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Toxicity of Agricultural Pesticide Applications to Several Mosquito Species in South Korean Rice Fields

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Abstract

A study carried out in rural areas of South Korea has revealed that farmer pesticide applications of fenitrothion, fenthion and certain other organophosphorus materials are highly toxic to mosquito larvae. The rates of application (0.3 to 0.9 kg/ha), although not highly residual, are from 4 to 8 times higher than those required for *Cu. tritaeniorhynchus* control. The commonly used knapsack sprayer provides very thorough coverage on small ($\leq$ 1 ha) farmer plots. Application by power equipment and helicopters also provides excellent larval control. In comparison to previous years, the marked increase in pesticide usage may be a partial explanation for the much lower incidence of Japanese encephalitis in rural area.

Introduction

Many Korean rice farmers now apply insecticide three to six times during the short growing season to control stem borers, plant hoppers and other pest insects. During 1969 and 1970, the quantities applied to rice fields more than

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doubled over previous years. Korea is striving for self-sufficiency in rice by increasing yields on existing paddy acreage (about 60% of arable land), rather than extending to new areas which is not a practical alternative on a developing, densely populated, mountainous peninsula where other important food crops are also grown. Although Surtees (1970) recently cited a number of world-wide examples in which rice field development profoundly influenced mosquito-borne diseases, JEVRU-Korea found high larval populations of *Cu. tritaeniorhynchus* only in marshes and other non-rice-growing localities in 1970.

Korean rice fields total about 1.2 million ha and are normally treated by means of lever-operated knapsack sprayers, of which it is estimated there are approximately 200,000 in Korea. Power-driven knapsack sprayers (about 12,000) are slowly becoming more available, and some helicopter applications are now routinely made in late August and early September. The main purpose of this report is to clarify whether these treatments are capable of killing to mosquito larvae in the rice fields. The information obtained could be useful for interpreting existing biological data on suspected vector mosquitos as well as provide data on their control.

Description of experiments

Farmer knapsack applications

The formulations and rates of application were determined by on-the-spot observations. No prior contacts were made to influence normal farmer practices. Emulsifiable concentrates of fenthion, fenitrothion and Cidial, all marketed in 100-ml quantities, were commonly applied. Other organo-phosphorus materials encountered were diazinon, EPN and sometimes methyl parathion.

In June and July 1970, 13 treatments were observed and evaluated for their effect on mosquito larvae at Paju (32 km north of Seoul) and 10 at Sintaein (202 km south of Seoul). Sintaein is located in the rice belt plain of Cholla Pukdo Province, where more cases (5295) of Japanese encephalitis were reported than in any other province from 1955–1966 (Kono and Kim, 1969). These treatments included two hand granular applications of gamma-HCH and two power knapsack treatments with fenthion and Cidial.

In June, the height of the rice in the treated plots at Paju averaged 40 cm and the water depth averaged 15 cm. Comparable figures for July were 60 cm and 11 cm. The average plot size was 0.16 ha. At Sintaein, the rice height and water depth for June averaged 35 cm and 17 cm, respectively, and in July they were 75 cm and 7 cm. The Sintaein plots averaged 1.5 ha, being 10 times larger than at Paju. In both areas taller rice was associated with lower water depth, and this trend continued into August and September.

The lever-operated knapsacks normally held 16 *l* of 0.1 % solutions (range 0.04 –0.5 %), and discharged about 325 *l* (range 250–400) per ha. It will be seen

that these dosages of organo-phosphorus compounds (average of 0.25 kg/ha) were much higher than those required for control of culicine mosquitos. These sprayers had at least three nozzles and, with the outstretched arm, about 2.5 m were treated to each side of the sprayman. Over 20 knapsack applications were required to cover the Sintaein plots, and this provided good opportunities for calculating application rates. Although the fields were measured, the farmers themselves were well aware of plot sizes in which case 1 pyong was equal to 3.3 m^2. Farm families are limited to 3 ha of paddy field; the average size being 0.9 ha.

The power knapsacks held only 10 *l*, of which all was discharged in five minutes; nevertheless their area coverage was faster than with the intermittent manual sprayers, and they treated 1 ha in about three hours. With hand granular applications, one man treated about 3 ha per day.

