CHAPTER III

Saligenin Cyclic Phosphorus Compounds Having Pesticidal Activity.

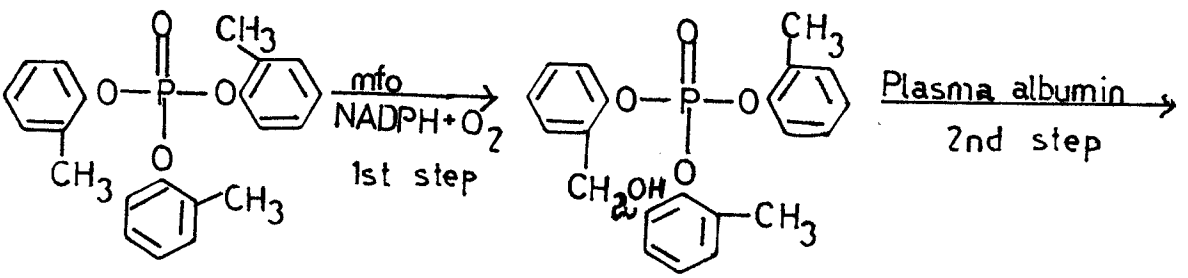
3a. Introduction:

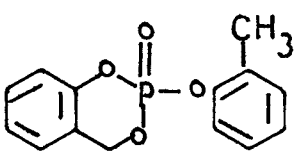
Discovery of saligenin cyclic phosphate as a biologically active metabolite of tri-o-tolyl phosphate[1,2] had lead to the extensive studies on synthesis and chemical, biochemical and biological properties of many related compound[3,4]. Of them salithion (2-methoxy-4H-1,3,2-benzodioxaphosphorin-2-sulphide) has been produced in a large quantity and practically used as an insecticide in Japan[4,5]. This review describes how salithion was discovered and developed into practical insecticide and also the chemical, pesticidal, biochemical and other properties of saligenin cyclic phosphorus compounds.

3b. History of discovery of salithion and related compounds:

In 1930 about ten thousand people in U.S.A. were suffered by flaccid paralysis of the lower limbs about ten days after drinking an adulterated fluid extract of ginger[6]. This was due to the phosphate triester of O-cresol, a contaminant present in the ginger extract. In Morocco a similar big outbreak of paralysis took place in 1959 from cooking oil contaminated with lubricating oil of turbo-jet aircraft engines[7]. This was also due to O-cresyl phosphate (TOCP) poisoning. The phosphate triester of cresols have been widely used in industries as plasticizers, lubricants, solvents, oil additives etc. Hatter, Aldridge and Barnes observed that all neurotoxic aryl phosphate, except tri-p-ethylphenyl phosphate, had at least

one alkyl group carrying the α-hydrogen atom on the ortho position[8]. This structure -neurotoxicity relationship of triaryl phosphate became clearly understandable by the isolation and characterization of the active metabolites of TOCP[1,2]. The main active metabolite (M) was o-tolyl saligenin cyclic phosphate. This compound (M) was about 100 times more potent to cause ataxia in hens than TOCP, and potentiated the toxicity of malathion 100 times by the dose of 20 mg/kg in mice, while TOCP 4 times by the dose 100 mg/kg. M was ten million times more active than TOCP in the *in vitro* inhibition of plasma cholinesterase. The conversion of TOCP into active metabolite M proceeds via two steps; the first step, which is catalysed by mixed-function oxidases (mfo) involves the hydroxylation of a ring methyl group; the second step involves the cyclization of this intermediate product to M through intramolecular transphosphorylation; the latter reaction is catalysed by plasma albumin[9] ; [Fig-1]





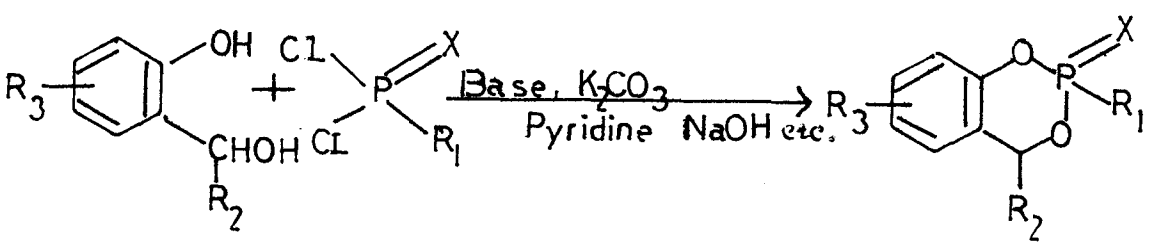
[M]

