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Agriculture Pollution and its Countermeasures with Special Consideration of Pesticides

Li, Gwo-Chen*

作物生産과 農業公害 및 그 對策

李 國 欽*

ABSTRACT

Because of the continuing rapid increase in pesticide usage in Taiwan, much attention has been focus on pesticide contamination of food and effect of pesticides on human and environmental health. The Plant Protection Center (PPC) conducts safety evaluation of pesticides used in Taiwan.

The pesticides are classified into different groups based on their acute toxicities. Pesticides which are classified into extremely toxic group are not allow to used on short term crops or the continuously harvest crops.

The acute toxicity of pesticides to the beneficial insects are also studied, special attention has been paid to the two predators of rice brown planthopper.

60% of cultivated land in Taiwan are paddy field; therefore, acute fish toxicity was taken into consideration when a pesticide was applied for registration to be used in the paddy. Fish toxicities were evaluated by the dangerous rating value which is the amount of pesticide residue in the field water over the TLM value.

Mutagenicity of pesticides was continuously evaluated by using Ame's microbial testing method.

Island wide survey of residual levels of pesticides of known pollutants such as chlorinated hydrocarbon insecticides, mercurial compounds in soil, water and biological samples were carried out constantly.

The potential of a newly imported pesticides to pollute the environment were studied by using model ecosystem. Ecological magnification (EM) of a chemical was calculated from model ecosystem. A chemical was considered as a pollutant when its EM value over 5000.

In order to ensure the levels of pesticides residue of the crop within the safety limit. The "tolerance" of pesticides on different crop groupings were established base on 1) acceptable daily intake value of individual pesticides, 2) average daily consumption of each crop groupings by Chinese person, 3) Actual residues of pesticides on different crops obtained from supervised trials. Total about 79 pesticides for which the tolerances have been established on different crop groupings.

Because the intensive agricultural system was adopted in Taiwan. The phytotoxicity of pesticides to the non-target crops was therefore become one of the important factor in the safety evaluation of pesticide usage. These will include 1) direct injury, 2) injury caused by pesticide polluted irrigation water, 3) injury caused by the pesticide polluted soil, 4) reduction of growth caused by the effect of pesticide on the soil

* 國立植物保護硏究센터 所長, 植物保護學 會長, 自由中國.

* Director of Plant Protection Center, Professor of National Chunghsing Univ. & President of China Plant Protection Society, Wufeng, Taichung Hsien, Taiwan, Republic of China.

microorganisms.

This paper will reviewed all the aspects mentioned in the previous paragraphs. Most the works have done in Taiwan by the PPC.

INTRODUCTION

In Taiwan, the use of pesticides by farmers has increased very rapidly. The total value of pesticides used in one year rose from NT$2 millions in 1952 to NT$662 millions in 1969, and more than 2 billions in 1979. Right now about 3.4 billion New Taiwan Dollars have been spent by the farmers for pesticides. Because of the continuing rapid increase in pesticide usage, much attention has been paid to the prevention of side effects resulted by the pesticide usage. This report will review the works have been done in Taiwan related to these aspects.

PESTICIDE CONTROL ACT

A Pesticide Control Act[9] was promulgated and implemented by the Central Government and come into force in 1973, prohibits the sale and distribution of pesticides without Government approval, which is given only after all necessary data on their effectiveness, physical and chemical properties and residue tolerance are established under local environmental conditions and found to be satisfactory. The Plant Protection Center is responsible for residue analysis and evaluating the safety of these pesticides and for making the necessary recommendation for registration. The procedure for the registration of a pesticide is shown in Fig. 1.

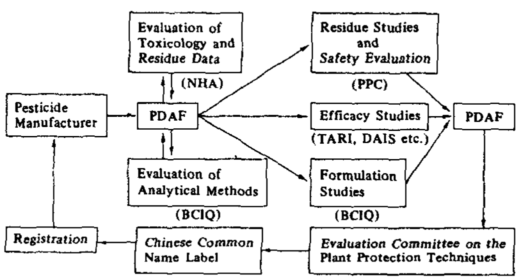


Fig. 1. Procedure for the registration of a pesticide.

ACUTE TOXICITY OF PESTICIDES

Pesticides are classified into four catagories based on the acute toxicity to the animal, as shown in Table 1. The one classified into extremely toxic some time are not recommended to be used on leafy vegetables and continuously harvest crops such as mushrooms, asparagus and strawberries etc., and on the feed crops.

Acute toxicity of pesticides to the natural enemies of insect pests were also studied[5]. Special attention has been paid to the natural enemies of brown planthopper and green rice leafhopper. 15 commonly used insecticides were tested their toxicities to two natural enemeis – the mirid bug (*Cyrtorhius lividipennis* Renter) and walf spider (*Lycosa pseudoannulata* Boesen berg & Stand). The result as shown in Table 2 indicated that if judged by their capability of effectively controlling the rice insect pests and simultaneously protecting their natural enmies, MTMC had the best selectivity, followed by carbary, Hokbal and then unden, These data are useful for integrated control of rice pests. Further works related to these area are planned to be carried out on the broconid, a nature enemy of diamond-back moth; lady beetles, natural enemies of citrus mealy bug and citrus spider mites; phytophagous mites, natural enemies of strawberry spidermites; trichogramatids, natural enemies of European corn borers and sugarcan borers; parastic

Table 1. The rank of pesticide acute toxicity.

Rank	LD_{50}(mg/Kg)		LC_{50}(ppb)
	Oral	Dermal	Inhalation
Extremely Toxic	<50	<200	<2,000
Toxic	50-500	200-2,000	2,000-20,000
Slight Toxic	500-5,000	2,000-20,000	–
Non Toxic	>5,000	>20,000	–

chalcids, natural enemies of soybean miner; Green lacewings, natural enemies of mulberry psyllid, etc[1].

60% of cultivated land in Taiwan are paddy field, it is suspected that field water in the paddy are the major sources of pesticides found in the river water. Therefore the acute toxicity of pesticides used in the paddy have been attracted much attention. By

Table 2. Comparison of LC_{50} among different insecticides in brown planthopper, wolf spider, mirid bug, mosquitofish as express by LC_{50} value.

Insecticides	LC_{50}(ppm)			Toxicity factor	
	B.P.H.	W.S.	M.B.	W.S./B.P.H.	M.B./B.P.H.
BPMC	21.38	406.16	20.35	19.00	1.08
Carbaryl	33.02	1022.25	40.23	30.96	1.22
Furadan	30.21	18.28	8.92	0.61	0.30
Hokbal	16.74	481.16	18.10	28.74	1.08
Lannate	11.63	47.32	6.33	4.07	0.54
MIPC	17.74	233.51	10.60	13.16	0.60
MTMC	8.51	1001.11	27.26	117.64	3.20
Unden	57.64	1060.74	3.70	18.40	0.06
Azodrin	45.10	3496.43	8.80	77.53	0.20
E-parathion	26.82	7722.16	4.26	287.93	0.16
Kilval	156.57	2359.11	56.11	15.07	0.36
Malathion	64.42	12814.22	24.62	198.92	0.38
M-parathion	273.84	7407.51	6.49	27.05	0.02
Orthene	70.85	1129.21	100.64	15.94	1.42

B.P.H. = Brown planthopper
W.S. = Wolf spider
M.B. = Mirid bug

$$\text{Toxicity factor} = \frac{\text{W.S. or M.B. or M.P. } LC_{50}}{\text{B.P.H. } LC_{50}}$$

Cited from Ku et. al (1981)

Table 3. The danger level of *Tilapia sop.* and *Gumbusia patruelis* with different pesticides

Pesticides	Maximum residue in field water	Actual residue in field water	Danger level*	
			Gumbusia patruelis	Tilapia sp.
	(ppm)	Max. R/10	Act. R/TLm	
Butachlor	6.4	0.64	0.40	0.66
Nitrofen	7.7	0.77	0.98	0.76
Diazinon	5.0	0.50	0.39	0.34
Phenthoate	2.0	0.20	22.22	8.89
BPMC	2.0	0.20	0.05	0.11
Cyanofenphos	2.0	0.20	0.13	0.15
Endosulfan	2.3	0.23	3.65	38.89
Benthiocarb	13.3	1.33	1.14	0.80
Carbaryl	4.0	0.40	0.54	0.20
Oxadiazon	2.4	0.24	0.08	0.16

$$* : \text{Danger level} = \frac{\text{Actual residue in field water}}{\text{TLm}}$$

Cited from Li, et. al (1981)

comparing acute fish toxicities of pesticides which were expressed by the Median Tolerance Limit (TLM) of pesticides to Tilapia sp., with the maximum residue levels of pesticides in field water

Table 4. The Name of Pesticides Tested in the Salmonella/mammalian Mutagenicity Test

