseudomonas cepacicola* and *Staphylococcus aureus*). Adequate temperature, requisite nutrient and growth media free from other microorganisms were employed for the growth of cultures of both fungi and bacteria.[25] The incubation periods for the fungi and bacteria were 96 h at 37 °C and 24 h at 28 °C respectively.

The antimicrobial activity of the ligand can be ascribed to the hydrogen bond formation between the azomethine nitrogen atom of the ligand and some bioreceptors in the cells of fungi and bacteria,[26] as a result of which protein synthesis is inhibited. They might combine with the 50s ribosome subunit and interfere with translocation, i.e. movement of the m-RNA on the ribosome to expose the next codon for aminoacyl-t-RNA attachment. Thus, synthesis of larger proteins is specifically suppressed. The activity of the complexes is thought to be enhanced due to introduction of metal ions in the ligand.[27] One reason might be that complexation reduces such hydrogen bonding, but bioactivity increases on complexation.

Nematicidal property: step-by-step method

Phytonematodes occur throughout the world. In fact, they cause substantial reductions in crop yield and quality of produce for all major and minor crop plants. Nematodes are one of the oldest existing life forms and cause heavy economic losses to plants on Earth. The estimated overall average yield loss to the world's major crop due to damage by plant parasitic nematodes is 12.3%.[28] The growth and progress of nematology in India have been reported by many scientists.[29–31] The nematode population levels present in soil are directly correlated with damage to cereal crops.[32] In India, overall crop losses due to nematodes have been estimated[33] as 10.6%. Nematode *Meloidogyne incognita* is known to attack more than 3000 host plants.[34] *M. incognita* produces galls on

Table 6. Average percentage inhibition after 96 h

	A. niger			*M. phaseolina*			*F. oxysporum*			*A. alternata*		
Compound	25 ppm	50 ppm	100 ppm	25 ppm	50 ppm	100 ppm	25 ppm	50 ppm	100 ppm	25 ppm	50 ppm	100 ppm
Ligand	37	45	63	38	46	64	41	53	60	43	55	62
$Me_2SnCl(L)$	42	54	67	43	54	68	42	58	68	45	58	69
$Me_2Sn(L)_2$	50	61	81	52	60	83	49	62	79	48	59	78
$Ph_2SnCl(L)$	46	59	79	47	60	81	43	56	77	47	57	74
$Ph_2Sn(L)_2$	49	61	83	48	61	84	48	62	80	52	60	85
$Ph_3Sn(L)$	47	60	80	49	64	82	45	58	78	49	60	77
Bavistin	69	86	98	72	82	96	70	91	100	71	86	100

Table 7. Diameter of inhibition zone (mm) after 24 h

	E. coli (−)		*K. aerogenous* (−)		*P. cepacicola* (−)		*S. aureus* (+)	
Compound	500 ppm	1000 ppm	500 ppm	1000 ppm	500 ppm	1000 ppm	500 ppm	1000 ppm
Ligand	6.1	8.6	6.0	8.9	10.3	12.2	11.2	13.1
$Me_2SnCl(L)$	7.1	10.1	8.2	11.2	12.9	15.8	13.0	14.2
$Me_2Sn(L)_2$	10.5	12.5	11.2	14.0	15.1	17.2	14.4	17.1
$Ph_2SnCl(L)$	10.2	12.5	11.2	14.0	15.1	17.2	14.4	17.1
$Ph_2Sn(L)_2$	13.3	15.6	12.1	16.4	17.1	18.2	16.8	18.3
$Ph_3Sn(L)$	11.0	15.2	12.3	15.6	16.2	17.0	16.5	17.9
Streptomycin	1	2	3.0	5.0	2.0	5.0	15	17

Table 8. Nematicidal screening data of the ligand and its complexes; hatching (%) after 24 h

Compound	*M. incognita* hatching (%)		
	25 ppm	50 ppm	100 ppm
Ligand	23.6	19.0	14.2
$Me_2SnCl(L)$	20.0	15.4	—
$Me_2Sn(L)_2$	16.9	13.0	—
$Ph_2SnCl(L)$	18.0	15.5	—
$Ph_2Sn(L)_2$	13.5	10.4	—
$Ph_3Sn(L)$	15.8	11.0	—

the roots of many host plants and is responsible for 44.87% yield loss in brinjal.[35]

Literature of past work concerning nematode problems indicates that there is an urgent need to check these pests by control practices using different chemicals. For this experiment, egg masses were separated from heavily infected brinjal roots and washed under running water. To obtain pure quantities of *M. incognita* eggs, a step-by-step procedure was adopted, viz. cutting the clean root, addition of 1% NaOCl solution, shaking it and then sieving through 150 and 400 mesh sieves.[36] For each chemical, 230 nematode eggs were counted and replicated three times. The temperature range for this experiment was $30 \pm 2\,^{\circ}C$. The eggs were treated with the various complexes in 100, 50, and 25 ppm concentrations for 24 h. The observations in relation to hatching of these *Meloidogyne* eggs were noted. Results revealed that maximum hatching was recorded in control (H_2O) treatment, but very poor hatching was observed in the eggs treated with the different chemicals. Hence, the nematicidal properties were recorded.

Toxicity

The ability of the ligand to exhibit nematicidal and pesticidal properties is shown in Tables 6–8 and a comparison of the toxicity of the ligand with that of the various complexes has been made.

Such a study of the ligand and its complexes has been made against commonly growing fungi and bacteria. The pests treated with the complexes show greater growth retardation than those treated with the ligand. It is apparent that complexation enhances the toxicity of the ligand.

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