In the cyclisation reaction, no alkyl ester group participates as the leaving group[9]. Actually no aryl but alkyl saligenin cyclic phosphate was formed *in vivo* from alkyl di-o-tolyl phosphate[10]. Such metabolic conversion of TOCP or its analogs was observed in hens[3], rats[3], cats[11] and insects[10].

All aryl saligenin cyclic phosphates have showed no insecticidal activity but manifested a high delayed neurotoxicity to cause ataxia in hens; surprisingly the corresponding cyclic esters (both X = O and X = S compounds) having a small alkyl group on phosphorus revealed high insecticidal activity[1,12]. As a result of this research salithion was discovered by the pesticide research group of Kyushu University in Japan in 1963 and was developed into a commercial insecticide in 1965 by Sumitomo Chemical Co.

3c. Synthesis of Saligenin Cyclic Phosphorus esters:

The saligenin cyclic phosphorus esters can be prepared by the reaction shown below[13]: [Fig-2]



Fig—2

where, R_1 = R, OR, SR, NHR, NRR (R = alkyl);
R_2 = alkyl, Cl; R_3 = CH_3, Cl, NO_2 etc; X = S or O.

Several saligenin cyclic phosphorus esters have been prepared by the above reaction. The chemical, pesticidal, biological and other properties of these compounds have been discussed below (Table I-VIII).

3d. Properties of Salithion:

Pure salithion is a colourless crystalline powder m.p. 55-56°C practically insoluble in water, easily soluble in acetone and benzene, moderately soluble in cyclohexane, toluene and xylene; vapour pressure, 1.5×10^{-6} mm Hg at 25°C; UV λ_{max}^{nm} (ϵ) 274 (360), 267(360). Salithion has a characteristic IR band at 1020 cm^{-1} for P-O-CH_2 in hetero ring, N.M.R δ (CS_2) ppm: 3.76 (3H, doublet, J_{PH} = 14 H_z, OCH_3), 5.21 (2H, doublet, J_{PH} = 15 H_z, CH_2), 6.3-7.2 (4H, multiplet, benzene ring).

Salithion gives a characteristic fragmentation pattern in mass spectrometry. It gives an intense peak of (M-CH_3) (m/e 201) by a β-cleavage occurring at the exocyclic ester group. Another characteristic fragmentation process is the direct loss of H followed by the elimination of formaldehyde. Salithion is relatively unstable in storage. Some secondary

amines, such as carbazole and N-phenyl-α-naphthylamine, stabilise the formulation[31]. In a phosphate buffer (pH 7.7), salithion is hydrolysed slowly through opening of the hetero ring by the P-O-(aryl) bond cleavage: the hydrolysis rate constant (25°) $k = 2.4 \times 10^{-4}$ min^{-1}. The hydrolysis rates of the corresponding cyclic methyl phosphonate, O-methylphosphorothiolate (the thiolate isomer of salithion, MTB), methyl phosphate (salioxon), and N-methyl phosphoramidate are, respectively, 90, 60, 6 and 0.6 times more than that of salithion. Salithion is completely hydrolysed by heating at 100°C for 5 min. with N/6 sodium hydroxide to yield saligenin. This is applied for the colorimetric determination of salithion in formulations by allowing the formed saligenin to react, after adjusting pH-8, with 4-aminoantipyrine and then with potassium ferricyanide[19,20].

An oxidation by bromine water salithion is covered to its oxon (salioxon). Since salioxon (2-methoxy-4H-1,3,2-benzodioxaphosphorin 2-oxide) is some thousand times more active in cholinesterase inhibition than salithion, an enzymatic method after the oxidation can be used for the residue analysis of salithion[32].