Trade Name	Chemical Name	Purity (%)
Acricid	2-sec-butyl-4, 6-dinitrophenyl-3-methyl-2-butenoate	100
Aldicarb	2-methyl-2-(methythio) propyl ideneamino methyl-carbamate	100
Aldicarb sulfone	metabolite of aldicarb	100
Aldicarb sulfoxide	metabolite of aldicarb	100
Amiben	3-amino-2, 5-dichloroben-zoic acid	92.2
Antracol	zinc (N, N'-propylene-1, 2-bisdithiocarbamate)	87.3
Bavistin	methyl-benzimidazol-2-yl-carmate	96.9
Bayrusil	0, 0'-diethyl-0-quinoxalin-2-yl phosphorothioate	99.6
Bendiocarb	2, 3-isopropylidene-dioxyphenyl methylcarbamate	100
Benomyl	methyl-1-(butylcarbamoyl) benzimidazol-2-yl carbamate	99
Bentazon	3-isopropyl-(H)-benzo-2, 1, 3-thiadiazin-4-one 2, 2-dioxide	99.9
Bidrin	dimethyl cis-2-dimethyl-carbamoyl-1-methylvinyl phosphate	24 EC
Blazer	sodium 5-(2-chloro-4-(trifluoromethyl)-phenoxy)-2-nitrobenzoate	94
BPMC	2-sec-butylphenyl N-methylcarbamate	99
Bux	m-(ethylpropyl) phenyl methylcarbamate & m-(1-methylbutyl) phenyl methylcarbamate	97.8
Calixin	N-tridecyl-2, 6-diemthylmorpholine	99.7
Counter	S-((1, 1-dimethylethyl) thio) methyl) 0, 0-diethyl phosphorodithioate	98
CL-94302	metabolite of counter	95
Curzate	2-cyano-N-((ethylamino)-carbomyl)-2-(methoxyimino) acetamide	99
Cytrolane	diethyl-4-methyl-1, 3-dithiolan-2-ylidene phosphoroamidate	98.2
Daconil	tetrachloroisophthalonitrile	98
DBCP	dibromochloropropane	99.4
2, 4-DCP	2, 4-dichlorophenol	97.9
Decis	a-1-cyano-3-phenoxyvenzyl-d-cis-dibromochrysanthemate	98
Delan	2, 3-dicyano-1, 4-dithia-anthraquinone	99.5
Denmert	S-n-butyl S-p-tert-butyl benzyl N-3-pyridyldithio carbonimidate	100
Diazinon	0, 0'-diethyl-0-2-isopropyp-6-methyl pyrimidin 4-yl phosphorothioate	99.8
Dicloran	2, 6-dichloro-4-nitroaniline	99.5
Disyston	0, 0'-diethyl S-2-ethylsulphinyl ethyl phosphorodithioate	98.6
Dyfonate	0-ethyl S phenyl ethyl phosphonodithioate	95
Diuron	3-(3, 4-dichlorophenyl)-1, 1-dime thylurea	99
Drawin	2-mercaptomethyl-3-(N-methyl-carbamoyl) butanoroxim	99
EL-291	S-methyl-S-triazole (3, 4, 6) benzothiazole	96.5
Elsan	S-a-ethoxycarbonylbenzyl 0, 0-dinthyl phosphorodithioate	93
Endosulfan	6, 7, 8, 9, 10, 10-hexachloro-1, 5, 5a, 6, 9, 9a-hexahydro-6, 9-methano-2, 3, 4-benzo(e) dioxathiepin 3-oxide	99
Ethirimol	5-butyl-2-ethylamono-4-hydroxy-6-methylpyrimidine	99 2
Ethofumesate	(±)-2-ethoxy-2; 3-dihydro-3, 3-diemthyl benzofuran-5-yl methanesulphonate	100
Fuji-one	di-isoporpyl-1, 3-dithiolame-2-yl idenemalonate	99.8
Furadan	2, 3-dihydro-2, 2-dimethylbenzofuran-7-yl methylcarbamate	99.2
Geofos	diethyl-1, 3-dithietan-2-ylidenephosphoroimidate	95.9
Goal	2-chloro-1-(3-ethoxy-4-nitrophenoxy)-4-(trifluromethyl) benzene	98
Guthion	0, 0' dimethyl S-((4-oxo-1, 2, 3-benzothriazine-3 (4H)-yl) methyl) phosphorodithioate	99.4
Hexachlorophene	2, 2-methylene bis (3, 4, 6-trichlorophenyl)	99
Karphos	0, 0'-diethyl-0, 5-phenylisoxazolyl phosphorothioate	96.1
Kestrel	3-phenoxybenzyl (±) cis, trans-2, 2-dimethyl-3-(2, 2-dichlorovynil) cyclopropane carboxylate	100
MIPC	2-isopropyl-phenyl-N-methyl carbamate	99
Morestan	6-methyl-2-oxo-1, 3-dithiolo (4, 5, 6)-quinoxaline	100
Mo-338	2, 4, 6-trichlorophenyl-4-nitrophenylether	100
MTMC	m-totyl-N-methylcarbamate	100
Nemacur	ethyl-2-methyl-4-Lmethylthio-phenyl (1-methylethyl) phosphoramidate	97.9
Neo-pynamin	3, 4, 5, 6-tetraphdrophthalimidomethyl-(±)-cis, trans-chrysanthemate	–
Nimrod	5-butyl-2-ethylamino-methylphrimidine-4-yl-diemthylsulfamate	100
Ofunack	N-(3, 5-dichlorophenyl) succinimide	97.8
Orthene	O, S-dimethylacetylphosphoramidothioate	99.8
Ortho-dimethoate	O, O-dimethyl S-methylcarbamoylmethyl phosphorodithioate	95
Oryzemate	3-allyloxy-1, 2-benzisothiozole-1, 1-dioxide	99.1
Padan	1, 3-di (carbamoylthio)-2-dimethylaminopropane	100
Phosvel	O-4-brome-2, 5-dichlorophenyl-o-methyl phenylphosphonothioate	100
Pirimiphos-ethyl	0-2-diethylamino-6-methylpyrimidin-4-yl 0, 0-diethyl phosphorothioate	97.5
Plictran	tricyclohexyltin hydroxide	100
Plondrel	0, 0-diethyl phthalimidophosphonothioate	99
Propazine	2-chloro-4, 6-bis (isopropylamino)-2-triazine	99.7
Sicarol	3, 4-dihydro-6-methylpyran-5-carboxanilide	98
SK-223	N-(a, 2-dimethyl)-3-(ptotyl) urea	99
SK-41	N, N-methyl benzyl N'-(2-benzyl-propyl) urea	99
Spanon	N' (4-chloro-O-totyl)-N, N-diemthyl formamidine	99.9
Sumicidin	a-cyano-m-phenoxybenzyl-2-(4-chlorophenyl)-isovalerate	97.6
Stomp	N-(ethylpropyl)-3, 4-dimethyl-2, 6-dinitrobenzenamide	93.2
Supracide	S-2, 3-dihydro-5-methoxy-2-oxo-1, 3, 4-thiadiazole-3-yl methyl 0, 0-dimethyl-phosphorodithioate	99.9
Surflan	3, 5-dinitro-N4, N4-dipropyl sulfanilamide	99
Tamaron	O, S-dimethyl phosphoramidothioate	98.6
TCMTB	2-(thiocyanomethylthio)-benzothiazole	100
TBPMC	3-tert-butylphenyl-N-methylcarbamate	98
Terracur-P	0, 0-diethyl 0-4-methylsulphinyl phosphorothioate	97.4
Terrazole	5-ethoxy-3-trichloromethyl-1, 2, 4-thiadiazole	98.6
Thiophonate-methyl	1, 2-di-(3-methoxycarbonyl-2-thioureido) benzene	100
Thimet	0, 0-diethyl S-ethylthiomethyl phosphorodithioate	90.6
Torak	S-2-chloro-1-phthalinidoethyl 0, 0-diethyl phosphorothioate	88.7
TOK	2, 4-dichlorophenyl 4-nitrophenyl ether	99.9
Volaton	0-a-cyanobenzylideneamino 0, 0-diethyl phosphorothioate	98
X-52	2, 4-dichlorophenyl-3-methoxy-4-nitrophenyl	99.5
Zincofol	cis-N-((1, 1, 2, 2-tetrachloroethyl) thio)-4-cyclohexane combined with zinc & copper	99.3

arrived at by the common application method recommended by the Government, it was possible to calculate a dangerous level of the particular application method in term of fish toxicity. By employing this rating method, 10 commonly used pesticides were evaluated (Table 3). Among those pesticides, endosulfan and phenthoate were not suitable for use in the paddy field; the field applied dosage of benthiocarb and butachlor should be restricted to the dosages recommended by the Government, while the field applied dosage of diazinon, BPMC, cyanofenphos, carbaryl, oxadiazon were considered safe.[18]

