Applied Organometallic Chemistry (1987) 1 241–244

0268-2605/87/01304241/$03.50

Synthesis, ^{119}Sn NMR and Mössbauer studies and bioassay data of *O*-tricyclohexylstannyl derivatives of substituted 8-hydroxyquinolines

S J Blunden*, B N Patel, P J Smith and B Sugavanam†‡
International Tin Research Institute, Kingston Lane, Uxbridge, Middlesex UB8 3PJ and ‡ICI Plc, Plant Protection Division, Jealott's Hill Research Station, Bracknell, Berkshire RG12 6EY, UK

Received 29 September 1986 Accepted 25 January 1987

Eight novel tricyclohexyltin derivatives of substituted 8-hydroxyquinolines have been synthesised and their structures studied in the solid state by ^{119m}Sn Mössbauer and, in solution, by ^{119}Sn NMR, spectroscopy. Bioassay data are reported for these compounds against an organophosphorus-resistant species of the two-spotted spider mite, *Tetranychus urticae*, and a range of fungal and bacterial diseases of crops. The relationship between the activity and the coordination number of the tin atom is discussed, and it is shown that the anionic group can, in some cases, significantly affect the biological properties.

Keywords: Tricyclohexyltin, substituted 8-hydroxyquinoline, ^{119}Sn NMR and Mössbauer, bioassay data

INTRODUCTION

Tricyclohexyltin compounds, Cy_3SnX, are finding increasing applications in agriculture for the control of mites on a wide range of deciduous fruits, the two acaricides in commercial use at the present time being tricyclohexyltin hydroxide ('Plictran') and 1-tricyclohexylstannyl-1,2,4-triazole ('Peropal').[1,2] The present writers have previously found[3] that the combination of non-biologically active bidentate organic ligands, such as 3-hydroxyflavone or dibenzoylmethane, with the tricyclohexyltin moiety, produces a marked reduction in acaricidal effectiveness of the resulting complexes—in which the tin atoms are penta-coordinate through intramolecular chelation[4–6]—compared to tricyclohexyltin hydroxide.

Since certain organic chelates and their derivatives, e.g. 8-hydroxyquinolinium sulphate, are known[7] to possess fungicidal activity, we have synthesised and tested a series of novel *O*-tricyclohexylstannyl complexes of substituted 8-hydroxyquinolines, in order to examine the effects of these ligands and their coordination behaviour on the biological properties. The structures of these compounds in the solid state and in solution have been studied by ^{119}Sn Mössbauer and NMR spectroscopy.

EXPERIMENTAL SECTION

The substituted 8-hydroxyquinolines were obtained from Fluka A.G., Aldrich Chemical Co. or Koch-Light Laboratories Ltd and were used without further purification.

Mössbauer spectra

Mössbauer spectra were obtained using a constant acceleration microprocessor spectrometer (Cryophysics Ltd, Oxford) with a 512-channel data store. A Ba $^{119}SnO_3$ source was used at room temperature and samples were packed in perspex discs and cooled to 80K, using a liquid nitrogen cryostat. The experimental error in the isomer shift, δ, and quadrupole splitting, ΔE_Q, parameters is $\pm 0.05\,mm\,s^{-1}$ and the isomer shifts are quoted relative to $BaSnO_3$.

^{119}Sn NMR spectra

^{119}Sn NMR spectra were recorded on a JEOL FX60Q spectrometer under nuclear Overhauser

*Author to whom correspondence should be addressed.
†*Present address* Chemical Industries Branch, UNIDO, PO Box No. 300, A-1400 Vienna, Austria.

suppressed conditions and with field frequency lock to external D_2O. Chemical shifts, $\delta(^{119}Sn)$, are relative to Me_4Sn and are accurate to ± 0.2 ppm. Solutions were approximately 10% w/v in CCl_4, except where stated otherwise.