Salithion is isomerised into O-alkyl saligenin cyclic phosphorothiolates by heating with alkyl iodides (the Pistchimuka reaction)[33]. The reaction is greatly accelerated in such a polar solvent as dimethyl formamide. Potassium carbonate also

assists the reaction. When methyl iodide is used, isomerization occurs to give 2-methylthio-4H-1,3,2-benzodioxaphosphorin-2-oxide (MTBO)[33,34]. Salithion is demethylated to form the salt of saligenin cyclic phosphorothionic acid by the action of certain nucleophile such as cyclohexylamine[35] and potassium diethyl-dithiothiocarbamate[35,36]. The latter agent is particularly suitable for the preparation of MTBO by methylating the obtained salt with methyl iodide.

MTBO is a unique phosphorylating agent. The reaction of salithion are summarised in the following scheme (Fig. 3):

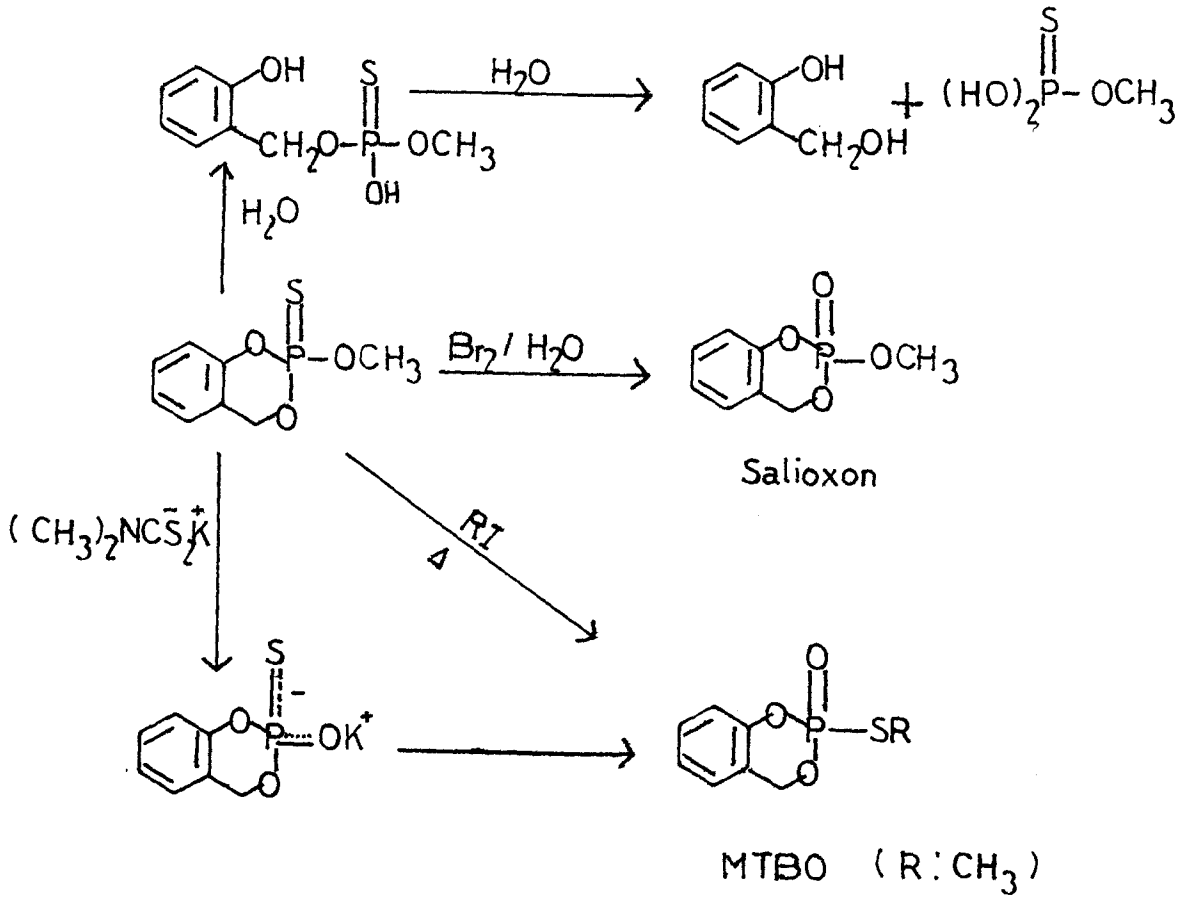


Fig. 3: Chemical Reaction of Salithion.