SCREENING OF PESTICIDES FOR MUTAGENICITY IN THE MICROBIAL SYSTEM

80 pesticides (including 23 fungicides, 13 herbicides and 44 insecticides) and 3 pesticide metabolites (Table 4) were studied to determine their capacity for inducing mutation with the Salmonella/ mammalian-microsome mutagenicity test as developed by Ames *et al.*

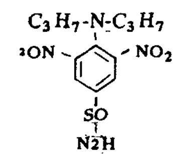
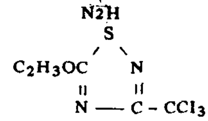
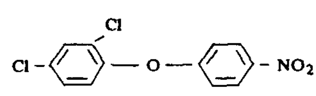
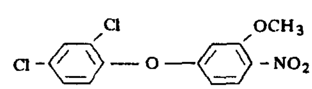
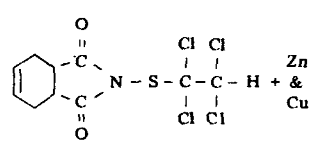
Results indicated that: (1) three herbicides — surflan, TOK, X-52 and one fungicide-terrazole were mutagenic on strain TA100, and their mutagenic capacity was not changed in the presence of liver microsomal fraction; (2) the nematocide-DBCP was mutagenic on both strain TA100 and TA98, and the mutagenic capacity was increased in the presence of liver microsomal fraction after preincubation; (3) the fungicide — zincofol was mutagenic on strain TA100, and the mutagenic capacity was decreased in the presence of liver microsomal fraction (Table 5).[2]

Further studies are underway to combine this assay with other shortterm mutagenicity tests as a buttery of tests to run on the pesticide applied *for registration in* Taiwan.

ENVIRONMENTAL POLLUTION BY PESTICIDES

1. Organochlorine insecticides

Table 5. Chemical structure of pesticides inciting postive reponses in the Salmonella/ mammalian microsome mutagenicity test.

Common name	Chemical name	Use	Chemical structure
DBCP	Dibromochloropropane	Fu	$CH_2BrCHBrCH_2Cl$
Surflan	3, 5-dinitro-N^4 N^4-dipropyl sulfanilamide	H	
Terrazole	5-ethoxy-3-trichloromethyl-1, 2, 4-thiadiazole	F	
TOK	2, 4-dichlorophenyl-4-Nitrophenyl ether	H	
X-52	2, 4-dichlorophenyl-3-methoxy-4-nitrophenyl ether	H	
Zincofol	cis-N-((1, 1, 2, 2-tetrachloroethyl) thio)-4-cyclohexane combined with zinc & copper	F	

Although the use of organochlorine insecticides, such as aldrin, dieldrin, BHC, heptachlor and DDT for agricultural purposes has been banned in Taiwan during recent years, their residues still remain in the environment. In an attempt to evaluate the possibility of contamination of food by these residues, a large-scale research program has been carried out by the Plant Protection Center to monitor their concentrations in river water and sediments in soils of various types of crop land and in biotic samples. While most of these organochlorine residues have been found in the various components of the environment (Table 6 & 7)[4], the levels were rather low mostly within the ppb range. Relatively high residue levels in the eggs of ducks raised in river water (Table 8)[4], show that contamination of food with these residues is possible. However, the overall residue levels, both in the water and the sediments of the major rivers, have shown a tendency to decline over the three year period (1973-1976) of monitoring.

Residual levels of some chlorinated hydrocarbon insecticides in the paddy soils of different geographical locations in Taiwan were examined in 1972. The average residual levels of 8 insecticides in the uppermost five inches, second five inches, and third five inches of the soil were analyzed and results were as follows: lindane — 11.8, 4.7, 2.8 ppb; heptachlor — 1.2, 0.5, 0.4 ppb; aldrin — 11.3, 1.6 ppb; dieldrin — 17.8, 11.7, 7.4 ppb;

Table 6. Residual levels of organochlorine insecticides in water samples collected from Tatu Chi (November 1973-December 1976)

Compound	Number of samples analyzed	Number of positive sample	Percent positive samples	Average residue levels (ppb)	Range of detected residue (ppb)
Aldrin	456	120	46.1	0.030	0.001-1.596
Dieldrin	456	186	40.8	0.022	0.001-0.277
Lindane	456	360	78.9	0.022	0.001-0.149
Heptachlor	456	78	19.2	0.016	0.001-0.247
Heptachlor epoxide	456	86	18.9	0.009	0.001-0.127
DDT	456	74	35.1	0.077	0.002-0.568
DDE	456	136	29.8	0.007	0.001-0.066
TDE	456	60	13.2	0.020	0.001-0.227
DDTR	456	154	33.8	0.022	0.001-0.568

Cited from Ku *et al* (1976)

Table 7. Residual levels of organochlorine insecticides in sediment samples from Tatu Chi.

Compound	Number of samples analyzed	Number of positive sample	Percent positive samples	Average residue levels (ppb)	Range of detected residue (ppb)
Aldrine	304	158	51.8	3.4	0.1-66.0
Dieldrin	304	134	44.1	3.7	0.1-55.0
Lindane	304	244	80.2	2.8	0.1-13.3
Heptachlor	304	89	29.3	1.4	0.1- 2.4
Heptachlor epoxide	304	67	22.0	1.5	0.1-13.9
DDT	304	112	36.8	2.4	0.4-55.4
DDE	304	152	50.0	3.1	0.2-27.2
TDE	304	101	33.2	7.0	0.3-35.1
DDTR	304	148	48.7	4.9	0.1-103.0

Cited from Ku *et al* (1976).

Table 8. Summary of organochlorine residue in duck eggs from duck raising farms in Taiwan.

Compound	Number of samples analyzed	Number of positive sample	Percent positive samples	Average residue levels (ppb)	Range of detected residue (ppb)
Aldrin	81	39	48.19	6.2	1.3- 18.7
Dieldrin	81	78	96.30	39.2	6.3- 344.4
Lindane	81	5	6.17	9.4	5.8- 15.5
Heptachlor	81	24	29.63	5.1	2.6- 8.9
Heptachlor epoxide	81	36	44.44	5.3	1.5- 18.9
DDT	81	78	96.30	128.2	3.3- 652.3
DDE	81	80	98.77	486.7	18.5-3268.2
TDE	81	31	38.27	20.5	0.5- 83.9
DDTR	81	80	98.77	635.4	29.1-3859.0

Cited from Ku *et al* (1976).

Table 9. Residual levels of chlorinated hydrocarbon insecticides in the pork samples of Taiwan (1975).*

	Percentage of positive samples		Average of residual levels (ppm)		Maximum residual levels (ppm)		
Insecticide	Muscular tissue	Adipose tissue	Muscular tissue	Adipose tissue	Muscular tissue	Adipose tissue	Tolerance (ppm)*
Lindane	23	12	0.004	0.009	0.0078	0.0169	0.3
Heptachlor	22	22	0.004	0.006	0.0085	0.0116	
Heptachlor epoxide	0	6	–	0.017	–	0.0371	0.3
Aldrin	0	0	–	–	–	–	
Dieldrin	28	33	0.008	0.037	0.0126	0.0848	0.3
Endrin	0	0	–	–	–	–	0.3
DDT	58	95	0.061	1.294	0.2355	1.9928	7.0
DDD	8	22	0.014	0.033	0.0319	0.3208	7.0
DDE	98	100	0.036	0.290	0.1074	0.9463	7.0
Methoxychlor	0	0	–	–	–	–	

*Cited from Food & Drug Administration, U.S.A. (1971).

dieldrin — 17.8, 11.7, 7.4 ppb; DDT — 17.1, 2.2, 0.5 ppb; DDD — 47.9, 10.9, 0.6 ppb; and DDE — 20.3, 7.4, 2.6 ppb, respectively.[6]

A study of the organochlorine pesticide residues in cultured fish and shellfish was made by S. S. Jeng of the Academia Sinica in 1972-73. The study revealed that small amounts of residues of the BHC group were present in almost all fish and shellfish, with a maximum value not exceeding 0.16 ppm. Also present in the edible parts of the fish and oysters were DDT group residues, with values below 0.15 ppm. Less than 0.05 ppm of dieldrin was found in the fish.[3]

An analysis of pork samples collected by the PPC from sixty retail markets all over the island showed the presence of DDT and its metabolites in all samples. Residues of lindane, heptachlor, heptachlor epoxide and dieldrin were also found in 6% to 33% of the samples. Residues of aldrin, endrin and methoxychlor were not detected. The concentrations of all pesticide residues found in the pork samples were much lower than the tolerances set by the U.S. Food and Drug Administration (Table 9).[8]

The survey of residual levels of chlorinated hydrocarbon insecticides in the human milk were also carried out. The summerized results were given in Table 11. There were no correlation between the

Table 10. Residual levels of chlorinated hydrocarbon insecticides in the human milk samples.