Synthesis of the complexes

The complexes were prepared by an azeotropic dehydration reaction between equimolar amounts (0.005 mol) of tricyclohexyltin hydroxide and the appropriate substituted 8-hydroxyquinoline in refluxing toluene (100 cm^3) using a Dean and Stark separator. Reflux times were typically 1–2 h. After removal of the toluene, the crude products were recrystallised from methanol or isopropanol. The melting points and analytical data for the complexes are shown in Table 1.

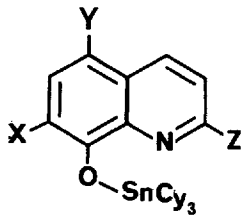
Bioassay data

Acaricidal activity against *Tetranychus urticae* was evaluated using the French bean dip test[3].

French bean plants at the two-true leaf stage were infested with *Tetranychus urticae* (organophosphorus-resistant) 1 day prior to spraying. The organotin compound (10 mg) was dissolved in 1 cm^3 of ethanol + acetone (1 + 1 by volume) and diluted with 39 cm^3 of a solution of 'Lissapol NX' (1.0 g dm^{-3}). One cm^3 of the final solution was then sprayed, using a Burkard Potter tower, on to each of the upper and lower surfaces of the leaves. The standard compound (tricyclohexyltin hydroxide) was applied by dissolving 10 mg in the same ethanol/acetone mixture (1 cm^3) and diluting with the same 'Lissapol NX' solution (319 cm^3). The plants were kept at 25°C for 3 days, after which time the adult mortality was assessed using a microscope. Any dead mites falling from the plants were observed on filter papers placed over the pots at the base of the stems.

Fungicidal and bactericidal activity against a range of species was performed by incorporating the chemical into petri dish/agar plates at 25 ppm. Organisms were inoculated as 7-day-old

Table 1 Analytical data for the complexes,



Compound No.	X	Y	Z	M.P. (°C)	Recryst. solvent	Analysis (%)[a] C	H	N	Cl
1	H	H	H	95–7	MeOH	63.3 (63.3)	7.5 (7.6)	2.7 (2.7)	—
2	H	Cl	H	78–80	^{i}PrOH	59.3 (59.3)	7.0 (7.0)	2.5 (2.6)	6.8 (6.5)
3	H	H	Me	91–3	^{i}PrOH	63.7 (63.9)	7.6 (7.8)	2.6 (2.6)	
4	Cl	Cl	H	125–7	^{i}PrOH	55.5 (55.8)	6.3 (6.4)	2.4 (2.4)	12.5 (12.2)
5	Cl	Cl	Me	129–31	^{i}PrOH	55.9 (56.5)	6.5 (6.6)	2.5 (2.4)	12.4 (11.9)
6	I	Cl	H	125–8	^{i}PrOH	47.6 (48.2)	5.5 (5.5)	2.0 (2.1)	4.4[b] (5.3)
7	Br	Br	H	126–8	^{i}PrOH	48.5 (48.4)	5.5 (5.5)	2.1 (2.1)	[c] [c]
8	H	NO_2	H	115–8	^{i}PrOH	58.0 (58.2)	6.8 (6.8)	5.1 (5.0)	—

[a]Calculated figures are in parentheses.
[b]I, 20.8 (18.9).
[c]Br, 23.6 (23.9).

spore suspensions or as mycelial plugs. Incubation was at 19 or 25°C. Disease assessment was made after 2 days.

RESULTS AND DISCUSSION

^{119}Sn Mössbauer data and ^{119}Sn NMR chemical shifts for the compounds studied are presented in Table 2.

Unfortunately, it is difficult to distinguish between a tetrahedral R_3SnX geometry and a five coordinate *cis*-R_3SnX_2 configuration (in this case involving coordination from the N atom on the liquid) on the basis of the quadrupole splitting parameter,[8] and the range of values recorded ($\Delta E_Q = 2.29 - 2.80\,mm\,s^{-1}$) are consistent with either of these stereochemistries in the solid state.