3e. Insecticidal Activity:

The insecticidal activities of various saligenin cyclic phosphorus compounds including phosphates[14,15], phosphoramidates[17], phosphorothiolates[13], phosphonates[16] and their thiono analogs[20,14,15] have been tabulated (Table I-VII). The saligenin cyclic compounds in any series having an aryl group as an exocyclic substituent on the phosphorus atom have either poor or no insecticidal activity, but small alkyl derivatives have high insecticidal activity, related to the size of the exocyclic substituent on the phosphorus atom[21]. Methyl derivatives are much more active than higher alkyl and aryl derivatives, except for phosphonothionate series in which ethyl derivative is more active than methyl derivative. N, N-dialkyl phosphoramidates are much less active than NH-alkyl derivatives. It is interesting to note that the exocyclic substituent of the most active compound in each series (OCH_3, SCH_3, $NHCH_3$, $CH_2.CH_3$) differs each other in electronic characteristics, but is similar in size and resembles in steric property such as the distance (about 2.9 Å) between P and C atoms in the P-X-C function, if the bond angle of bivalent S is near 90° rather than 109.5°. The phosphorothiolothionates are not enough in insecticidal activity (Table-VII). The phosphates, phosphorothiolates, and phosphonates are too unstable to be used practically as insecticides. The phosphoramidates are several times more toxic to mammals than phosphorothionates.

Introduction of any substituents on the benzene ring, the hetero ring or the exocyclic ester group decreases the insecticidal activity (Table-I, II, III). Thus, the simplest phosphorothionate, salithion, was the most useful compound as the whole series of saligenin cyclic phosphorus compounds.

3f. Nematocidal Activity:

Some saligenin cyclic phosphoramidates and phosphoramidothionates are very effective to kill nematodes (Table-V). N-methyl phosphoramidate is most active, but N,N-dimethyl-phosphoramidate is inactive against Rhabditis sp. suspended in water. Phosphates and phosphonates are almost inactive, but their thiono analogs are effective. Saligenin cyclic phenyl-phosphonothionate exhibit high activity.

3g. Fungicidal Activity:

Salithion has no fungicidal activity. But saligenin cyclic phosphorothiolates have fungicidal activity (Table-VI). Some of them are effective to protect rice plants from rice blast disease (due to infection by Piricularia oryzae). Ethyl and n-butyl phosphorothiolates are most promising as fungicides.

3h. Synergistic Activity:

Saligenin cyclic aryl phosphates and phosphonates have synergistic activity with malathion against insects and mites, particularly their resistant strains[21]. 7-methyl-2-phenyl-4H-1,3,2-benzodioxaphosphorin-2-oxide is the most active synergist

against resistant houseflies and green rice leafhoppers. For the resistant strains of red citrus mite, Panonychus citri (McGregor) saligenin cyclic phenylphosphonate showed good synergistic action with malathion. Saligenin cyclic alkyl phosphates and phosphorothionates are not, or only poorly active as synergists of malathion against houseflies and green rice leafhoppers.

31. Antiesterase Activity:

The insecticidal saligenin cyclic methyl phosphate (saliloxon) is very active as an inhibitor of cholinesterase. However, the highly neurotoxic aryl phosphate is a poor inhibitor of cholinesterase, but it is a very specific inhibitor of aliesterase[5,22]. The less neurotoxic arylphosphonate occupies an intermediate position. In any series, when the size of the exocyclic substituent increases, the compound becomes a more selective inhibitor of aliesterase; in contrast, the compound carrying a small substituent is a more selective inhibitor of cholinesterase (Table-VIII). Arylphosphonates are more specific inhibitors of pseudo-cholinesterase, alkyl phosphates are less specific and aryl phosphates are intermediate.