Assessment techniques for mosquito numbers consisted of larval dipping before and after the area was treated, and bioassay tests of the treated water in which larvae were subsequently exposed. Pre-treatment dipping was commenced in untreated sections before applications were completed and post-treatment dipping was made in random sections of the entire plot the day after treatment. The larval counts attempted during the process of treatment were often negative or too low for adequate evaluation. Assessments made on the next day, when about two man-hours were spent searching for living and dead larvae, were more meaningful.

The bio-assay method was used to ascertain whether the absence of larval populations after treatment was associated with water toxic to mosquito larvae. An open-end cylindrical cage of thin mesh netting was secured to a wire frame (12 cm long, diameter 10 cm) and then tied to thin wooden stakes pushed into the ground. Late-instar larvae of field-collected *Cu. pipiens*, and sometimes *Ae. tegoi*, were introduced and left for 24 hours before the percentage mortality was determined. These vigorous susceptible larvae were obtained from non-rice-growing localities free of insecticide. About two to three cages totalling 100 or more larvae were placed in the treated fields within two hours after treatment or on the next day. Controls in untreated water, run simultaneously, showed mortalities below 10%.

Extensive insecticide-susceptibility tests had been carried out with the two species used for bio-assay, as well as other species such as *Cu. tritaeniorhynchus* and *An. sinensis*. Except for *An. sinensis*, most species appeared to be normally susceptible to organo-phosphorus compounds such as fenthion, fenitrothion, Cidial, and EPN. While details of these tests will be given in a future report, the reader can refer to the WHO Information Circular on Insecticide Resistance for many of the test results obtained in 1970.

Experimental knapsack applications

The objectives here were to determine the approximate minimum dosages required for control of the mosquito larvae and to obtain other data to support farmer evaluations. Fenitrothion emulsion concentrate, the most popular rice pesticide

in Korea, was applied at various application rates to experimental plots at the field station of the Office of Rural Development (ORD) located at Suwon, 30 km south of Seoul. These treatments were applied in early September to tall rice (95–105 cm) with seedheads, and thus spray penetration would appear to be less adequate than in the tests made earlier in the season. However, it should be noted that more liquid is applied to the late-season rice partly because the spraymen have to walk through the densely vegetated and muddy fields at slower speeds.

The plots at Suwon measured 0.005 to 0.025 ha, and spray solutions from 0.0025 % to 0.037% were applied at rates of 400 to 2000 *l*/ha. The water depth varied from 2 to 8 cm. Mosquito larvae, grasshoppers and other insects were found to be fairly abundant because insecticides had not been recently used. Assessment techniques consisted of larval dipping and bio-assay as previously described. Within two hours after treatment, numerous swallows were observed feeding on the dying insects ; when one of us (D.H.B.) fed these insects to baby birds, they were found to be lethal.

Further tests were made at Sintaein in late September, applying several organophosphorus pesticides at 0.1 kg/ha (average water depth 5 cm). About 5 *l* of 0.005% solutions were applied to plots of 0.0025 ha. Comparative tests with malathion and Cidial also were made to similar sized plots having water depths of 2.5 cm.

At Sintaein, the rice also was tall (100 cm) and near maturity, but culicine larvae were absent. However bio-assay tests provided some information on penetration through foliage and on the comparative mortality with different treatments. In addition to *Cu. pipiens*, *Cu. tritaeniorhynchus* and *An. sinensis* were also exposed.

Helicopter applications

About 10,000 ha (38.6 mi^2) were treated with fenthion and fenitrothion in 1970, under the sponsorship of the Ministry of Agriculture and Forestry, and the technical guidance of the Office of Rural Development. The applications of fenitrothion e.c. to 1496 ha (5.8 mi^2) located in a coastal area of Cholla Pukdo province in Kwang Hwal and Jin Bong Myons (190 km southwest of Seoul) are reported here. These treatments were applied on four days between 28 August and 3 September, using one helicopter and sometimes two.

These helicopters (280 HP Bell 47G–3–B2) were equipped with a single long boom containing 50 diaphragm nozzles (Spraying Systems Inc.) with D–4 disc-type orifices; in addition they were fitted with a second boom with 12 nozzles. An engine-driven centrifugal pump dispensed insecticide at 50–60 psi through these 62 nozzles, which were directed rearwards.

For each flight the helicopter carried about 3 kg of active ingredient derived from an emulsion concentrate and diluted with 240 *l* of water. This 1.25% fenitrothion emulsion was dispensed over 8 ha in about 45 seconds, while travelling at 96 km/h at heights of 5–8 m. Since two minutes was required to load, and about two minutes to fly to and from the target area, about five minutes was actually required to treat the 8 ha. About 32 flights covered 259 ha (1 mi^2) in about

two hours 45 minutes.

