RESIDUE AND TOXICITY PROBLEMS ASSOCIATED WITH PESTICIDE USE IN TAIWAN

Gwo-chen LI*

Abstract

Because of the continuing and rapid increase in pesticide use in Taiwan, much attention has been focused on pesticide contamination of food and effect of pesticides on human health and the environment. The Plant Protection Center (PPC) conducts tests to evaluate the safety of the pesticides used in Taiwan.

In accordance with the Pesticide Control Act, waiting periods for harvest after the last application of pesticides, and tolerance level of pesticides for different crop groups are established before pesticides are recommended for use in the field. The "tolerance" level of pesticides for different crop groupings was determined based on 1) the acceptable daily intake value of individual pesticides, 2) average daily consumption of each crop group by Chinese people, 3) actual residue content of pesticides on different crops estimated from supervised trials. The total number of pesticides for which the tolerance levels of different crop groups have been established amounts to 79 approximately.

Acute toxicity of pesticides to useful insects has also been studied, and special attention has been paid to the two predators of the rice brown planthopper.

Paddy fields account for 60% of the cultivated land in Taiwan and therefore, acute toxicity to fish is taken into account when applications for registration of pesticides to be used in paddy fields are submitted. Fish toxicity was evaluated by the so-called "dangerous rating value" which refers to the amount of pesticides in the field water exceeding the TLM value.

Mutagenicity of pesticides is continuously being tested by using Ame's microbial method.

Nationwide surveys of residual levels of pesticides which are known to be pollutants such as chlorinated hydrocarbon insecticides, mercurial compounds in soil, water and biological samples are being carried out constantly. So far the levels of these residues do not appear to be significantly high.

Higher residual levels of arsenic compounds were detected in the paddy soil samples from different localities of Taiwan. The arsenic derivates present in the soil were found to limit the growth of rice.

The potential of a pesticide to pollute the environment was studied by using model ecosystems. The distribution of residues in the various components of the system and the "ecological magnification" of a chemical were derived from model ecosystems.

Since intensive agricultural systems have been adopted in Taiwan, the phytotoxicity of pesticides to non target crops became one of the most important factors for the evaluation of the safety of pesticide use. Criteria include: 1) direct injury, 2) injury caused by pesticide pollution of irrigation water, 3) injury caused by soil polluted by pesticides, 4) reduction of growth caused by the effect of pesticides on the soil microorganisms.

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 million in 1952 to NT$662 million in 1969, and more than 2 billion in 1979. Presently about NT$3.4 billion have been spent by the farmers for pesticide purchase. Because of the continuing rapid increase in pesticide use, much attention has been focused on pesticide contamination of food and the environment.

---

* Director, Plant Protection Center, and Chief, Pesticide Residue Division, 189 Chung Cheng Rd, Wufeng, Taichung Hsien, Taiwan.

Research to promote the pesticide control act

The Pesticide Control Act (Li *et al.*, 1976a) which was promulgated and implemented by the Central Government and which came 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 evaluated under local environmental conditions and after such criteria are found to be satisfactory. On the average, applications for the registration of pesticides number about 70 every year. The Plant Protection Center (PPC) is responsible for residue analysis, for evaluating the safety of these pesticides and for making the necessary recommendations for registration. The procedure for the registration of a pesticide is shown in Fig. 1.