32. Anti-SH-enzyme Activity:

The saligenin cyclic phosphorothiolates (Table-VII) have high activity to salicylate (alkylate) mercaptans and to inhibit "SH enzymes" such as alcohol dehydrogenase[13,23]. The

activities seem to be related with fungicidal property but not with insecticidal activity. Saligenin cyclic phosphorothiolates are partially hydrolysed by openingof the heterocyclic POC (aryl) bond, more easily than phosphate esters. It was demonstrated that the hydrolysate of saligenin cyclic methyl phosphorothiolate, i.e. O-ortho-hydroxybenzyl, O-methyl hydrogen phosphorothiolate, reacted with mercaptans to give saligyl thioethers[23]. These observations indicate that the saligenin cyclic phosphorothiolates may react with cholinesterase to phosphorylate its serine hydroxyl group and may, on the other hand, be hydrolysed, to the o-hydroxybenzyl esters which react with "OH enzymes" to alkylate their thiol group. "SH-enzymes" may be essential for the life of fungi.

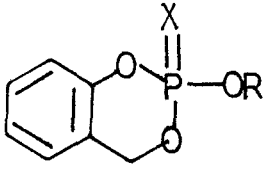
3k. Conclusions:

The high biological activities of saligenin cyclic phosphorus compounds may be attributed to the hetero ring involving enol and benzyl ester linkages. The alkylation reaction may be responsible for "SH-enzyme" inhibition and fungicidal activity. The phosphorylation reaction is responsible for esterase inhibition and insecticidal activity and animal toxicity. An exocyclic substituent group affects physical and biological properties by virtue of its electronic and steric characteristics. Thus, methyl phosphorothionate is useful as an insecticide, alkylamidates have systemic activity, alkyl

phosphorothiolates have fungicidal activity, phenyl phosphonates have antifilarial activity, and aryl phosphates are neurotoxic and have synergistic activity.

Table - I

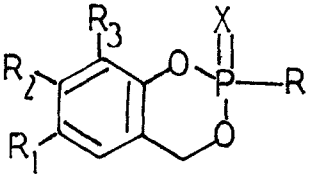
Saligenin cyclic phosphates and phosphorothionates: Physical properties, insecticidal activity, toxicity and nematocidal activity[24].



X	R	B.P. °C/mm Hg m.p. °C	LD_{50} µg/female (Housefly)	LD_{50} mg/kg (Mouse)	Nematocidal Activity (Mortality % for Rhabditis sp.		
					800 ppm	400 ppm	200 ppm
O	CH_3 (Saliexon)	110-112/0.05	0.035	52	-	-	-
O	C_2H_5	liq	0.33	76	100	95	70
O	n-C_3H_7	129-132/0.05	7.1	-	-	-	-
O	n-C_4H_9	150-154/0.05	>10(40)	-	-	-	-
O	C_6H_5		>10(3)	-	100	82	22
S	CH_3 (Salithion)	(55-56)	0.05	33	-	-	-
S	C_2H_5		0.3	-	-	-	-
S	C_6H_5	36	2.0	-	-	-	-

Table - II

Ring-substituted saligenin cyclic Phosphorus esters (thiono-Compounds): Physical properties and insecticidal activity.[25]



X	R_1	R_2	R_3	R	B.P. °C/mm Hg (mp °C)	LD_{50} (µg/housefly)
S	CH_3	H	H	OCH_3	(34-36)	2.0
S	CH_3	H	H	OC_2H_5	(71-72)	>10
S	CH_3	H	H	O-n-C_3H_7	153-160/0.2	>10
S	H	CH_3	H	OCH_3	110-115/0.65	0.25
S	H	CH_3	H	OC_2H_5	125-130/0.65	3.0
S	H	CH_3	H	O-n-C_3H_7	140-142/0.65	7.5
S	H	H	CH_3	OCH_3	63-70/0.15	1.3
S	H	H	CH_3	OC_2H_5	108-109/0.15	3.0

Contd..

Table-II (Contd..)