Pesticide	No. of sample analyzed	% of positive sample	Average residue levels (ppm)	Range of detected residue (ppm)
Lindane	106	0	ND	ND
Aldrin	106	30.2	0.00003	0-0.00650
Dieldrin	106	41.5	0.00070	0-0.00740
Heptachlor	106	10.4	0.00015	0-0.00458
Heptachlor epoxide	106	70.8	0.00067	0-0.01030
Endrin	106	0	ND	ND
p,p'-DDT	106	94.3	0.01600	0-0.12400
p,p'-DDE	106	100.0	0.08100	0.002-0.717

Cited from Li *et al* (1981)

Table 11. Residual levels of chlorinated hydrocarbon insecticides in the fat of human milk samples

Pesticide	No. of sample analyzed	% of positive sample	Average residue levels (ppm)	Range of detected residue (ppm)
Lindane	106	0	ND	ND
Heptachlor	106	10.4	0.00392	0-0.1530
Heptachlor epoxide	106	70.8	0.01951	0-0.8230
Aldrin	106	30.2	0.00113	0-0.0455
Dieldrin	106	41.5	0.02222	0-0.0173
Endrin	106	0	ND	ND
p,p'-DDT	106	94.3	0.50000	0-2.7100
p,p'-DDE	106	100.0	3.09000	0.56-15.71

Cited from Li, *et al* (1981)

Table 12. Total arsenic levels in paddy soils of Taiwan (1973).

Depth of soil (inches)	Average (ppm)	Range (ppm)
0-5	8.22	1.3- 44.2
5-10	14.07	1.7- 34.4
10-15	18.85	2.7-176.6

Total number of samples analyzed = 114
Percentage of positive sample = 100%
Cited from Li *et al* (1979).

residual levels and the age, the occupation of the women from which the samples were obtained.

2. **Arsenicals**

The arsenic content of paddy soils varied greatly from place to place, ranging from 1.3 ppm to 176 ppm. The arverage arsenic content in paddy soil was found to be 8.22 ppm in the top 5 inches, 14.07 ppm in the second 5 inches, and 18.85 ppm in the third 5 inches (Table 12).[17] Further study on the uptake of arsenic from soil by rice plants revealed that the arsenic residue in the soil was translocated into the rice plants. The amounts of arsenic found in the different portions of the rice plant were in the following order: root > rice straws > grains (Table 13).[12] The residual levels in the unpolished rice increased with the increase of arsenic residual levels in the soil. The amount of arsenic taken up by unpolished rice depends on the forms of compounds which are incorporated in the soil. Neo-asozin caused higher arsenic residuals in rough rice than those caused by As_2O_3 (arsenic

Table 13. The uptake of arsenic (As) by rice plant from soil.

Compound added	Total As levels in soil	As levels in different portions of rice* plant (ppm)			
		roots	straws	grains	rough rice
Blank	5.19	72.74	5.40	0.71	0.27
Neo-Asozin	22.49	384.35	31.23	1.65	0.38
AS_2O_3	30.58	466.90	40.63	1.06	0.37
$NaAsO_2$	35.60	536.22	44.36	1.41	0.37
$Na_2HAsO_4 \cdot 7H_2O$	34.07	551.03	48.01	2.16	0.40

* : Calculated on oven-dried basis; average of 5 replicates.
Cited from Li, et. al. (1980)

Table 14. Summary of arsenic levels in the rice grains from different locations of Taiwan (1975).

Description	Ponlai rice		Native rice		Sen rice	
	First crop	Second crop	First crop	Second crop	First crop	Second crop
No. of sample analyzed	83	84	67	53	22	20
No. of positive analyzed	80	79	61	50	21	19
Average residual levels (ppm)	0.43	0.53	0.40	0.41	0.30	0.50
Maximum residual levels (ppm)	1.04	1.74	1.41	1.47	0.58	1.25

Cited from Li, *et. al.* (1979).

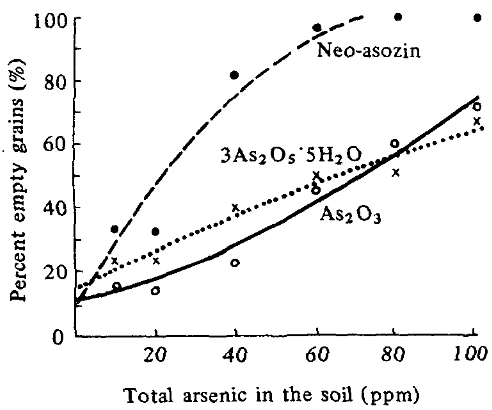


Fig. 2. The effect of arsenic in the soil on the percentage of empty grain of rice.

trioxide) and $3As_2O_5 \cdot 5H_2O$ (arsenic pentoxide).

A marked increase in the number of empty rice grains resulted from the incorporation of the soil with arsenic compounds (Fig. 2).[12] The number of effective tillers, plant height and weight and the collective weights of 1000 grains of rice also decreased with increase in soil arsenic residues.[12]

The analyses of rice grain samples collected from 86 townships in Taiwan during 1975 revealed that about 95% of the samples analyzed contained detectable amounts of arsenic. The arsenic levels in the grains of second crop rice were higher than that from first crop rice (Table 14). The townships from which the rice grain samples with high arsenic levels (<0.76 ppm) were found, were grographically widely distributed. Among the 86 townships, samples taken from 34 of them were found to have high arsenic levels.[13]

3. Mercurials

In 1972, paddy soil samples collected from different localities through out Taiwan were analyzed for total mercury. It was found that the mercury content of these samples averaged 0.22 ppm in the top 5 inches of soil, 0.15 ppm in the second 5 inches, and 0.10 ppm in the third 5 inches (Table 15).[7] The differences in mercury levels between different geographical locations were very small, ranging from 0.01 to 0.78 ppm and the mercury contents of rice plants grown on these soils were all below the detection limit.

Another study showed that compost is a source of mercury contamination of mushrooms. The amount of mercury uptake from compost by the mushrooms varied greatly according to the chemical structure of the mercury compounds present in the compost, and was in the order of methyl mercury > ethyl mercury > phenyl mercury > inorganic mercury (Fig. 3).[10]

Table 15. Mercury levels in paddy soils of Taiwan

Depth of soil (inches)	Average residue (ppm)	Range of residue (ppm)
0-5	0.224	0.05-0.78
5-10	0.147	0.03-0.65
10-15	0.097	0.01-0.51

Number of samples analyzed = 162
Percent positive sample = 100%
Cited from Li, *et. al.* (1974)

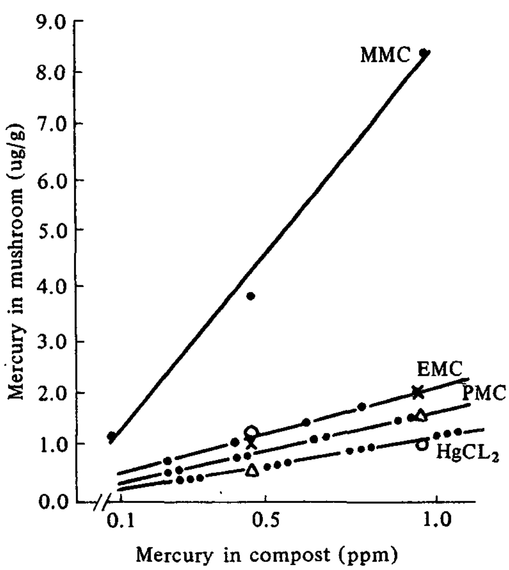


Fig. 3. The relationship between the mercury levels in the mushrooms and compost.

RESIDUES OF CURRENT USED PESTICIDES

Residues of current used pesticides in the soil and water samples were analysed constantly. The analysis of benthiocarb, butachlor and chloromethoxynil in the water and soil samples from different location of Taiwan at the time when rice were being harvest or close to harvest showed that in the top 15 cm of soil 44.1% of samples contain benthiocarb, 10.3% contain butachlor, and 17.6% contain chloromethoxynil. The average residual levels were 0.057 ppm, 0.004 ppm and 0.006 ppm respectively. Fifteen out of 17 water samples from different locations of Taiwan contain benthiocarb. The average residual levels were in ppb level. There were no residue of butachlor and chloromethoxynil found in the water samples.[23]

MODEL ECOSYSTEM

A rice paddy model ecosystem was established to study the behavior of a pesticide and the potential of a pesticide to pollute environment.

The behavior of carbofuran had been studied under this model ecosystem. Results indicated that carbofuran applied into soil under flooded condition disappeared faster than that applied without flooding.