With respect to ^{119}Sn NMR spectroscopy, an increase in coordination number is generally associated with the chemical shift moving to a lower frequency,[9] and it has previously been shown[6] that four and five coordinate geometries are distinguishable on this basis. For example, $(Cy_3Sn)_2O$ may be considered to be unambiguously four coordinate and has a much higher frequency resonance than the tricyclohexyltin derivative of tropolone, Cy_3Sn(trop), which has been shown[5] to possess a *cis*-R_3SnX_2 configuration (Table 2). It may be seen that the chemical shifts of compounds 1–8 are all significantly to low frequency of $(Cy_3Sn)_2O$, suggesting a five coordinate geometry at the tin atom. Since the $\delta(^{119}Sn)$ values were found to be independent of concentration, the fifth interaction is presumably intramolecular and results from electron donation from N→Sn. The range of chemical shifts recorded for the complexes ($\delta(119Sn) = -27.4$ to -57.6 ppm) may be interpreted in terms of the strength of the donor interaction, those compounds possessing the lowest frequency shift are likely to have the strongest chelation from the N-donor. Therefore, although all of the complexes may be considered to possess a *cis*-R_3SnX_2 structure, in some cases, e.g. compounds 4–7, the donor interaction is probably weak and distortion from the four coordinate tin atom geometry is perhaps small.

Compounds 2–8 were tested for their relative acaricidal activities against an organophosphorus-resistant species of the two-spotted spider mite, *Tetranychus urticae*, (Table 3), and for fungicidal and bactericidal activity against a range of species (Table 4).

With respect to the former test, it may be seen that all of the complexes were less active than the commercial acaricide, Cy_3SnOH ('Plictran'). Previous studies[3] suggested that triorganotin compounds, R_3SnX, containing a five coordinate structure, in which the anionic ligand, X, is chelated intramolecularly to the tin atom, may show a reduced biocidal activity, resulting from the lack of affinity of the organotin for active sites on proteins. The present results (Table 3) are therefore generally in agreement with this suggestion. In fact, if the ^{119}Sn NMR chemical shift is taken to indicate the strength of chelation, i.e. compounds having lower frequency shifts possess a stronger donor interaction to the tin atom, it is possible to compare the degree of chelation to the relative activity against *Tetranychus urticae*:

	Compound
Chelation strength:	$5 < 7 \approx 4 \approx 6 < 8 < 2 < 3$
Activity:	$3 > 5 > 7 > 4 > 6 > 8 = 2$

Table 2 ^{119m}Sn Mössbauer parameters and ^{119}Sn NMR chemical shifts

Compound	δ(mm s^{-1})	ΔE_Q(mm s^{-1})	$\delta(^{119}Sn)$(ppm)
$(Cy_3Sn)_2O$	1.34[a]	1.55[a]	−7.9[a,b]
Cy_3Sn(trop)[c]	1.39[a]	2.67[a]	−62.8[a,b]
1	1.30	2.34	−57.6
2	1.31	2.45	−49.5
3	1.31	2.29	−52.5
4	1.36	2.62	−31.4
5	1.38	2.70	−27.4
6	1.38	2.77	−31.4
7	1.40	2.80	−31.7
8	1.34	2.66	−40.4

[a]Ref. 6.
[b]10% w/v solution in toluene.
[c]trop = tropolone ligand.

Table 3 Comparison of the acarcidal activities of compounds 2–8 and Cy_3SnOH against *Tetranychus urticae*

Compound[a]	Relative activity
Cy_3SnOH	1.0
2	0.2
3	0.8
4	0.5
5	0.7
6	0.3
7	0.6
8	0.2

[a]No data is available for compound 1.