X	R_1	R_2	R_3	R	B.P. °C/mm Hg (mp °C)	LD_{50} (μg/housefly)
S	H	H	CH_3	O-n-C_3H_7	120-124/0.15	7.5
S	H	H	CH_3	$NHCH_3$	(30)	3.6
S	C_6H_5	H	H	OCH_3	Oil	0.4
S	C_6H_5	H	H	OC_2H_5	Oil	0.5
S	C_6H_5	H	H	O-n-C_3H_7	Oil	1.0
S	OCH_3	H	H	OCH_3	paste	0.55
S	$CO.CH_3$	H	H	OCH_3	paste	2.5
S	Cl	H	H	OCH_3	170-175/0.2	1.75
S	Cl	H	H	$NHCH_3$	175-180/0.25	0.06
S	Cl	H	H	SCH_3	160-170/0.2	-
S	H	H	Cl	OCH_3	(72-73)	0.13
S	H	H	Cl	$NHCH_3$	(46-47)	0.09
S	H	H	Cl	S-CH_3	oil	-

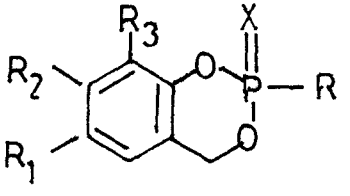
Contd..

Table-II (Contd..)

X	R_1	R_2	R_3	R	B.P. °C/mm Hg (mp °C)	LD_{50} (μg/housefly)
S	Cl	H	C_6H_5	OCH_3	pase	1.2
S	Cl	H	C_6H_5	OC_2H_5	paste	3.0
S	Cl	H	C_6H_5	O-n-C_3H_7	paste	>10
S	NO_2	H	H	OCH_3	paste	3.0
S	C_6H_5	H	Cl	OCH_3	paste	-
S	C_6H_5	H	Cl	OC_2H_5	paste	-
S	C_6H_5	H	Cl	O-n-C_3H_7	paste	-
S	Cl	H	Cl	OCH_3	(5Y-58)	0.3
S	Cl	H	Cl	OC_2H_5	oil	4.0
S	Cl	H	Cl	$NHCH_3$	oil	3.0

Table - III

Ring-substituted salicenin cyclic phosphorus esters (exo-compounds): Physical properties and insecticidal activity[25]



X	R_1	R_2	R_3	R	B.P. °C/mm Hg (m.p. °C)	LD_{50} (µg/housefly)
O	CH_3	H	H	OCH_3	139-140/0.3	0.1
O	CH_3	H	H	OC_2H_5	152-156/0.3	0.4
O	H	CH_3	H	OCH_3	109/0.05	0.43
O	H	CH_3	H	OC_2H_5	112-114/0.05	0.7
O	H	CH_3	H	O-n-C_3H_7	141-147/0.1	7.2
O	H	CH_3	H	OC_6H_5	(93-95)	>10
O	H	CH_3	H	$NHOCH_3$	(145-146)	0.14
O	H	H	CH_3	OCH_3	118-120/0.5	2.0

Contd..

Table-III (Contd..)

X	R_1	R_2	R_3	R	B.P. °C/mm Hg (m.p. °C)	LD_{50} (µg/housefly)
O	H	H	CH_3	OC_2H_5	165/0.6	2.1
O	H	H	CH_3	OC_6H_5	135-140/0.6	>10
O	Cl	H	H	OCH_3	148-152/0.2	0.09
O	Cl	H	H	OC_2H_5	160/0.2	0.13
O	Cl	H	H	O-n-C_3H_7	167-169/0.15	0.70
O	Cl	H	H	O-n-C_4H_9	167/0.18	2.5
O	Cl	H	H	O-C_6H_5	(89)	>10
O	Cl	H	H	$NHCH_3$	(148)	0.09
O	H	H	Cl	OCH_3	170-171/0.15	0.23

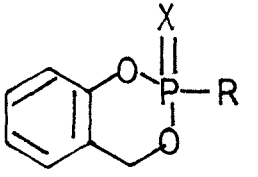
Contd..

Table-III (Contd..)