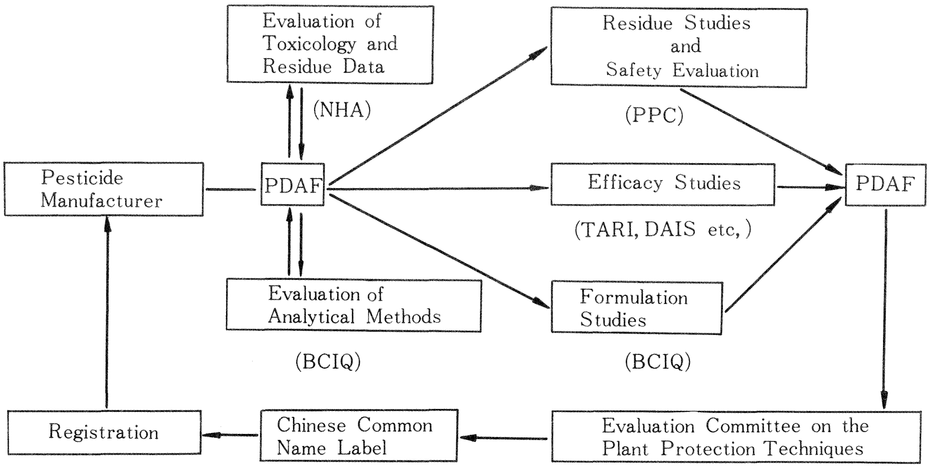

Fig. 1 Procedure for the registration of a pesticide.

MOEA = Ministry of Economic Affairs
MHA = National Health Administration
PPC = Plant Protection Center
PDAF = Provincial Department of Agriculture and Forestry
DAIS = District Agricultural Improvement Station
TARI = Taiwan Agriculture Research Institute
BCIQ = Bureau of Commodity Inspection and Quarantine

Supervised trials have been conducted by the PPC in cooperation with various agricultural research institutes and stations for this purpose. The waiting periods (interval between the last application and harvest) were recommended by the PPC by comparing the residue data from these supervised trials with the maximum tolerable residue limits established for the respective pesticides. These residue limits were derived from the values of acceptable daily intake, toxicological data on individual chemicals, and the daily consumption of crops by Chinese people.

In order to ensure the safety of pesticide residues in edible crops, tolerance level of pesticides for each group of crops has been established, based on the 1) actual amount of residues found for each group of crops resulting from the application of pesticides under recommended rates, 2) values of acceptable daily intake of the pesticides, 3) daily consumption of each group of crops per person.

MPI (maximum permissible intake) of a pesticide by Chinese people was calculated from the ADI, and all the crops were classified into sixteen groups (Table 1). The MPI for a pesticide was distributed among the sixteen crop groups based on the daily consumption of each crop group (Table 2) and designated as sub-MPI (Table 3).

Table 1 Crop group classification for tolerance establishment.

1. Rice. Penglai rice, Tsailai rice, Glue 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, Radish, Carrot, Bamboo shoot, Water oat, Onion, Ginger, Taro.
7. Fruiting vegetables: Cauliflower, Eggplant, Green pepper, Tomato, Mushroom.
8. Cucurbit vegetables: Oriental pickling melon, Cucumber, Wax gourd, Rag gourd.
9. Seed and pod vegetables: Kidney bean, Fresh soybean, Stringbean, Pea.
10. Cucurbit fruits. Water melon, Yellow melon.
11. Berries: Grape, Papaya, Guava, Persimmon, Wax-apple, Banana, Pineapple.
12. Stone fruits: Longan, Mango, Lychee
13. Pome fruits: Apple, Pear, Loquat.
14. Citrus fruits. Orange, Tangerine, Grapefruits, Pomelo, Lemon.
15. Sugarcane
16. Dried beans and peas: Red bean, Soybean, Mungbean, Peanut.
17. Special crops. Tea, Tobacco.

Table 2 Daily consumption of each crop group per person.

Crop group	Daily consumption per person (kg)	Percentage of 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. Sugarcane	0.0176	2.55
16. Dried beans and peas	0.0075	1.09

Table 3 Sub-MPI values of carbofuran on different crops.

Crop group	Percentage of 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 and 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. Sugarcane	2.55	0.0128
16. Dried beans and peas	1.09	0.0055

ADI of carbofuran = 0.01 mg/kg b.w./day
MPI of carbofuran = 0.5 mg/person/day

Tolerance levels were set for each group of crops in accordance with the actual amount of residues present at harvest time. However, these values were always set below the sub-MPI value for the respective pesticides in each crop grouping. If necessary, sometimes tolerance was set at a higher level than the sub-MPI values, but the total number of crop groups for which a pesticide was registered was limited by the MPI value. In other words the total actual amount of residues of a pesticide on the crop groups for which a pesticide had been registered could never exceed the established MPI value.