During these applications the wind blew from the north at 16–32 km/h, causing considerable drift, and swaths, which were laid across the wind, were 66 m apart on the average. The dosage delivered (about 0.38 kg/ha) was considered to be low for second-brood stem borers, but nonetheless adequate for mosquito evaluation. Some treatments were made at flight speeds of 64 km/ha using swaths 40 km apart, giving a dosage of 0.94 kg/ha. Based on 40 oil-sensitive dyed cards placed in open footpaths, the average number of droplets was found to be 8.6 per cm^2 and the volume median diameters were estimated to be between 200 and 300 μ. The rice height and water depth averaged 95 cm and 5.0 cm, respectively, and the dosages for the two treatments assessed were calculated to be 0.75 and 1.9 ppm fenitrothion.

Scattered village hamlets and animal shelters dotted this highly rural rice-growing plain. The helicopter pilots did not alter their flight patterns because of these obstacles, but flew up and over them usually without spraying. It was nevertheless considered possible that adult mosquitos resting indoors in these hamlets and shelters would be killed by drifting spray. A typical spray run for an application of 0.38 kg/ha consisted of a 600-m flight west, one turn, and a 600-m flight east. The aircraft landed at points next to an irrigation channel with ample quantities of piped water.

Before and after the treatments, the mosquito populations were sampled by larval dipping, and by collections from light-traps and from cows. The main assessment area was located in and around the village of Eunpar (20 mud houses) which proved to be within 500 m of unsprayed rice fields. In addition, bio-assay cages of larvae and adults were placed in the centre of rice fields and elsewhere including the interior of houses. Limited observations were made in the smaller village of Okpo, which received the higher rate of application. Control mortalities were below 10%. Except for *Cu. pipiens*, many of the mosquitos exposed in bio-assay cages were collected in the sprayed area one or two days before treatment, in which case *An. sinensis* and *Cu. tritaeniorhynchus* were the two most abundant species. *Cu. pipiens* was found to be virtually absent from this area, despite searches for larvae in polluted waters before the treatments were made. Both village areas were treated during the morning hours.

Results

Farmer knapsack applications

The percentage mortality of the mosquitos exposed to the treated water (Table 1) showed no noticeable differences ascribable to month of treatment, locality, height of rice and water depth of application (manual vs. power sprayer), or bio-assay species exposed. The mortalities of the late-instar larvae were consistently above 97% for 21 of the 23 treatments (Table 1). Two of the fenitrothion applications may have been adversely affected by flushing

Table 1. Toxicity of farmer knapsack sprayer applications to mosquito larvae in rice fields at Paju and Sintaein, June–July, 1970.

Insecticide	Recommended dosage kg/ha	No. of applications observed	Observed av. dosage kg/ha (range)	Observed av. dosage ppm[a] (range)	Laboratory LC_{95} value to *Culex pipiens*	Av. bio-assay mortality to 4th instar *Culex* larvae[b]
Fenthion	0.30	7	0.34 (0.17–0.68)	0.35 (0.059–0.88)	0.040	99
Fenitrothion	0.38	4	0.24 (0.06–0.41)	0.20 (0.086–0.45)	0.032	87
Cidial	0.36	4	0.28 (0.17–0.36)	0.52 (0.23–0.72)	0.028	98
Diazinon	0.40	3	0.28 (0.24–0.31)	0.38 (0.33–0.48)	0.092	98
EPN	0.27	2	0.20 (0.15–0.24)	0.28 (0.26–0.30)	0.0040	99
Gamma-HCH[c]	1.80	2	1.25 (1.2–1.3)	0.82 (0.44–1.2)	0.180	100
Methyl parathion	—	1	0.17	0.34	0.0042	98

a Water depth varied from 7–15 cm, and rice height from 35–75 cm.

b Minimum of 100 larvae (25 per cage) of *Cu. pipiens* or *Ae. togoi* exposed for 24 hours shortly after treatment in sprayed fields.

c Six per cent. granular formulation; all other insecticides derived from emulsifiable concentrates.

rains shortly after treatment.

The high bio-assay mortalities obtained were confirmed by the absence of living *Culex* larvae on the treated plots on the day after treatment, except for one gamma-HCH application at 1.3 kg/ha. In this case, four *Cu. orientalis* larvae were collected in a plot of 0.18 ha. In five of the remaining 22 plots, living larvae of *Cu. orientalis*, *Cu. pipiens* and *Ae. vexans* were collected before treatment.