X	R_1	R_2	R_3	R	B.P. °C/mm Hg (m.p. °C)	LD_{50} (µg/housefly)
O	H	H	Cl	OC_2H_5	151/0.18	0.15
O	H	H	Cl	O-n-C_3H_7	153/0.18	0.30
O	H	H	Cl	O-i-C_3H_7	137/0.04	-
O	H	H	Cl	O-C_6H_5	203/0.82(54)	>10
O	H	H	Cl	$NHCH_3$	(128-129)	0.30

Table - IV

Saligenin cyclic Phosphonates and Phosphorothionates: Physical properties, toxicity, insecticidal and nematocidal activity[26]



X	R	B.P. °C/mm Hg (m.p. °C)	LD_{50} µg/fly (Housefly)	LD_{50} mg/kg (Mouse-oral)	LC_{100} ppm (nematodes-Rhabditis)
O	CH_3	140/0.5 (35)	0.19	25-50	
O	C_2H_5	143-142/0.3(25)	0.17	25-50	
O	i-C_3H_7	(30)	0.33	-	
O	sec-C_4H_9	110/0.5	7.0	-	
O	t-C_4H_9	(74)	>10 (0)	-	
O	$CH = CH_2$	155/2.5	0.63	>100	
O	CH_2Cl	160/0.8 (51)	<10 (6)	25-50	
O	CH_2CH_2Cl	133-141/0	0.99	50-75	
O	C_6H_5		>10 (0)	-	

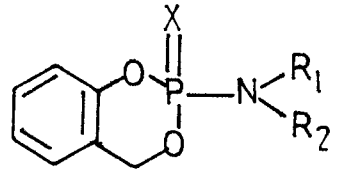
Contd..

Table - IV (Contd..)

X	R	B.P. °C/mm Hg (m.p. °C)	LD_{50} µg/fly (Housefly)	LD_{50} mg/kg (Mouse-oral)	LC_{100} ppm (nematodes-Rhabditis)
S	CH_3	130/0.6	0.31	5-10	25
S	C_2H_5	120/0.6	0.08	5-10	25
S	$1-C_3H_7$	108/0.6	0.09	-	-
S	CH_2Cl	146-155/0.4	1.14	25-50	25
S	C_6H_5	(37)	0.3	-	

Table - V

Saligenin cyclic Phosphoramidates and Phosphoramidothioates: Physical properties, insecticidal activity, toxicity and nematocidal activity[27]



X	$N\begin{matrix}R_1\\R_2\end{matrix}$	B.P. °C/mm Hg (m.p. °C)	LD_{50} µg/female H.fly	LD_{50} µg/gm (Rice stem-borer)	LD_{50} µg/gm (Green rice leaf-hopper)	LD_{50} mg/kg (Mouse)	Minimum conc. (ppm) to kill 100% nematodes-Rhabditis
O	NHMe	(87)	0.05	2.34	0.4	5-7.5	<10
O	NH	(68)	0.66	22.29	3.5	30-50	10-25
O	NHnPr	135-140/0.5	1.50	33.60	33.0	>50	25-50
O	NHiPr	(84)	3.44	103.34	>350	>50	50-100
O	NHnBu	(46-47)	<10(54%)	>214	>400	>50	25-50
O	NH.Ph	(131-133)	>10(5%)	-	-	-	-
O	$N(Me)_2$	(221)	0.3	13.80	4.0	-	>200(10%)

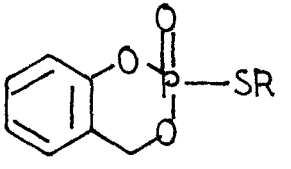
Contd..

Table - V (Contd..)

X	$N<^{R_1}_{R_2}$	B.P. °C/mm Hg (m.p. °C)	LD_{50} µg/female H.fly	LD_{50} µg/gm (Rice stem-borer)	LD_{50} µg/gm (Green rice leaf-hopper)	LD_{50} mg/kg (Mouse)	Minimum conc.(ppm) to kill 100% nema-todes-Rhabditis
O	$N(Et)_2$	133-136/0.5 (44)	>10(0%)	167.61	34.1	>50	100-150
S	NHMe	120-123/0.2	0.044	4.84	4.1	20-30	25-50
S	NH.Et	liq(undisti-llable)	0.43	36-25	-	-	-
S	$N(Me)_2$	118-122/0.2	0.38	-	-	-	50-100
S	$N(Et)_2$	110/0.2	0.63	-	-	-	>200(80%)
S	OMe(Salithion)	-	0.05	1.13	30.6	68	-
O	OMe(Salioxon)	-	0.035	2.16	1.6	52	-
Parathion	-	-	0.04	3.43	3.6	5-7	-
Malathion	-	-	0.6	-	0.8	347	-
D-D mixture (Mixture of 1-3 dichloropropene and 1,2-dichloropropane)	-	-	-	-	-	-	>300(35%)

