CONFERENCE ON THE
ECOLOGICAL ASPECTS OF
INTERNATIONAL DEVELOPMENT
AIRLIE HOUSE, WARRENTON, VA. DEC. 9-11, 1968

Title: Toxicity of Insecticides Used for Asiatic Rice Borer Control to Tropical Fish in the Rice Paddies

Author: L. T. Kok*

IMPORTANCE OF FISH CULTURE IN RICE PADDIES OF ASIA

Rice and fish are staple foods in the south east Asian countries and farmers often raise fish in rice fields to supplement their income. The combination of fish and rice culture is particularly important in rural areas because fish is a cheap source of protein and is acceptable to people of different ethnic groups. Besides the additional income obtainable with comparatively little extra effort, some benefit can also be derived from the excreta of fish acting as fertilizer for the rice plants. In addition, many of the caterpillars of insect pests are eaten by the fish and the rat problem is reduced because the greater water depth in fields where fish culture is practised prevents rats from digging holes in the bunds.

Countries in the Asian region with fish culture in the rice paddies include Indonesia, Malaysia, Pakistan, Taiwan, India and Vietnam, with substantial acreages in the first three, (Table 1). The most common fish species are the common carp (*Cyprinus carpio* Linnaeus), tilapia (*Tilapia mossambica* Peters), tawes (*Puntius javanicus* Bleeker) and sepat siam (*Trichogaster pectoralis* Regan), (Table 2). Stocking of the rice fields with fish fry is common in some countries, namely Indonesia (Simizu 1943), Japan (Hiyama 1949) and Taiwan (Chen 1953). In Malaysia, the natural fish population of sepat siam (*T. pectoralis*), aruan (*Ophiocephalus striatus* Bloch) and sometimes catfish (*Clarias batrachus* Linnaeus) is large (Soong 1948, 49 and 50), and yields of up to 2,800 katies*

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* Lecturer, Faculty of Agriculture,
University of Malaya,
Kuala Lumpur, Malaysia.

* 1 kati : $1\frac{1}{3}$ lb.

have been recorded (Heath 1934). In more recent years, stocking of fish fry in the rice fields of Malaysia has also been introduced in some areas.

Chemical control of rice pests is common in all these countries. Present trend indicates a distinct increase in the use of pesticides in the control of the major insect pests, the most important of which are the lepidopterous rice borers. Some of the popular insecticides used in rice borer control are endrin, dieldrin and r-BHC which are chlorinated hydrocarbons and EPN, methyl parathion, dipterex and diazinon which are organo phosphorus compounds (Table 1). When used as sprays or dusts applied on the leaves, only a part of the insecticides come into direct contact with the fish in the rice paddies. But the introduction of insecticides to the paddy water is fast becoming popular as this method of insecticidal application gives efficient rice borer control (Koshihara and Okamoto 1957; Okamoto 1963; Kok and Pathak 1967; Okamoto et al. 1963; Pathak 1967). With this new technique the entire amount of insecticides comes into contact with the fish. The resulting contamination of the aquatic medium, therefore, raises a serious problem to fish in the rice fields as they are directly exposed to the toxicants and it is imperative that the toxic effects of insecticides to fish be carefully evaluated before any can be advocated for wide usage.

EFFECTS OF PESTICIDES ON FISH IN RICE PADDIES

Although pesticidal effects on temperate fish species have received much attention, such studies in the tropics are very recent. In particular, information regarding toxicity of pesticides to fish in rice paddies is scarce as investigations along such lines have been somewhat neglected.

In Malaysia, this problem first received some attention in 1957 when Wyatt carried out some laboratory tests to study the effects of several chlorinated hydrocarbon insecticides mixed in water in aquaria on aruan (*Ophiocephalus striatus*). The insecticides were toxic to fish at very low concentrations; endrin and dieldrin being more toxic than DDT and r-BHC. The wettable powders of these compounds were significantly less toxic than the emulsifiable concentrates (Wyatt 1957). The high toxicity of r-BHC in water alone to fish was confirmed in laboratory tests but field tests conducted in the rice paddies revealed that tilapia, carp and tawes fishes can tolerate up to 2 kg./ha. active ingredient of a single application of r-BHC (Kok and Pathak 1966).

In the rice paddies of Bengal, the weedicides Brestan-60, copper sulphate and copper oxychloride give good control of algal weeds and were not ~~toxic~~ lethal to fish at the recommended dosages (Mukherji 1968). Results of tests carried out by workers in temperate countries showed that in general, chlorinated hydrocarbon insecticides are much more toxic than organo phosphorus compounds and that herbicides at equivalent rates are ~~harmless~~ non-lethal to fish (Jones 1964). Herbicides, however, are used at much higher concentrations in the control of weeds and may affect fish at the applied dosages.