By using the above method, tolerance levels for 75 pesticides in different crop groups have been established (as shown in Table 4) (Li *et al.*, 1981d).

Screening of pesticides for mutagenicity in the microbial systems has also been conducted in this country for the assessment of the safety of pesticides.

Eighty pesticides (including 23 fungicides, 13 herbicides and 44 insecticides) and 3 pesticide metabolites were studied to determine their capacity of inducing mutations in using the Salmonella/mammalian-microsome mutagenicity test 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 did not change in the presence of liver microsomal fraction; 2) the nematocide – DBCP was mutagenic on both strains TA100 and TA98, and the mutagenic capacity was increased in the presence of liver microsomal fraction after pre-incubation; 3) the fungicide – Zincofol was mutagenic on strain TA100, and the mutagenic capacity was decreased in the presence of liver microsomal fraction (Jeang *et al.*, 1980).

Further studies are underway to combine this assay with other short-term mutagenicity tests as a battery of tests to run for the pesticides applied for registration in Taiwan.

Since paddy fields account for 60% of the cultivated land in Taiwan, it is assumed that the water in the fields is the major source of pesticide contamination of river water. Therefore the

Table 4 Tolerance of pesticides for different crop groups as proposed by Plant Protection Center.

Pesticide	Tolerance (ppm)	Crop grouping #
Acephate	0.1	1
	2.5*	4
	0.5	13
Aldicarb	0.05	14
	0.07	6, 16
	0.15*	11
Azinphos-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
Acifluorfen	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
Cyanofenphos	0.25	4
	0.2	1
Cypermethrin	0.5	4
Captafol	0.5	12
Chlorothalonil	0.5	4, 11, 16
Alloxydim-sodium	0.5	16
Decamethrin	0.3*	4
Dialifos	0.2*	1
	0.02	11
Diazinon	1.0*	13
	0.05	1
Buthiobate	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

Pesticide	Tolerance (ppm)	Crop grouping #
Ethirimol	0.1	8, 12
Endosulfan	0.5	4
	0.1	6
Etrimfos	0.01	11
Ethofumesate	0.1	16
Fenvalerate	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
Fosthietan	0.2	1
Hexachlorophene	0.1	7
Isoprothiolane	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
MTMC	0.5	1
MIMC	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
Pirimiphos-ethyl	0.03*	7
Pyridaphenthion	0.2	1
	0.1	

Pesticide	Tolerance (ppm)	Crop grouping #
Pirimiphos-methyl	0.8*	1
Phosmet	0.1	1, 5
Fthalide	0.1	1
Metalaxyl	0.1	3
Thiocyclam 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
Fenbutatin oxide	1	13
Procymidone	1.5	8, 10
Profenofos	0.1*	4
Propineb	0.5	10

Crop groupings, see Table 1.
* Indicates that the value is higher than sub-MPI.

acute toxicity of pesticides used in the fields has attracted much attention. By comparing acute fish toxicity of pesticides expressed by the Median Tolerance Limit (TLM) to pesticides of *Tilapia* sp., with the maximum residue levels of pesticides in field water obtained by the methods recommended by the government, it was possible to determine the level at which a particular application method is toxic to fish. By employing this rating method, 10 pesticides commonly used were evaluated. Among these, endosulfan and phenthoate were not suitable for use in paddy fields; the dosage of benthiocarb and butachlor for field application should be restricted to the dosage recommended by the government, while the dosage for field application of diazinon, BPMC, cyanofenphos, carbaryl, oxadiazon was considered safe (Li *et al.*, 1981a).