Subsequent bio-assays and larval counts indicated that most of these treatments remained active against *Culex* larvae for three to five days after the application. However, one application of fenthion at 0.38 kg/ha and another of gamma-HCH at 1.2 kg/ha were effective for seven and 11 days, respectively.

Table 1 also shows that application rates made by the farmers are in good agreement with those recommended by agricultural officials. It may be remarked here that 1970 reports of increased deaths attributed to pesticides (440[1]) may have been more a result of longer hours spraying without protective clothing rather than the application of excessive field dosages. A comparison of the estimated field dosages in ppm to the LC_{95} value for *Cu. pipiens* larvae obtained in the laboratory sugggests that these agricultural application rates may be from four to eight times higher than those

[1] These official statistics alone suggest increased pesticide usage.

required for *Culex* control. It should be recognized however that it is not known how much of the spray hits and remains on the rice foliage, nor how much dilution occurs after the droplets land on the water surface. Hence, the calculated dosage in ppm, which is based on water depth and made on the assumption that all the spray reaches and mixes with the water, is probably too high.

Experimental knapsack applications

The fenitrothion treatments at Suwon (Table 2) showed that even the lowest dosage applied, 0.05 kg/ha, was toxic to caged *Cu. pipiens* larvae. The highest dosage, 1.6 kg/ha, provided one week of larval control before the field became dry. Dosages of fenitrothion at 0.5 to 0.75 kg/ha lasted for five days, whereas 0.1 to 0.37 kg/ha remained active for two or more days, in agreement with the previous evaluations with farmer knapsack applications.

Table 2. Residual toxicity of fenitrothion applied by knapsack sprayer to experimental rice plots at Suwon, September 1970.

Dosage kg/ha	Dosage ppm[a]	24 h bio-assay mortality to 100 4th instar *Cu. pipiens* larvae at day after treatment			
		1	2	5	7
0.05	0.16	100	42	0	0
0.10	0.25		90	15	20
0.25	0.49		100	20	15
0.37	0.45			65	30
0.50	2.5			100	65
0.63	1.2				25
0.75	1.9				70
1.60	3.1				100

a Water depth varied from 2-8 cm and rice height from 95−105 cm.

Before these fenitrothion treatments, the average number of larvae (combined stages) collected per man-hour of *Cu. tritaeniorhynchus*, *Cu. bitaeniorhynchus* and *An. sinensis* were 19, three and 35, respectively. No living larvae were found in any treated plot the day after treatment, except for five *An. sinensis* larvae in the plot treated at 0.05 kg/ha. By the fourth day, breeding of *An. sinensis* had become established in plots treated at dosages below 0.37 kg/ha, although *Culex* larvae still were undetected.

Tests made at Sintaein with several organo-phosphorus compounds at a dosage of 0.1 kg/ha (Table 3) indicated fenitrothion, fenthion, Cidial and EPN to be highly effective against caged *Culex* larvae, while trichlorfon and diazinon were

Table 3. Toxicity of several larvicides applied at 0.1 kg/ha by knapsack sprayer to rice fields[a] at Sintaein, September 1970.

Insecticide[b]	24 h bio-assay mortality to 100 *Cu. pipiens* larvae at day after treatment	
	1	2
Fenthion	100	91
Cidial	98	85
EPN	96	55
Fenitrothion	96	44
Trichlorfon[c]	62	69
Diazinon	55	40

a Rice height and water depth averaged 100 and 5 cm, respectively. Dosage in ppm was 0.19.

b Sprayed by diluting emulsion concentrates with water.

c LC_{95} value to Sintaein *Cu. pipiens* was 0.56 ppm.

not. Only fenthion and Cidial remained active for two days. Before treatment, an average of 32 *An. sinensis* larvae were collected per man-hour in each plot. After treatment, many living larvae (10 −20 per man-hour) were still found in plots treated with trichlorfon, fenitrothion, fenthion, diazinon or EPN, whereas the numbers in the control plots remained essentially unchanged. No living *sinensis* larvae were found in the Cidial plots. A comparison of the percentage mortalities of *Culex* and *Anopheles* larvae obtained at Sintaein with those obtained at Suwon indicated that the O-P compounds tested were less effective at Sintaein.