In view of the scarce information of pesticidal effects on fish in rice paddies and the increasing use of insecticides in south east Asia, investigations were carried out to evaluate the effects of r-BHC and diazinon, currently the most promising insecticides for rice borer control, to fish in the rice paddies. Tests were conducted first in the laboratory with r-BHC as toxicant using glass aquaria containing water alone, then water and soil and later in field fish ponds on the three most common tropical fresh water species of fish in the rice fields (Kok and Pathak 1966). Further field tests to determine the effect of multiple applications of r-BHC and diazinon on fish mortality were based on tilapia, the most sensitive of the three species in the initial series.

LABORATORY TESTS

Laboratory tests were conducted in glass aquaria of 24 x 10 x 12" each being fitted with tubings connected to compressed air-outlets for aeration. Twenty fish were placed in each aquarium tank for at least 24 hours before insecticidal application. Fish mortality was very high in aquaria containing r-BHC in water alone with tilapia and tawes suffering 95 percent mortality at 1.0 ppm. Carp was the most tolerant, with less than 12 percent mortality at this dosage. When a 3 inch layer of soil was placed at the bottom of each aquarium before treatment, mortality at rates below 1.0 ppm. was low (Table 3). This significant reduction in mortality indicated that the soil has a buffering effect on r-BHC, possibly due to adsorption and degradation of the chemical. Subsequent fields tests confirmed this.

FIELD TESTS:

1: EFFECT OF A SINGLE APPLICATION OF r-BHC TO FISH IN PONDS OF 10 cm. DEPTH.

In tests using small one metre tanks of 30 cm. wide corrugated metal sheets in the field, water was maintained at a depth of 10 cm. Fifty fish fingerlings were released in each tank one week before application of the chemical. Fish mortality was less than 5 percent up to 2 kg./ha. r-BHC, but at 3 kg./ha., significantly increased mortalities were found in the test fishes except for carp (Table 3). In terms of probits of mortalities, the fishes showed a 9, 7 and 5-fold increase in tolerance to r-BHC for tilapia, tawes and carp respectively. Biodegradation and volatilization of r-BHC could have resulted in the decreased toxicity of the insecticide in the presence of soil. Raghu and MacRae (1966) showed that r-BHC persisted for about 55 days in flooded soils and that a large proportion of it was degraded by micro-organisms within the first 30 days. A microbial population was set up which could degrade a subsequent application at a much faster rate.

The amount of r-BHC persisting in the soil and irrigation water after 30 days was confirmed to be very small in recent reports (IRRI 1967). This would imply that multiple applications of r-BHC should not adversely affect fish, but if the insecticide is not degraded rapidly enough, the recommended rates of r-BHC for rice borer control at 2 and 3 kg./ha. active ingredient within 30 days (total of 5 kg./ha.) would be highly toxic to fish. This was examined in the subsequent tests.

II: EFFECT OF DOUBLE APPLICATIONS OF r-BHC TO TILAPIA IN PONDS OF 10 cm. DEPTH.

Rice plants were grown in one metre square tanks in the field maintained at 10 cm. depth and tilapia were released in the tanks four weeks after transplanting of the rice seedlings. The first application of 1, 2 and 3 kg./ha. of r-BHC made one week after the introduction of fish showed low mortality except in the 3 kg./ha. treatment. A second application 30 days later at rates of 3, 2 and 1 kg./ha., (total of 4 kg./ha. per treatment) resulted in significantly increased mortalities in all treatments, (Table 4). This clearly confirms that single applications of up to 2 kg./ha. did not harm tilapia, but single applications of 3 kg./ha. and double applications totalling 4 kg./ha. or more would be highly toxic. Plant absorption of r-BHC did not appear to affect the mortality significantly.

III: EFFECT OF DOUBLE APPLICATIONS OF r-BHC TO TILAPIA IN PONDS OF VARYING DEPTHS.

As the concentration of toxicant is affected by depth of water in the rice fields, tests were conducted to study the effect of differences in water level on fish mortality. Rice plants were grown in field fish ponds maintained at the usual range of field water level of 5 to 20 cm. Tilapia were released in ponds of 5 - 10 cm., 10 - 15 cm., 15 - 20 cm., one week before the first application of r-BHC. Control was maintained between 5 - 20 cm.

Fish mortality was less than 10 percent in all treatments after the first application of 2 kg./ha. A second application of r-BHC was made 30 days later, making total insecticidal applications of 4.5 and 5.0 kg./ha. Mortality was slightly lower in the ponds with greatest water depth (15 - 20 cm.) because of the reduced concentration as a result of greater volume of water but this reduction was small when compared to the large increase caused by the additional application of r-BHC (Table 5).