Eighty percent carbofuran persisted in the soil when applied 14 days before flooding and degraded after irrigation. Under flooded condition, 70% of applied carbofuran remained in water and degraded rapidly (Table 16 & 17).[16]

When carbofuran was applied onto soils with different water contents, the residual level in the seedlings in decending order was saturated > field capacity > flooded. When applied at water contents of field capacity, carbofuran level reached its peak in the rice around five days after application and degraded after irrigation while its two metabolites, 3-keto and 3-hydroxycarbofuran took around 20 days to reach their peak. In contract it took 10 days

Table 16. Distribution of Carbofuran in Rice Paddy Model Ecosystem (Part I).[a]

Days after transplanting	Days after application	Pesticide Distribution (mg) Soil I[b]	Soil II	Soil III	Water I	Water II	Water III	Straw I	Straw II	Straw III
3	14	185.6	–	172.8	32.8	–	32.9	–	–	–
17	28	–	–	–	–	–	–	0.68	–	0.88
18	29(1)[c]	47.4	65.2	126.8	18.1	103.3	126.1	–	–	–
24	35(7)	–	–	–	–	–	–	0.87	0.35	1.42
31	42(14)	41.4	<9.4[d]	44.5	0.39	0.33	0.53	–	–	–
35	46(18)	–	–	–	–	–	–	0.37	0.09	0.50

a/ Pesticide dosage used in each treatment was 216 mg a.i. (=1.8 kg a.i./ha); All irrigated to 3 cm above soil at 1 day before transplantation.

b/ Carbofuran applied date: I: 10 days before transplantation; II: 17 days after transplantation; III: 10 days before and after transplantation.

c/ Date in parenthesis are days after second pesticide application.

d/ Means non-detectable (detection limit = 9.4 mg)

Cited from Li, *et. al.* (1980).

Table 17. Distribution of Carbofuran in Rice Paddy Model Ecosystem (part II).[a]

Days after application	Pesticide distribution (mg) Soil I[b]	Soil II	Soil III	Water I	Water II	Water III	Straw I	Straw II	Straw III	Age of plants (days)
1	214.6	59.6	138.9	–	119.3	16.5	–	–	–	90
3	–	–	–	–	–	–	1.57	2.38	15.57	93
6	203.3	24.7	15.8	–	2.45	1.57	3.19	2.49	17.20	96
13	16.03	6.4	7.8	3.62	<0.39[d]	<0.39	2.43	0.88	10.21	109
20	16.85	<3.6[c]	<3.6	0.85	–	–	2.60	0.93	8.61	116
31	<3.6	–	–	<0.39	–	–	1.84	0.25	6.74	121
48	–	–	–	–	–	–	0.69	0.17	1.18	138

a/ Pesticide dosage used in each treatment was 216 mg a.i. (= 1.8 kg a.i. /ha)

b/ Chemical applied under I. unflooded condition; II. Flooded condition; III. Water-saturated condition.

c/ Pesticide residue in soil was below detection limit (3.6 mg)

d/ Pesticide residue in water was below detection limit (0.39 mg)

Cited from Li, *et. al.* (1980).

for carbofuran to reach its peak content in rice when applied to the field saturated and flooded with water (Fig. 4, 5 & 6).[16]

Comparing the amount of residues in the mosquito fish and in the water of the model ecosystem, we found that the ecological magnification value was zero in terms of carbofuran per se and 1.4 to 7.6 in terms of carbofuran plus its two metabolities.[16]

Studies on the distribution of benthiocarb (S-(4-chlorobenzyl)-N, N-diethyl thiocarbamate) after soil application to the paddy model ecosystem were carried out. Most of the benthiocarb residue was found in the soil and very little in the run-off water.

After the rice plants were harvested 102 days after soil application of benthiocarb 10% granule at 30 and 60 kg/ha, 0.117 and 0.449 ppm of benthiocarb residue were found in the rice straw, 0.06 and 0.127 ppm in the unpolished rice, and 0.44 and 15.05 ppm in the soils of zero to five centimeter depth respectively (Table 18, 19, 20).[11]

No adverse effect of the residual benthiocarb

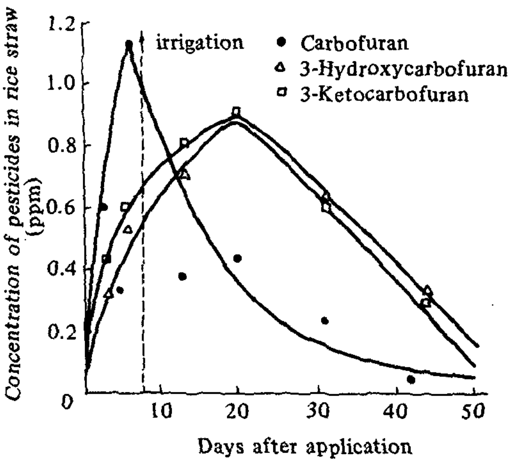


Fig. 4. The transformation and degradation of carbofuran in rice plants. (Applied under unflooded condition).

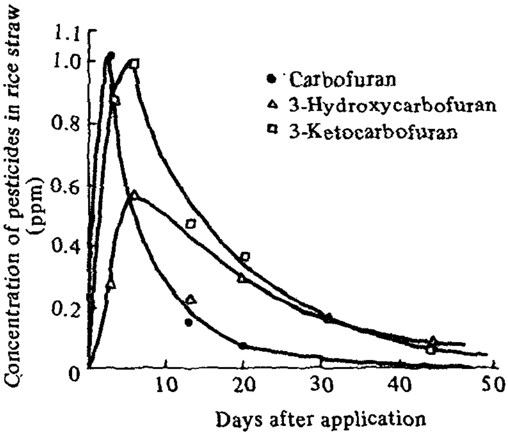


Fig. 6. The transformation and degradation of carbofuran in rice plants. (Applied under flooded condition)

Table 19. Residual levels of benthiocarb in the rice plants and grains.

Days after application	Benthiocarb residue (ppm)			
	Rate of application (kg 10% granule/ha)			
	Rice plants	Grains	Rice plants	Grains
30	ND*	–	0.036	–
39	0.014	–	0.136	–
74	0.492	–	0.640	–
102	0.117	Trace (≅0.06)	0.449	0.127

*ND = non-detectable (<0.06 ppm)
Cited from Li, *et. al.*(1979).

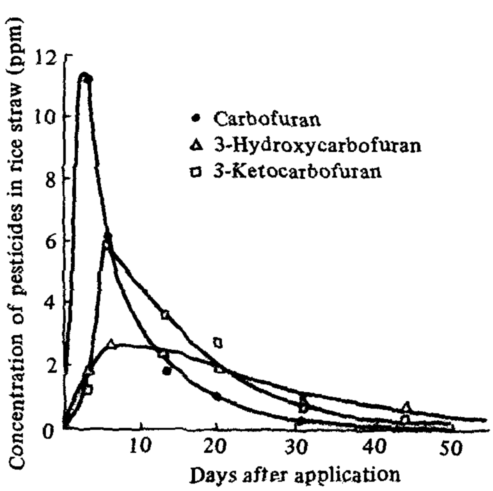


Fig. 5. Transformation and degradation of carbofuran in rice plants. (Applied under unflooded condition but saturated with water.)

Table 18. Residual levels of benthiocarb in the soil and water sample from "rice paddy paddy" under greenhouse condition.

Days after application	Benthiocarb residue in soil and in water (ppm)			
	Rate of application (kg 10% granule/ha)			
	30kg/ha		60kg/ha	
	In soil[1]	In water	In soil	In water
1	58.98	0.048	20.06	0.150
14	26.90	0.061	24.96	0.542
39	20.62	0.032	11.20	0.365
74	11.82	ND[2]	17.40	0.194
102	0.44	ND	15.05	0.109

1 : Dehydrated with centrifuge and air dried
2 : ND = non-detectable; Detection limit ≈ 0.015 ppm
Cited from Li, *et. al.*(1979)

Table 20. IC_{50} and IC_{20} of benthiocarb in the soil to several rice intercrops.

Crops	IC_{50} (ppm)	IC_{20} (ppm)
Maize	138.1	33.81
Cucumber	178	56.89
Black bean	118.3	28.29
Rape	323.6	50.7
Cabbage	182	52.72
Oat	389.1	88.73
Radish	426.6	98.4

IC = inhibition concentration
Cited from Li, *et. al.* (1979).

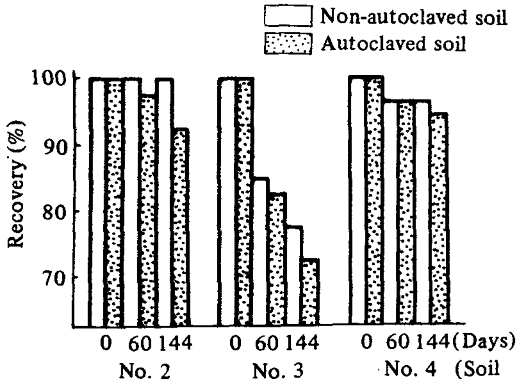


Fig. 7. The Disappearance of Ronstar in Different soils.