Acute toxicity of pesticides to the natural enemies of insect pests was also studied (Ku *et al.*, 1981). Special attention has been paid to the natural enemies of the brown planthopper and green rice leafhopper – the mirid bug (*Cyrtorhinus lividipennis* Renter) and wolf spider (*Lycosa pseudoannulata* Boesenberg and Stand). Judging from the capacity to effectively control these rice insect pests while at the same time protecting the natural enemies, MTMC showed the highest selectivity, followed by undan and carbaryl. These data are useful for the implementation of integrated control of rice pests. Further studies related to these areas will be carried out on the braconid, a natural enemy of the diamond back moth; lady beetles, natural enemies of the citrus mealy bug and citrus spider mites; phytophagous mites, natural enemies of strawberry spider mites; trichogrammatids, natural enemies of the European corn borers and sugarcane borers; parasitic chalcids, natural enemies of the soybean miner; green lacewings, natural enemies of the mulberry psyllid, etc. (Anon., 1982).

Studies on persistent pesticide residues in food and environment

1 Organochlorine insecticides

Although the use of organochlorine insecticides, such as aldrin, dieldrin, BHC, heptachlor and DDT for agricultural purposes has been banned in Taiwan since 1973, 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 PPC 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 (Ku, 1976), the levels were rather low, mostly within the ppb range. Relatively high residue levels in the eggs of ducks raised in river water (Ku, 1976), 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 in the uppermost five inches, second five inches, and third five inches of the soil were analysed and results were as follows: lindane – 11.8, 4.7, 2.8 ppb; heptachlor – 1.2, 0.5, 0.4 ppb; heptachlor epoxide – 2.1, 2.1, 0.6 ppb; aldrin – 11.3, 1.6 ppb; 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 (Li *et al.*, 1974a).

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 fish (Jeng *et al.*, 1974).

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 tolerance levels set by the U.S. Food and Drug Administration (Li *et al.*, 1975).

Surveys of residual levels of chlorinated hydrocarbon insecticides in human milk were also carried out. Results are summarized in Table 5. There was no correlation between the residual

Table 5 Residual levels of chlorinated hydrocarbon insecticides in the fat of human milk samples.

Pesticide	No. of samples analysed	% of positive samples	Average residue levels (ppm)	Range of detected residues (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	3.090000	0.56–15.71

levels and the age or 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 average arsenic content in paddy soil was found to be 8.22 ppm in the uppermost 5 inches, 14.07 ppm in the second 5 inches, and 18.85 ppm in the third 5 inches (Li *et al.*, 1980d). Further studies on the uptake of arsenic from soil by rice plants revealed that the arsenic residues in the soil were translocated to the rice plants. The amounts of arsenic found in the different portions of the rice plant were in the following order: root > rice straw > grains (Li *et al.*, 1979b). The residual levels in 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 gave rise to higher levels of arsenic residues in rough rice than As_2O_3 (arsenic trioxide) and $3As_2O_5 \cdot 5H_2O$ (arsenic pentoxide).

A marked increase in the number of empty rice grains resulted from the incorporation in the soil of arsenic compounds (Li *et al.* 1979b). The number of effective tillers, plant height and weight and the collective weight of 1,000 grains of rice also decreased with the increase in the levels of soil arsenic residues (Li *et al.*, 1979b).

The analyses of rice grain samples collected from 86 townships in Taiwan during 1975 revealed that about 95% of the samples analysed contained detectable amounts of arsenic. The arsenic levels in the grains of the second crop of rice were higher than those from the first crop of rice. The townships from which the rice grain samples with high arsenic levels (> 0.76 ppm) were collected, were geographically widely distributed. Among the 86 townships, samples taken from 34 of them were found to contain high arsenic levels (Li *et al.*, 1979c).

3. **Mercurials**

In 1972, paddy soil samples collected from different localities throughout Taiwan were analysed for total mercury content. It was found that the mercury content of these samples averaged 0.22 ppm in the uppermost 5 inches of soil, 0.15 ppm in the second 5 inches, and 0.10 0.10 ppm in the third 5 inches (Li *et al.*, 1974b). The differences in mercury levels among 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 (Li *et al.*, 1976b).