IV: EFFECT OF TRIPLE APPLICATIONS OF r-BHC AND DIAZINON TO TILAPIA IN PONDS OF 10 cm. DEPTH.

Because of the high toxicity of r-BHC to tilapia at concentrations of more than 2 kg./ha., 3 applications of 1.5 kg./ha. of r-BHC or less were applied at 20 day intervals and this was compared with triple applications of diazinon. Treatments were made at 50, 70 and 90 days after transplanting. Two applications of 1.5 kg./ha. of r-BHC caused less than 25 percent mortality, but mortality was doubled when the third application was made. Applications totalling more than 5.0 kg./ha. resulted in more than 65 percent mortality (Table 6).

These results show that plant absorption, soil adsorption, degradation of r-BHC and the lowering of insecticidal concentration due to increased water depth are not sufficient to reduce the toxic effects of multiple applications of r-BHC to tilapia. Hence, multiple applications of this insecticide at rates essential for efficient control of rice borers are toxic to fish.

Diazinon on the other hand was apparently harmless to fish, Even three applications of 2.5 kg./ha., totalling 7.5 kg./ha. did not cause any mortality (Table 6). This shows that diazinon is either of very low toxicity to fish or that it is rapidly degraded in the rice paddies. At these rates, it gives almost as good control of the rice borers as r-BHC and compared to the latter, diazinon is therefore more satisfactory for use in areas where fish culture is common. However, further bioassay tests are necessary to determine the cumulative effects of regular applications of the chemical to fishes as well as to the whole food chain of the ecosystem of the rice paddies. Its cumulative effect in the fishes would be of prime importance and bioassays of diazinon in fish would have to be carefully evaluated before it can be safely advocated for general usage on a national or international scale.

SUMMARY

Application of insecticides into the water to control lepidopterous rice borers has become common in Asia. The resulting contamination of the

aquatic environment necessitates evaluation of the effects of such insecticides to fish. This is essential because of the importance of fish culture in the rice paddies of Asia, especially in Indonesia, Malaysia and Pakistan. Hence, the toxicity of the two most popularly used insecticides for rice borer control, r-BHC and diazinon, was investigated.

In initial tests conducted in aquaria containing water alone, carp (Cyprinus carpio Linnaeus), tawes (Puntius javanicus Bleeker) and tilapia (Tilapia mossambica Peters) suffered high mortalities even at 1.0 ppm. r-BHC. Remarkable reductions in mortalities were obtained when soil was introduced into the aquaria, and in field fish ponds with a water level of 10 cm. deep, the test species could tolerate up to 2 kg./ha. active ingredient of a single application of r-BHC. Further tests conducted on tilapia in rice fields revealed that multiple applications of r-BHC were toxic to fish, and differences in field water level had little effect on the mortality rate for single applications of 2 kg. per hectare of r-BHC. Mortality, however, was slightly lower in fields with greater water depth for double applications. This reduction was small compared to the large increase in mortality rate as a result of multiple applications. These results indicate that plant absorption, soil adsorption, degradation of r-BHC and the lowering of the insecticidal concentration due to increased water depth, are not sufficient to reduce the toxic effects of multiple applications of r-BHC to fish. Compared to r-BHC, diazinon was far less toxic to tilapia. Even with three applications of 2.5 kg. per hectare, fish mortality was negligibly low, suggesting that diazinon is either of very low toxicity to fish or that it is degraded rapidly in rice paddies. At these rates, it is almost equal to r-BHC in effectiveness for the control of the rice borers.

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Table 1: Insecticides commonly used for rice borer control in countries with fish culture in rice paddies.

Country	Wet rice fields in hectares* Without fish culture	With fish culture	% Area with fish culture	Insecticides commonly used against borers
Indonesia	4,500,000	67,000	1.5	Endrin, methyl parathion
Malaya	314,500	45,500	14.5	Dieldrin, r-BHC dipterex, diazinon
Pakistan	43,400	12,000	27.6	Methyl parathion, diazinon, endrin, r-BHC EPN
Japan	2,991,100	8,500	0.3	Methyl parathion, dipterex, diazinon
Taiwan	520,000	8,000	1.5	Endrin, parathion
India	5,762,792	1,619	0.03	r-BHC, EPN, (Methyl parathion)
Vietnam	4,067,990	1,550	0.04	Endrin, diazinon, dipterex

*FAO Fisheries Biology Technical Paper No.14, 1962.