When Cidial was compared with malathion at three application dosages (Table 4) it was found that Cidial at 0.05 kg/ha was highly effective against caged *Cu. pipiens* and *Cu. tritaeniorhynchus* larvae, whereas malathion had to be applied at dosages five times higher to obtain similar results. However, against *An. sinensis* the high dosage of 0.25 kg/ha was required to achieve high mortality with Cidial. These plots had been irrigated shortly before treatment and natural larval populations were absent. No treatments remained effective after two days.

Helicopter applications

Fenitrothion applied from the air at Kwang Hwal Myon at 0.38 and 0.94 kg/ha caused initial mortatities of 98 to 100% to caged larvae and adults of *Cu. pipiens* and *Cu. tritaeniorhynchus* (Tables 5 and 6). It was evident that the spray droplets penetrated the dense foliage and killed the protected *Culex* larvae and adults as well as those situated in the open and inside houses.

Table 4. Comparative toxicity of Cidial and malathion applied by knapsack sprayer to rice fields[a] at Sintaein, September 1970.

Species used for bio-assay	24 h percentage mortality at one day after treatment	
	Cidial[b]	Malathion[b]
	0.05 *kg/ha* (0.20 ppm)	
Cu. pipiens	99	0
Cu. tritaeniorhynchus	100	0
An. sinensis	58	0
	0.1 *kg/ha* (0.39. ppm)	
Cu. pipiens	98	88
Cu. tritaeniorhynchus	100	40
An. sinensis	63	8
	0.25 *kg/ha* (0.98 ppm)	
Cu. pipiens	100	97
Cu. tritaeniorhynchus	100	100
An. sinensis	98	75

a With *Cu. pipiens*, 100 larvae per treatment; 25 larvae with others. Rice height and water depth averaged 100 and 2.5 cm, respectively.

b Sprayed by diluting emulsion concentrate with water.

Table 5. Toxicity of helicopter applications of fenitrothion ec against caged adults at Kwang Hwal Myon, August 1970.

Location of bio-assay cage	Species exposed[c]	24 h percentage mortality at dosage shown	
		0.38 kg/ha (No. females exposed)	0.94 kg/ha (No. females exposed)
Under rice foliage[a]	*Cu. pipiens*	100 (100)	100 (400)
	Cu. tritaeniorhynchus	100 (20)	
	An. sinensis	80 (90)	100 (100)
Under bean[b] foliage	*Cu. pipiens*	100 (75)	100 (400)
	An. sinensis	49 (56)	100 (50)
Inside houses	*Cu. pipiens*	100 (75)	
Open areas	*Cu. pipiens*	100 (50)	
	Cu. tritaeniorhynchus	100 (45)	
	An. sinensis	83 (89)	

a Rice height ranged from 93–98 cm; average water depth of 5 cm gave dosages of 0.75 and 1.9 ppm.
b Bean height averaged 60 cm.
c About 20–25 mosquitos per cage removed about 2 h after treatment.

Table 6. Toxicity of helicopter applications of fenitrothion to caged larvae at Kwang Hwal Myon, August 1970.

Location of bio-assay cage in natural breeding water	Species exposed[a]	24 h percentage mortality at dosage shown	
		0.38 kg/ha (No. late instar exposed)	0.94 kg/ha (No. late instar exposed)
Centre of rice field	*Cu. pipiens*	99 (1600)	99 (600)
	Ae. vexans	100 (103)	
	An. sinensis	74 (81)	
Edge of rice field	*Cu. pipiens*	100 (400)	99 (250)
Open channel	*Cu. pipiens*	99 (200)	98 (125)

a With *Cu. pipiens* about 100–200 larvae per cage.

With *An. sinensis*, about 30% of the larvae and adults survived the application at 0.38 kg/ha. WHO susceptibility tests showed 80–90% larval mortality between 0.4 and 0.8 ppm (LC_{100}, 0.9 ppm), and 45% adult mortality (55 females) to 1.6% impregnated papers after one hour exposure. Although these field and laboratory data provide a sufficient indication of this species showing a high tolerance to fenitrothion, more tests are required before it can be certain that this is a case of organo-phosphorus resistance in an *Anopheles* species in Asia. A few *Ae. vexans* larvae were also exposed to 0.38 kg/ha, and all died.

When lots of 200 *Cu. pipiens* larvae were exposed in 10 rearing pans placed in the centre of rice fields under dense foliage, in open footpaths and inside houses, it was found that all were killed within two hours after treatment at both

the application rates.