Table 21. Some characteristics of soils used in the oxadiazon experiment.

Soil	Clay (%)	Organic matter (%)	CEC (meq/100g)	PH (1:1)	Texture
No. 1	8.75	9.40	61.75	4.9	loam
No. 2	7.17	10.19	70.38	5.4	Silt loam
No. 3	24.70	0.69	45.48	5.4	loam
No. 4	6.61	1.16	30.21	6.5	Sandy loam

Cited from Li, et. al (1980)

on the growth of broccoli, radish, and rape were found. These vegetables were planted in the same system after the rice was harvested.[11].

The rate of disappearance of ronstar (oxadiazon) in three different soils (Table 21) was studied.[14] The results indicated that after 144 days, 73.1 to 96% of the initial ronstar applied still remained in the soil. The rate of disappearance of ronstar in the soil of high clay content was slightly faster than that of low clay content (Fig. 7).[14]

THE ESTABLISHMENT OF PESTICIDE TOLERANCES ON THE EDIBLE CROPS IN TAIWAN

In order to ensure the safety of pesticide residue in the edible crops, tolerances of pesticides for each group of crops have been established based on the 1) actual residues found for each group of crops resulted by the application of pesticides under recommended rates; 2) values of acceptable daily

Table 22. Sub-MPI values of Carbofuran on Different Crops.

Crop group	Percentage on daily intake	Sub-MPI (mg/person)
1. Rice	22.19	0.1110
2. Flour	11.12	0.0556
3. Sundry provisions	1.81	0.0091
4. Large leafy vegetables	6.24	0.0312
5. Small leafy vegetables	12.12	0.0606
6. Root crop vegetables	8.33	0.0417
7. Fruiting vegetables	5.55	0.0278
8. Cucurbit vegetables	3.92	0.0196
9. Seed anf pod vegetables	1.51	0.0076
10. Cucurbit fruits	7.81	0.0391
11. Berries	7.08	0.0354
12. Stone fruits	1.10	0.0055
13. Pome fruits	1.48	0.0074
14. Citrus fruits	6.08	0.0304
15. Sugar cane	2.55	0.0128
16. Dried beans and peas	1.09	0.0055

AID of Carbofuran = 0.01 mg/kg b.w./day
MPI of Carbofuran = 0.5 mg/person/day
Cited from Li, *et. al.*(1981).

Table 23. Crop Groups Classification for Tolerance Establishment.

1. Rice	:	Penglai rice, Tsailai rice, Glue rice, rice, Rice Noodle.
2. Flour	:	Bread, Noodle, Cake, Bun.
3. Sundry provisions	:	Corn, Yam.
4. Large leafy vegetables	:	Cabbage, Head cabbage, Leaf-mustard.
5. Small leafy vegetables	:	Leek, Spinach, Lettuce, water convolvulus, Rape, Non-heading type Chinese cabbage.
6. Root crop vegetables	:	Potato, Raddish, Carrot, Bambo Bamboo shout, water oat, Onion, Cinger, Taro.
7. Fruiting vegetables	:	Cauliflower, Eggplant, Green pepper, tomato, mushroom.
8. Cucurbit vegetables	:	Oriental pickling melon, Cucumber, Wax grord, Rag gourd.
9. Seed and pod vegetables	:	Kindney bean, Fresh soy bean, String bean, Pea.
10. Cucurbit fruits	:	Water melon, Yellow melon
11. Berries	:	Grape, Papaya, Guava, Persimmon, Wax-apple, Banana, Pineapple.
12. Stone fruits	:	Longan, Mango, Litchi.
13. Pome fruits	:	Apple, Pear, Loquat.
14. Citrus fruits	:	Orange, Tangerine, Grape fruits, Pomelo, Lemon.
15. Sugar cane		
16. Dried beans and peas	:	Red bean, Soy bean, Mung bean, Peanut.
17. Special crops	:	Tea, Tobacco.

Table 24. Daily Consumption of Each Crop Groups Per Person.

Crop Group	Daily consumption per person (kg)	Percentage on daily intake
1. Rice	0.1529	22.19
2. Flour	0.0766	11.12
3. Sundry provisions	0.0125	1.81
4. Large leafy vegetables	0.0430	6.24
5. Small leafy vegetables	0.0835	12.12
6. Root Crop vegetables	0.0574	8.33
7. Fruiting vegetables	0.0382	5.55
8. Cucurbit vegetables	0.0270	3.92
9. Seed and pod vegetables	0.0140	1.51
10. Cucurbit fruits	0.0538	7.81
11. Berries	0.0488	7.08
12. Stone fruits	0.0076	1.10
13. Pome fruits	0.0102	1.48
14. Citrus fruits	0.0419	6.08
15. Sugar cane	0.0176	2.55
16. Dried beans and peas	0.0075	1.09

Cited from Li, *et. al.* (1981).

intake of the pesticides; 3) daily consumption of each group of crops by each person.

MPI(maximum permission intake) of a pesticide by Chinese person was calculated from ADI. The MPI for a pesticide was evenly distributed onto the sixteen crop groups base on the daily consumption of each crop groups and named sub-MPI, as shown in Table 22, 23 and 24.

Tolerances were set for each group of crops in accordance with the actual residue present at harvest time, however, these values were always set below sub-MPI value for the respective pesticide on each crop groupings. If it is necessary, sometimes the tolerances were set higher than sub-MPI values, but the total number of crop groups to which a pesticide registered was limited by the MPI value. Another words the total actual residue of a pesticide on the crop groups to which this pesticide has been registered in no case can exceed the established MPI value.

By using the above mentioned method, tolerances for 75 pesticides on different crop groups have been established (as shown in Table 25).[21]

Table 25. Tolerances of Pesticide on Different *Crop Groups Proposed by Plant Protection Center*

Pesticide	Tolerance (ppm)	Crop Grouping 1/
Acephate	0.1	1
	2.5*	4
	0.5	13
Aldicarb	0.05	14
	0.07	6, 16
	0.15*	11
Azinophos-methyl	0.15	11
Bendiocarb	0.1	1
BPMC	0.5	1
Bufencarb	0.05	1
Benomyl	2	11, 12
	3	13
Bupirimate	0.5	8, 12
Blazer	0.1	16
Butachlor	1	1
Carbaryl	1.5*	1
	0.1	12
Carbofuran	0.4*	1, 6
	0.3*	3, 4
	0.1	7, 11, 12, 14
Carbophenothion	0.01	1
Chlorpyrifos	0.25*	1
	0.05	8
	0.03	6, 11
	0.01	4
Cyanophenphos	0.25	4
	0.2	1
Cypermethrin	0.5	4
Captafol	0.5	12
Chlorothalonil	0.5	4, 11, 16
Carbodimedon	0.5	16
Decamethrin	0.3*	4
Dialifor	0.2*	11
	0.02	11
Diazinon	1.0*	13
	0.05	1
Denmert	1	8, 10
Dicloran	1	4, 5
Ditalimfos	1	10
Dichlorvos	0.1	6, 7
Dimethoate	1	11
Disulfoton	0.01	6
Dinoseb	0.05	16
Ethirimol	0.1	8, 12
Endosulfan	0.5	4
	0.1	6

Pesticide	Tolerance (ppm)	Crop Grouping1/
Etrimfos	0.01	11
Ethefumesate	0.1	16
Fenalevate	0.3	4
	0.1	1, 12
Fenthion	0.08*	7
	0.01	1, 8
Fenitrothion	0.1	12
Fonofos	0.1	4, 9
Formothion	1	11, 12
Fenamiphos	0.4	7
	0.1	6
Chinomethionate	0.05	11
Chlordimeform	2.0*	1
Cyhexatin	0.5	13, 14
DBCP	1	6
Glyodin	0.2*	1
Geofos	0.2	1
Hexachlorophene	0.1	7
Isoprothiolan	0.5	1
Leptophos	0.02	6
Malathion	0.5	11
Methamidophos	0.5*	1
	0.2*	12
	0.1	6, 16
Mephosfolan	1	3
	0.05	1
Methomyl	1	10, 16
	0.5	3, 11
	0.2	6
	0.1	1
MIPC	0.5	1
MTMC	0.5	1
NK-049	0.5	1
Oxamyl	0.2	7
Oryzalin	0.1	11
Oxyfluorfen	0.1	1, 16
Permethrin	1	4
	0.1	1
Pirimiphosephyl	0.3*	7
Pyridaphenthion	0.2	1
	0.1	
Pirimiphosmethyl	0.8*	1
Phosmet	0.1	1, 5
Phthalide	0.1	1
Ridomil	0.1	3
Thyocyclam hydrogenoxalate	1	4
Terbufos	0.05	11
Thiabendazole	1	6
Triadimefon	0.5	8, 16
Tricyclazole	0.5	1
Tridemorph	0.5	5
Trifluralin	1	3, 16
	0.5	4, 7
Triforine	0.5	9
Torque	1	13
Procymidone	1.5	8, 10
Profonofos	0.1*	4
Propineb	0.5	10

* represented that the value higher than sub-MPI.