Residues of currently used pesticides

Residues of currently 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 localities in Taiwan at the time when rice was being harvested or close to harvest showed that in the uppermost 15 cm of soil 44.1% of the samples contained benthiocarb, 10.3% contained butachlor, and 17.6% contained chloromethoxynil. The average residual levels were 0.057, 0.004 and 0.006 ppm, respectively. Fifteen out of 17 water samples from different localities in Taiwan contained benthiocarb. The average residual levels were within the ppb range. No residues of butachlor and chloromethoxynil were found in the water samples (Li, *et al.*, 1982b).

Model ecosystem

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

The behavior of carbofuran was studied under these conditions. Results indicated that carbofuran applied into soil under flooded conditions disappeared faster than when applied to soil without flooding.

Carbofuran was degraded in the soil much more slowly when applied 14 days before flooding than when applied under flooded conditions (Li *et al.,* 1980c).

When carbofuran was applied onto soil with different water contents, the residual level in the seedlings decreased in the following order: saturated $\gg$ field capacity $>$ flooded. When applied on soil with water content corresponding to field capacity, carbofuran level reached a peak in rice approximately five days after application and was degraded after irrigation while it took about 20 days for its two metabolites, 3-keto and 3-hydroxycarbofuran to reach a peak. In contrast it took 10 days for carbofuran levels to reach a peak in rice when applied to fields saturated and flooded with water (Li *et al.,* 1980c).

Comparison of the amount of residues in mosquito fish and in the water of the model ecosystem, showed 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 metabolites (Li *et al.*, 1980c).

Studies on the distribution of benthiocarb [S-(4-chlorobenzyl)-N, N-diethyl thiocarbamate] after soil application to the paddy model ecosystem were also carried out. Most of the benthiocarb residues were found in the soil and very small amounts were detected in 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 residues were found in rice straws, 0.06 and 0.127 ppm in unpolished rice, and 0.44 and 15.05 ppm in the soils within zero to five centimeter depth, respectively (Li *et al.,* 1979a).

No adverse effect of residual benthiocarb on the growth of broccoli, radish, and rape was observed. These vegetables were planted in the same field after rice was harvested (Li *et al.,* 1979a).

The rate of disappearance of Ronstar (oxadiazon) in three different soils was studied (Li *et al.,* 1980a). The results indicated that after 144 days, 73.1 to 96% of the initial amounts of ronstar applied still remained in the soil. The rate of disappearance of Ronstar in soil with high clay content was slightly faster than that in soil with low clay content (Li *et al.*, 1980a).

Toxicity of pesticides to non target crops

Since intensive agricultural systems have been adopted in Taiwan, in a field, not only three crops per year, but also a variety of crops make the pattern of crop growing much more complex than in other countries. Attention has therefore been paid to the effect of pesticides on the non target crops.

These studies can be classified into several categories, 1) direct effects caused by inappropriate use of pesticides, 2) injury caused by pesticide pollution of irrigation water, 3) injury caused by pesticide-polluted soil, 4) reduction of growth resulting from the effect of pesticides on the soil microorganisms.

Direct injury of pesticides to non target crops was evaluated in glasshouse under controlled conditions (Li *et al.,* 1982a). If injury of non target crops was found after treating the crops at application rates three times higher than the normal recommended rates, dosage-response curve studies were carried out.

In order to evaluate the effect of pesticide pollution of irrigation water on the growth of non target crops, bioassay methods were applied (Li *et al.,* 1981b). Three bioassay methods, root bioassay, shoot bioassay and water culture were used for this study. In water culture, the root growth of the crop responded significantly to the various pesticides tested.

In studying the effects of the most commonly used pesticides in rice fields on the growth of radish, muskmelon, pea, mustard and cucumber, equations expressing the relationship between the concentration of pesticides in water and growth inhibition of crops were derived. By calculating the maximum residue limit of the pesticides in the paddy water according to the recommended rate of application and substituting the residual value for the above equations, it was possible to determine the effect of pesticides on non target crops before the pesticides were recommended for field use (Li *et al.,* 1982a).

Attention has also been paid to the injury of non target crops caused by pesticide-polluted soils. The evaluation of phytotoxicity of pesticide residues in soil was conducted under simulated natural conditions. One hundred and two days after soil application of benthiocarb (10% granule at 30 and 60 kg/ha), vegetables were planted in the field after rice was harvested, and no adverse effect of residual benthiocarb on the growth of broccoli, radish, and rape was detected. However, laboratory experiments showed that when benthiocarb residues 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 was observed (Li *et al.,* 1979a).