Table - VI

Salicyclo Cyclic Phosphorothiolates: Physical properties, insecticidal activity and fungicidal activity[28]



R	B.P. °C/mm Hg (m.p. °C)	LD_{50} µg/gm (Oriental housefly)	Protective value (%) against Piricularia oryzae 250 ppm	100 ppm	50 ppm	25ppm	Therapeutic value(%) to P.oryzae at 200 ppm
CH_3(MTBO)	144-145/0.1(44)	3.00	100	100	100	84.8	7.1
C_2H_5	140-145/0.04	11.21	100	93.7	92.5	81.5	100
n-C_3H_7	145-147/0.07	94.50	100	57.1	34	-	-
i-C_3H_7	155-159/0.1	17.23	-	68.7	34.4	-	-
n-C_4H_9	157-160/0.02	211.8	100	91.7	93.3	75.6	97.6
C_6H_5	(38-39)	73.61	50.2	-	-	-	-

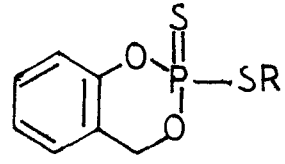
Contd..

Table - VI (Contd..)

R	B.P. °C/mm Hg (m.p. °C)	LD_{50} µg/gm (Oriental housefly)	Protective value (%) against Pirimularia oryzae 250 ppm	100 ppm	50 ppm	25 ppm	Therapeutic value (%) to Pyricularia at 250 ppm
Salithion	-	1.60	52(at 500 ppm)	-	-	-	-
Hinosan	-	-	100	-	86.2	-	95.2(at 250 ppm)
Blasticidin S	-	-	93.5	-	86.3	-	97.6
Pentachloro-benzyl alcohol	-	-		98.8	93.8	-	0

Table - VII

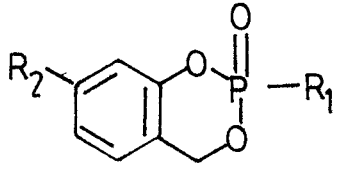
Saligenin Cyclic Phosphorodithionates: Physical Properties and insecticidal activity[29]



R	b.p. °C/mm Hg (m.p. °C)	LD_{50} (μg/fly)
CH_3	(69-70)	0.18
C_2H_5	145-147/0.2	9
n-C_3H_7	145-150/0.25	2.2
i-C_3H_7	140-143/0.1	5
$C_3H_5(CH_2-CH = CH_2)$	140-147/0.3	1.7
n-C_4H_9	160-167/0.25	10
C_6H_5	(72-80)	>10(0)

Table - VIII

The Inhibition of Housefly, Human Blood and Horse Serum Esterases by some Saligenin Cyclic Phosphorus Compounds[30]



R_1	R_2	Housefly I_{50}(M)x 10^8		Human blood I_{50}(M) x 10^8		Horse plasma I_{50}(M) x 10^8	
		ChE	AliE	p-ChE	t-ChE	AliE	Malathionase
OCH_3	H(Saliloxon)	7.6	3.4	1.8	17.0	230	620
OC_2H_5	H	13.2	2.1	1.6	25.0	240	-
O-n-C_3H_7	H	50.7	3.0	-	-	-	-
O-n-C_4H_9	H	37.5	2.5	-	-	-	-
O-C_6H_5	H	155	1.4	0.5	12.0	120	120
C_6H_5	H	-	-	0.65	72.0	150	470
C_6H_5	CH_3	-	-	1.6	68.0	230	-
O-Ph-2-CH_3	H	-	-	1.3	39.0	200	-

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