Table 4 In vitro fungicidal and bactericidal activity of compounds 2–8[a]

Organism	Compound						
	2	3	4	5	6	7	8
Cladosporium sphaerospermum	4	0	2	2	0	0	2
Auerobasidium pullulans	4	4	2	4	0	2	4
Alternaria tenuis	4	2	2	4	0	2	4
Aspergillus niger	4	2	2	4	0	2	2
Trichoderma viride	2	2	2	2	0	2	2
Penicillium digitatum	4	4	2	4	0	2	4
Colletotrichum musae	4	2	4	4	0	2	4
Botrytis cinerea	4	2	2	4	0	2	4
Fusarium culmorum	4	2	2	4	0	4	4
Geotrichum candidum	4	2	2	4	0	2	2
Verticillium albo-atrum	4	2	4	4	0	2	4
Erwinia carotovora	0	0	0	0	0	0	2
Xanthomonas campestris malvacearum	0	0	0	0	0	0	4
Pseudomonas solanacearum	0	0	0	0	0	0	0
Phytophthora cinnamomi	2	2	2	2	0	2	4
Colletotrichum coffeanum	4	4	4	4	0	4	4
Cercospora beticola	4	4	4	2	0	2	4
Septoria nodorum	4	2	4	4	0	2	4
Pseudocercosporella herpotrichoides	4	0	2	2	0	0	4

[a]Activity is on a 0–4 scale where 4 = no disease remaining, 3 = trace – 5% disease left, 2 = 6–25% disease, 1 = 26–60% disease, 0 = > 60% disease still present.

Therefore, with the exception of Compound 3, for which no apparent explanation can be found, it appears that a correlation exists between the extent of five coordinate character and the relative acaricidal activity. It should, however, be mentioned that coordination number is of course only one of many factors which affect the Sn chemical shift, others being, for example, inductive and mesomeric effects. Consequently, in making the above correlation with regard to the strength of a donor interaction, we are assuming that since all of the compounds have the same basic Cy_3Sn-O-Aryl structure these additional effects are similar.

From Table 4 it may be seen that, with one exception, all of the complexes exhibit some fungicidal activity at the 25 ppm level, although most were inactive on bacterial diseases. Compound 6 was found to be inactive against all of the species tested. This is probably due to a steric effect, arising from the presence of the bulky I atom on the quinoline ring, which prevents the molecule from exhibiting its toxic action against the target organism.

It is difficult to infer any meaningful structure/activity relationships concerning positions and nature of the substituents on the quinoline ring, since the group of complexes studied is insufficiently large. There is therefore insufficient data to comment on the different activity trends shown between Tables 3 and 4.

CONCLUSION

It may be concluded from these studies that, in agreement with earlier work,[3] there is an approximate correlation between the acaricidal activity and the strength of the donor atom interaction in a series of chelated tricyclohexyltin compounds.

Acknowledgements The International Tin Research Council, London, is thanked for permission to publish this paper. The authors are grateful to the Plant Pathology and Entomology Sections, ICI plc Plant Protection Division, for biological testing.

REFERENCES

1. Blunden, SJ, Cusack, PA and Hill, R *The Industrial Uses of Tin Chemicals*, Royal Society of Chemistry, London, 1985
2. Sugavanam, B *Tin Its Uses*, 1980, 126: 4
3. Blunden, SJ, Smith, PJ and Sugavanam, B *Pestic. Sci.*, 1984, 15: 253
4. Blunden, SJ and Smith PJ *J. Organomet. Chem.*, 1982, 226: 157
5. Brahma, SK, Nelson, WH and Howard, WF Jr., *Inorg. Chem.*, 1987 (in press).
6. Blunden, SJ and Hill, R *Inorg. Chim. Acta*, 1985, 98: L7
7. Kidd, H, Hartley, D and Kennedy, JM (eds) *European Directory of Agrochemical Products, Part 1, Fungicides* Royal Society of Chemistry, London, 1984
8. Davies, AG and Smith, PJ, In: *Comprehensive Organometallic Chemistry*, Wilkinson, G (ed) Vol. 2, Pergamon Press, New York, 1982, p 519
9. Wrackmeyer, B In: *Annual Reports on NMR Spectroscopy*, Webb, GA (ed) Vol. 16, Academic Press, London, 1985, p 73