1/ Crop groupings see table 22.

Cited from Li, *et. al.*(1981).

TOXICITY OF PESTICIDES TO NON-TARGET CROPS

Because the intensive agricultural system has been adopted in Taiwan in the field not only three crops per year, but also the variety of crops make the pattern of crops growing much more complex than other countries. The attention has been therefore paid to the effect of pesticides on the non-target crops.

These studies can be classified into several catagories, 1) direct effects caused by the miss using of pesticides, 2) injury caused by the pesticide polluted irrigation water, 3) injury caused by the pesticide polluted soil, 4) reduction of growth resulted by the effects of pesticide on the soil microorganisms.

Direct injury of pesticides to non-target crops was evaluated in the glass house under control condition. Some of the results were shown in Table 26.[22] If injury of non-target crops was found after treated the crops at the application rates, three folds more than the normal recommended rates, then the dosage-response curve studies will be carried out.

In order to evaluate the effect of pesticide pollutted irrigation water on the growth of non-target crops, the bioassay methods were used.[19] Three bioassay methods, root bioassay, shoot

Table 26. Phytotoxicity of Pesticides to Non-target Crops.

Pesticide	Concentration	Radish	Pea	Chinese spinach	Tomato	Mustard	Soybean	Cucumber
50% Methyl parathion EC	1,000 X	-	-	-	-	–	-	-
55% Azodrin S	500 X	+	-	+	++	+++	+	-
	250X	++	+	+++	+++	++++	+++	+
55% Azodrin S	2,000 X	-	-	-	-	-	-	-
	1,000 X	-	-	-	-	-	-	-
	500 X	-	-	-	-	-	-	-
48% Kitazin-P EC	1,000 X	+	+	+	+	+	+	+
	500 X	+	+	+	+++	+++	++	+
	250 X	++++	+++	+++	++++	++++	+++	+++
10% Kestrel EC	1,000 X	-	-	-	-	-	-	-
	1,000 X	-	-	-	-	-	-	-
	500 X	-	-	-	-	-	-	-
6.5% Neo-asozin EC	2,000 X	-	-	-	-	-	-	-
	1,000 X	-	-	-	-	-	-	-
	500 X	-	-	-	-	-	-	-
80% Dithane M-45 WP	400 X	-	-	-	-	-	-	-
	200 X	-	-	-	-	-	-	-
	100 X	-	-	-	-	-	-	-
50% Benlate WP	1,500 X	-	-	-	-	-	-	-
	750 X	-	-	-	-	-	-	-
	375 X	-	-	-	-	-	-	-
40% Hokbal EC	800 X	-	-	-	+	-	-	-
	400 X	-	-	-	++	+	++	-
	200 X	++	-	+	++	++	+++	++

Degree of phytotoxicity:
- No leaves been injuried.
+ 25% of leaf area been injuried.
++ 25% to 50% of leaf area been injuried.
+++ 50% to 75% of leaf area been injuried.
++++ 75% to 100% of leaf area been injuried.

Cited from Li, *et. al.*(1982).

Table 27. The Maximal Residues in Paddy Water of Different Pesticides.

Pesticide	Recommended field rate	Maximum residue in* field water m(ppm)
75% Acephate SP	1.2 kg/ha	3.0
50% Benthiocarb EC	10 L/ha	16.7
50% Benomyl WP	0.8 kg/ha	1.3
5% Butachlor G	40 kg/ha	6.7
50% Carbaryl WP	2.4 kg/ha	4.0
3% Carbofuran G	50 kg/ha	5.0
10% Diazonon G	18 kg/ha	6.0
3% Fenitrothion D	40 kg/ha	4.0
50% Fenthion EC	1.2 L/ha	2.0
50% Methamidophos S	1.2 L/ha	2.0
90% Methomyl WP	0.7 kg/ha	2.1
8% MIPC G	20 kg/ha	5.3
8% Molinate G	30 kg/ha	8.0
7.7% Nitrofen G	30 kg/ha	7.7
20% Phenovalerate EC	0.4 L/ha	0.3
2.5% Rabcide D	40 kg/ha	3.3
41.7% Tricyclazole F	0.8 L/ha	1.1

* Assumed that the field was flooded with water 3 cm in depth.

Cited from Li, *et. al.*(1981).

Table 28. The extent of growth inhibition for various crops when water containing maximal residues resulted from pesticide application.

Pesticide	Percentage of Growth Inhibition				
	Radish	Muskmelon	Mustard	Cucumber	Pea
Acephate	x	x	x	x	x
Benthiocarb	42.5	80.2	67.7	77.7	26.7
Benomyl	4.2	1.8	43.7	x	x
Butachlor	65.0	61.0	60.3	72.3	27.0
Carbaryl	1.3	13.0	13.2	4.1	6.7
Carbofuran	–	x	x	x	x
Diazinon	x	10.3	x	5.4	–
Fenitrothion	1.0	5.1	1.0	x	4.0
Fenthion	x	x	1.5	x	x
Methamidophos	x	1.0	x	x	x
Methomyl	x	x	x	x	x
MIPC	x	x	x	x	x
Molinate	10.4	29.0	4.8	47.3	24.1
Nitrofen	8.0	25.7	49.1	–	x
Phenovalerate	x	x	x	x	x
Rabcide	x	x	x	x	x
Tricyclazole	x	1.4	1.3	1.2	x

x No effect
– Data not available
Cited from Li, *et. al.* (1981)

bioassay and water culture were used for this study. In water culture, the root growth of the crop responded sharply to the various pesticide tested.

In studying the effects of 17 of the most commonly used pesticides in rice fields on the growth of radish, muskmelon, pea, mustard and cucumber, 65 equations expressing the relationship between the concentration of pesticides in water and growth inhibition of crops were derived.

By calculating the maximum residue of these pesticides in the paddy water according to the recommended rate of application (Table 27) and substituting the residual value into the above equations, it was found that 4 herbicides, 1 fungicide, and 2 insecticides might have adverse effect on the growth of crops (Table 28). This method could be used to measure the effect of pesticides on non-target crops before the pesticides are recommended for field use.

Attentions have also been paid on the injury of non-target crops caused by the pesticide polluted soils. The evaluation of phytotoxicity of pesticide residue in soil was done under simulated natural condition. 102 days after soil application of benthiocarb 10% granule at 30 and 60 kg/ha, vegetables were planted in the system after the rice was harvested, no adverse effect of the residual benthiocarb on the growth of broccoli, radish, and rape were found. However, laboratory experiments showed that when benthiocarb residue in the soil reached 33.81, 56.87, 28.29, 50.70, 50.72, 88.73, 98.4 ppm, 20% inhibition of the growth of maize, cucumber, black bean, rape, broccoli oat and radish respectively were found.[11]

In the pesticide heavily used area such as Taiwan, much attention have to be paid to the effect of pesticide residue in the soil on the soil microorganisms. Special consideration have been given to the effect of pesticides on the ammonification and nitrification in the soil.

When Saturn, Machete, and Tok were added to soils which had been pretreated with $(NH_4)_2SO_4$, was found that the three herbicides were at relatively low concentrations in soil (Saturn 10 $\mu g/g$; Tok 10 $\mu g/g$; Machete 25 $\mu g/g$), they had almost no effect on the production of NO_3^--N in the soil, while at higher concentration (Saturn > 25 $\mu g/g$; Tok > 100 $\mu g/g$; Machete > 100 $\mu g/g$) the production of NO_3^--N in the soil was markedly inhibited. The degree of inhibition of NO_3-N production in the soil of the three herbicides tested was in the following order: Machete > Saturn > Tok.

All three herbicides studied in this experiment increased the accumulation NH_4^+-N in the soil even at low concentrations (Machete 25 $\mu g/g$; Saturn 10 $\mu g/g$; Tok 10 $\mu g/g$). The tendency to stimulate NH_4^+-N production in the soil for the three herbicides studied was found to occur in the following order: Tok > Saturn > Machete (Fig. 8, 9, 10).