In a country such as Taiwan, where pesticides are heavily used, much attention has to be paid to the effect of pesticide residues in soil on the soil microorganisms. Special consideration has been given to the effect of pesticides on the ammonification and nitrification processes in the soil.

When the herbicides Saturn, Machete and Tok were applied to soils which had been pretreated with $(NH_4)_2SO_4$, it was found that the three herbicides were at a relatively low concentration in soil (Saturn 10 μg/g; Tok 10 μg/g; Machete 25 μg/g). They had almost no effect on the production of NO_3^--N in the soil, while at higher concentrations (Saturn > 25 μg/g; Tok> 100 μg/g; Machete > 100 μg/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 of NH_4^+-N in the soil even at low concentrations (Machete 25 μg/g; Saturn 10 μg/g; Tok 10 μg/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.

No detectable amounts of NO_2^--N were found in the soils subjected to any of the treatments (Li *et al.,* 1980b).

Similar studies have been carried out at the PPC, to evaluate the effect of insecticides and fungicides on the soil microorganisms.

Conclusion

Pesticides play a very important role in modern agriculture. The use of pesticides has increased rapidly in recent years. Although toxicological data of most pesticides have been documented before pesticides are being marketed, toxic effects are always modified or enhanced depending on the application methods in various agricultural systems. The side-effects of pesticides therefore have to be considered based on their use and on the agricultural system to which a particular pesticide is applied.

In Taiwan, emphasis is placed on the acute toxicity of pesticides to fish and predators of insect pests, mutagenicity of pesticides, residues on food crops, potential to pollute the environment, effect on the growth of non target crops, and on the soil microorganisms.

References

1) ANONYMOUS (1982): Report for Evaluation Committee of Plant Protection Techniques.
2) JEANG, C.L. and LI, G.C. (1980): Screening of pesticides for mutagenicity in the microbial system. II. Mammalian microsomal activation. *Natl. Sci. Counc. Monthly,* R.O.C. **8**, 551–559.
3) JENG, S.S. and SUN, L.T. (1974): Residues of chlorinated hydrocarbon insecticides in fishes. *Bull. Inst. Zool.,* Academia Sinica **13**, 37–45.