Table 2: Species of fish common in the rice paddies of Asia

Common name	Scientific name	Distribution	Country of major importance
Common carp	Cyprinus carpio	China, Japan, Vietnam, Thailand, Ceylon, India, Philippines, Malaysia, Indonesia.	Indonesia, Japan, Vietnam.
Tilapia	Tilapia mossambica	Africa, Indonesia, Malaysia, Philippines, Thailand, Ceylon, Pakistan and India.	Indonesia, Malaysia, Taiwan, Thailand.
Tawes	Puntius javanicus	Indonesia, Thailand, Vietnam, Malaysia, Philippines, Ceylon.	Indonesia.
Sepat siam	Trichogaster pectoralis	Thailand, Cambodia, Vietnam, Malaysia, Indonesia, East Pakistan, Ceylon.	Malaysia.
Catla	Catla catla	West Pakistan, India, East Pakistan, Burma, Ceylon.	India, Pakistan.
Cat fish	Clarias batrachus	India, Ceylon, East Pakistan, Burma, Malaysia, Thailand, Cambodia, Vietnam, Indonesia, Philippines.	Malaysia
Aruan	Ophiocephalus striatus	India, Ceylon, China, Indonesia, Malaysia Philippines.	Malaysia

Table 3: Toxicity of r-BHC to fresh-water fish in laboratory and field experiments

% Mortality* in:	Aquaria containing						Field fishponds		
Dosage (PPM)	Water alone			Water and soil					
	Tawes	Tilapia	Carp	Tawes	Tilapia	Carp	Tawes	Tilapia	Carp
0.25	7.50	34.00	1.25						
.50	30.00	57.00	2.50	3.30	0.00				
.75	87.50	78.00	5.0						
1.00	96.25	97.00	11.25	26.70	3.30	6.70	1.00	0.00	0.00
1.50					13.30	26.70			
2.00	100.00	100.00	77.5	60.00	100.00	30.00	3.50	1.50	.50
3.00							47.50	51.50	.50
4.00			98.75	100.00		46.70	56.50	84.0	7.50
Control	0.00	0.00	1.25	0.00	0.0	0.0	0.0	0.0	0.0

Size of test fish : 2 - 4"

* Average of 4 replications

Table 4: Effect of double applications of r-BHC to tilapia in field fish ponds of 10 cm depth.

Treatment: kg/ha 1st : 2nd Appl.	Total insecticide kg/ha	% Mortality* 1st Appl.	2nd Appl.
r-BHC : 3.0 : 1.0	4.0	82.6	82.6
r-BHC : 2.0 : 2.0	4.0	6.6	70.0
r-BHC : 1.0 : 3.0	4.0	0	85.0
CONTROL : 0	0.0	0	0

Size of test fish : 4-6"

* Average of 4 replications

Table 5: Effect of double applications of r-BHC to tilapia in field fishponds of varying depths.

Treatment kg/ha 1st : 2nd Appl.	Depth of pond	Total insecticide kg/ha	% Mortality* 1st Appl.	2nd Appl.
r-BHC: 2 : 2.5	5 - 10	4.5	10.0	68.0
r-BHC: 2 : 3.0	5 - 10	5.0	1.3	83.8
r-BHC: 2 : 2.5	10 - 15	4.5	3.8	77.5
r-BHC: 2 : 3.0	10 - 15	5.0	0.0	91.3
r-BHC: 2 : 2.5	15 - 20	4.5	6.3	51.3
r-BHC: 2 : 3.0	15 - 20	5.0	1.3	67.5
CONTROL: 0	50 - 10	0	0	0
CONTROL: 0	10 - 20	0	0	0

Size of test fish : 4 - 6"

* Average of 4 replications

Table 6: Effect of triple applications of r-BHC and diazinon to tilapia in field fishponds of 10 cm depth.

Treatment kg/ha 1st : 2nd : 3rd Appl.	Total insecticide kg/ha	% Mortality* 1st	 2nd	 3rd Appl.
r-BHC: 1.0 : 1.5 :1.5	4.0	1.4	1.4	37.3
r-BHC: 1.5 : 1.5 :1.5	4.5	16.0	21.4	48.7
r-BHC: 1.5 : 1.5 :2.0	5.0	18.0	23.6	65.3
r-BHC: 2.0 : 2.0 :2.0	6.0	18.7	57.5	85.0
Diazinon:1.5 : 1.5: 1.5	4.5	1.4	1.4	1.4
Diazinon:2.0 : 2.0: 2.0	6.0	1.4	1.4	1.4
Diazinon:2.5 : 2.5: 2.5	7.5	0	0	0
CONTRO: 0 : 0 : 0	0	2.0	2.0	2.0

Size of test fish : 6-8"

* Average of 4 replications