No detectable amounts of NO_2^--N were found in the soils from any of the treatment (Fig. 11, 12, 13).[15]

Similar types of work have been carried out in

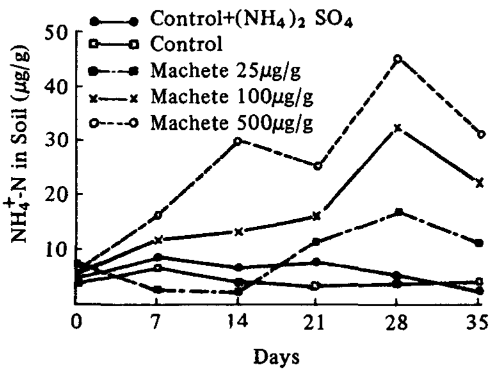


Fig. 9. The effect of soil treatment with Machete on the ammonification in soil.

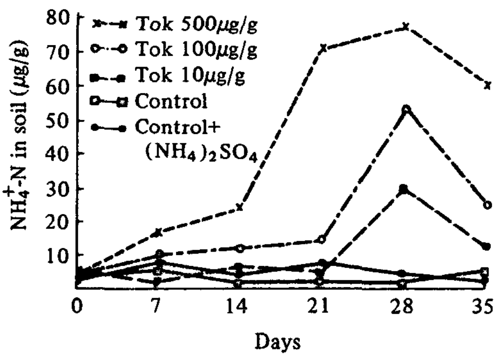


Fig. 8. The effect of soil treatment with Tok on the ammonification in soil.

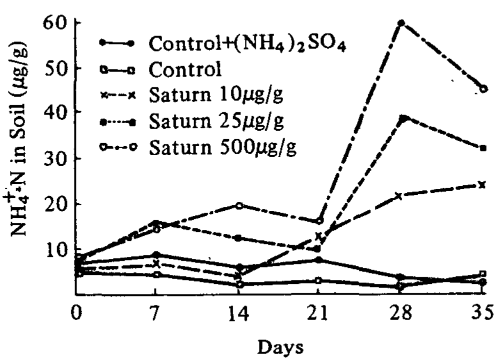


Fig. 10. The effect of soil treatment with Saturn on the ammonification in soil.

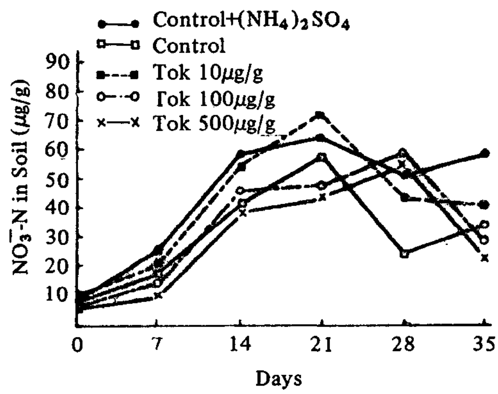


Fig. 11. The effect of soil treatment with Tok on the nitrification in soil.

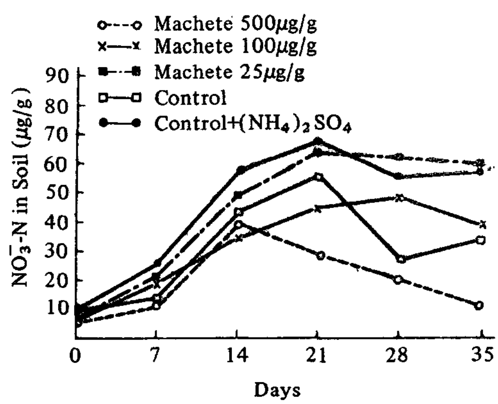


Fig. 12. The effect of soil treatment with Machete on the nitrification in soil.

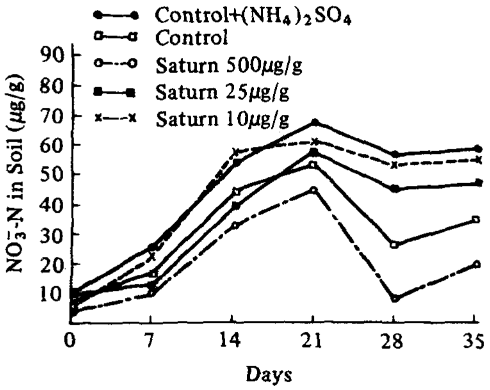


Fig. 13. The effect of soil treatment with *Saturn* on the nitrification in soil.

the PPC, by using Diazinon, Kestrel, MIPC, and many other fungicides.

CONCLUSION

Pesticides play one of very important role in the modern agriculture. The use of pesticides increased rapidly in the recent years. Although the toxicological data of most pesticides have been documented before they are available on the market, the toxic effects always altered or strengthened by the application methods in different agriculture systems. The side effects of pesticides therefore have to consider based on their usages and on the agriculture system to which this particular pesticide is applied.

In Taiwan, great efforts have been put on the acute toxicity of pesticides to the fish and predator of insect pest, mutagenicity of pesticides, residue on food crops, the potential to pollut environment, the effect on the growth of non-target crops, and the effect on the soil microorganisms.

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DISCUSSION

Question (Dr. Yong Wha Shin, Pesticide Research Institute)

I have some questions about the acute toxicity of pesticides to natural enemies and environmental pollution by pesticides.

Table 2 show us the E-parathion and malathion to be selective to wolf spide. You didn't comment these organophosphates. Would you please tell me whether E-parathion and malathion may be able to be used as the selective insecticides for the control of brown planthopper.

Answer (Dr. Gwo-Chen Li)

According to my opinion, E-paration may be able to be used as selective insecticides for the control of brown plant-hopper. Malathion have relatively low toxicity to Bph. But E-parathion as not registered in my country to control Bph.

Question (Dr. Yong-Wha Shin)

You pointed out that increase in the number of empty rice grains resulted from the incorporation of the soil with Neoasozine. We also spray at the rate of 120-160 g/ha with Neoasozine for the control of leaf sheath blight three times from early growth stage to heading of rice plant. How much rate of Neoasozine do you recommend against leaf sheath blight control in Taiwan.

Answer (Dr. Gwo-Chen Li)

Aerial spray of Neo-asozine at flowering stage will cause empty grain. No correlation was found between the amount of Neo-asozine sprayed and the increase of arsenic in the soil. In my country the recommended rate is the same as in Korea.

Question (Dr. Ki-Hak Han, Institute of Agricultural Science)

In connection with mercury contamination of mushrooms, if it is actually contaminated with mercury in mushrooms grown by farmers, what is the source of mercury in compost?

Answer (Dr. Gwo-Chen Li)

We have not yet found any mercury in mushroom, but we are trying to prevent the use of industrially polluted rice straw to grow mushroom.

Question (Dr. Ki-Hak Han)

Regarding on the arsenic levels in grains, why the arsenic contents in the second crop rice were higher than that from the first crop rice?

Answer (Dr. Gwo-Chen Li)

More pesticides are being used during the second crop than first crop, because more insect pests and disease occurs during the second crop than the first crop.

Question (Dr. Sun-Uk Lim, Seoul National University)

I would like to ask about the effect of herbicide treatment on ammonification and nitrification. 1) Formation or accumulation of NH_4^+-N was greatest at highest level of all three herbicides, and those nitrogens might come from mobilized organic matters in soil and from ammonium sulfate. How would you explain the cause of that increased mobilization rate at highest level of herbicides? 2) Formation of NO_3^--N, on the contrary to NH_4^+-N, was lowest at highest level of all three herbicides. What would be expected if Urea or other organic fertilizers were used as nitrogen sources? What do you think about the reason of increased NO_3^--N at lowest and intermediate level of the herbicides? 3) I also would like to ask whether the inhibited nitrification at highest level of the treatment cause inhibition of nutrient absorption or other physiological damages.

Answer (Dr. Gwo-Chen Li)

1) The ammonium may come from organic matter or ammonium sulfate in the soil. However, we measured the total NH_4^+-N in soil and campared the amount of NH_4^+-N in pesticide treated soil with the amount of NH_4^+-N in the soil to which ammonium sulfate was added. Higher mobilization rate might be caused either by the inhibition of nitification or by the stimulation of ammonification both will cause the accumulation of NH_4-N in the soil. However, in the experiment we care only the total amount of NH_4^+-N produced in soil due to the herbicide applications. 2) Only when the NO_3^--N produced in the herbicide treated soils more than the soil to which $(NH_4)_2SO_4$ was added, we then consider the herbicide stimulated the production of NO_3^--N in soil. That way we consider in this experiment. No effect or inhibition were found by treating the soils with three herbicides tested. No idea about urea and other organic fertilizer. For the time being, we are using only $(NH_4)_2SO_4$. 3) Heavy rainfall may cause the leaching of NO_3^--N from the soil because the NO_3^--N is not bound to the soil colloid. This may result in the loss of soil fertilities. This is the major concerned in this experiment. We do not want the increase of NO_3^--N in soil due to the herbicide application. No observations on nutrient absorption or other damage were made in this study.