4) KU, T.Y. (1976): Chlorinated hydrocarbon insecticide residues in the agriculture environment of Taiwan. PPC.
5) KU, T.Y. and WANG, S.C. (1981): Resistance of the major rice insect pests with the effect of insecticides on the natural enemies and non-target animals. *Phytopathologist and Entomologist,* NTU **8**, 1–17.
6) LI, G.C. and LEE, Y.S. (1974a): Residual levels of some chlorinated hydrocarbon insecticides in the paddy soils of Taiwan. *Plant Prot. Bull.* Taiwan. **15**, 163–169.
7) LI, G.C., LEE, Y.S. and LIU, S.T. (1974b): Residual mercury levels in the paddy soils of Taiwan. *Plant Prot. Bull.* Taiwan. **15**, 170–174.
8) LI, G.C., CHIANG, S.H., KAO, P.Y. and LEE. Y.S. (1975): Residual levels of chlorinated hydrocarbon insecticides in pork samples. Prelim. Rept. No. 3, PPC.
9) LI, G.C. and LIAO, L.S. (1976a): Pesticide regulation in Taiwan. Paper presented at the Seminar on "Impact of pesticide Law Conference", Honolulu.
10) LI, G.C., HUNG, C.Y. and HU, K.J. (1976b): The relationship between the residual levels of mercury in compost and that in mushrooms. Proceedings of the 5th Symposium of Mushroom Research, 449–454.
11) LI, G.C. and KANG, P.H. (1979a): Study on the distribution of benthiocarb in paddy model ecosystem and its effect on the growth of inter-crops of rice. *Plant Prot. Bull.* Taiwan. **21**, 188–193.
12) LI, G.C. FEI, W.C. and YEN, Y.P. (1979b): Survey of arsenic residual levels in rice grains from various locations in Taiwan. *Natl. Sci. Counc. Monthly* R.O.C. **7**, 700–706.
13) LI, G.C., FEI, W.C. and YEN, Y.P. (1979c): Survey of arsenical residual levels in the rice paddy soil and water samples from different locations of Taiwan. *Natl. Sci. Counc. Monthly* **7**, 798–809.
14) LI, G.C. and WONG, S.S. (1980a): The rate of degradation of Ronstar in three different types of soils. *Weed Sci. Bull.* **1**, 52–59.
15) LI, G.C. and CHEN, C.Y. (1980b): The effect of three herbicides on the ammonification and nitrification in the soil. *Natl. Sci. Counc. Monthly* R.O.C. **8**, 913–920.
16) LI, G.C. and WONG, S.S. (1980c): Distribution and degradation of carbofuran in a rice paddy model ecosystem. *Plant Prot. Bull.* Taiwan. **22**, 337–345.
17) LI, G.C, and FEI, W.C. (1980d): The relationship between arsenicals in the soil and the rice growth and the arsenic residues in rice. *Plant Prot. Bull.* Taiwan. **22**, 101–112.
18) LI, G.C. and CHEN, C.Y. (1981a): A study on the acute fish toxicities of commonly used pesticides. *Natl. Sci. Counc. Monthly* R.O.C. **9**, 146–152.
19) LI, G.C. and Lee, Y.H. (1981b): The effect of pesticides used in rice fields on the growth of other crops. *Natl. Sci. Counc. Monthly* R.O.C. **9**, 495–506.
20) LI, G.C., FANAGAN, M. and WU, L.J. (1981c): Residual levels of chlorinated hydrocarbon insecticides in the milk of Taiwanese women, (unpublished data).
21) LI, G.C., WONG, S.S. and JEANG, C.L. (1981d): The establishment of pesticide tolerance levels for the edible crops in Taiwan. *Sci. Agri.* Taiwan. **29**, 211–221.
22) LI, G.C. and LEE, Y.H. (1982a): Toxicity of pesticides to non-target crops, (unpublished data).
23) LI, G.C. and LEE, T.L. (1982b): Residual levels of three herbicides in the soil and water samples from different localities of Taiwan, (unpublished data).

Discussion

Pieters, A.J. (FAO/WHO): Could you explain why the content of As in rice and soil is so high. Is it due to pesticide use or natural causes?

Answer: The high level of As recorded is due to natural causes since we observed that the deeper the soil layers sampled, the higher the As content.

Ishikura, H. (Japan): If I recall, I believe that lead arsenate has been used for a long time in Taiwan for the control of pest orchards. Don't you have any problem of residual toxicity of arsenic for intercropped crops?

Answer: Lead arsenate has not been used for pest control in Taiwan since many years. It is possible that some residual effect may have persisted in soil. Presently we are worried about the effect of prolonged use of herbicides on the soil properties of orchards.

Lim, T.M. (Malaysia): Based on the excellent model system for detecting and monitoring the residue and toxicity problems of pesticides in Taiwan which you presented, I would like to know whether the same system could be adopted without too much cost or institutional constraints by other developing countries in the tropics?

Answer: I believe that the general concept for detecting and monitoring residues and toxicity problems of pesticides in Taiwan could be adopted by other tropical countries without major financial constraints. However, some modifications would have to be made depending on the environmental conditions and pattern of use of pesticides in the respective countries.

Snelson, J.T. (Australia): You illustrated the use of a glasshouse to conduct phytotoxicity tests. Do you find that the results of glasshouse tests for phytotoxicity can be translated in the field and that the results have a relevance to the field conditions in the tropics?

Answer: We only use the glasshouse for screening pesticides so as to select the ones that might be candidates for field studies. Without such screening, we would not be able to test every chemical under field conditions to determine which one will give rise to damage in crop rotation, recycling of irrigation water, etc.