Some information on residual effectiveness was obtained by placing lots of 100 *Cu. pipiens* larvae in 10 bio-assay cages in rice fields. The third day after treatment no mortality occurred in the plot treated at 0.38 kg/ha, whereas 100% mortality was still apparent after five days in the plot treated at 0.94 kg/ha.

The effectiveness of an application of fenitrothion at 0.38 kg/ha against natural adult populations is shown in Tables 7 and 8. As judged by light-trap collections, the densities of *Cu. tritaeniorhynchus* dropped to zero and remained there for two days, but they had returned to pre-control levels by the time four days had elapsed after treatment. With *An. sinensis*, the population was not completely eliminated, and the densities also sharply increased four days after treatment. A similar trend was evident in the assessments made with cow-biting collections.

It should be mentioned that only *An. sinensis* larvae were found in the rice fields (11 man-hours of collecting time) before they were treated at 0.38 kg/ha. The number per man-hour before treatment averaged 21, and by the third day after treatment established *sinensis* breeding had returned. The presence of adult *Cu. tritaeniorhynchus* in the rice fields despite the absence of larvae indicates that some breeding may have occurred in other types of habitats.

Table 7. Numbers of mosquitos collected in light traps at Kwang Hwal Myon, August-September 1970.

Species	Totals[a] per trap night at days after treatment[b] with fenitrothion at 0.38 kg/ha			
	0	0.5–1.0	1.5–2.0	3.5–4.0
An. sinensis	6355	220	43	601
Cu. tritaeniorhynchus	67	0	0	50

a Mixed sexes.
b Trap placed about 20.00 h, removed 12 h later.

Table 8. Numbers of mosquitos collected off cows at Kwang Hwal Myon, August-September 1970.

Species	Females per man-hour at day after treatment[a] with fenitrothion at 0.38 kg/ha			
	0	0.5	1.5	3.5
An. sinensis	111	86	14	101
Cu. tritaeniorhynchus	12	1	0	3

a One hour of collecting, with three scouts, began at 20.00 h.

Discussion

The different types of studies described here tend to support one another in showing that the dosages applied for pest control farmers to Korean rice fields are normally quite sufficient to control *Culex* mosquito larvae. The species naturally occurring in rice fields (*Cu. orientalis*, *Cu. vagans*, *Cu. tritaeniorhynchus*, *Cu. bitaeniorhynchus*, *Cu. pipiens*, and *Ae. vexans*), as well as those exposed by bio-assay (mainly *Cu. pipiens* and *Ae. togoi*), were found to be usually controlled by the farmer's applications and/or the experimental treatments. *An. sinensis* is at

least tolerant to organo-phosphorus compounds in Korea and clearly survives some pesticide applications. The development of marked organo-phosphorus resistance in *Culex* mosquitos could lead to increased densities and increased risk for Japanese encephalitis outbreaks.

As rice grows tall and becomes dense close to harvest, the farmer's knapsack-spraying technique still remains effective for the control of plant pests near the base of the plant, since the amount of liquid applied, which was 250−400 *l* per ha for the short early-season rice, is sometimes increased to 2000 *l* after seedheads appear in August. These high-volume ground applications appeared to be more effective than the helicopter applications in which 30 *l*/ha of a more concentrated spray solution was used.

Three compounds offering good prospects for combined pest and mosquito control are fenitrothion, fenthion and Cidial. In some tests, good larval control was obtained at an experimental dosage of 0.05 kg/ha on late-season rice, which is normally treated by the farmers at 0.80 kg/ha. Since these very low experimental dosage rates require considerable precision to be consistently effective, it may be concluded that the agricultural dosage rates employed with these compounds are about five to 10 times greater than those required for mosquito larval control. Low application rates (0.1 kg/ha) of diazinon and trichlorfon, however, were not highly effective against mosquitos, although diazinon at 0.30 kg/ha killed *Culex* larvae.

The knapsack applications with malathion at 0.25 kg/ha (roughly comparable to a ULV dosage of 3 fl/oz/ac of 95% technical malathion) provided good control of *Culex* larvae, although Cidial was larvicidal at much lower dosages. The helicopter application of fenitrothion at 0.38 kg/ha, a compound usually more larvicidal than malathion, provided outstanding control of *Culex* larvae and adults but not of *An. sinensis*. These results should be considered with reference to any future aerial treatment for vector control.

Cu. tritaeniorhynchus apparently infiltrated rapidly from distances of 500 metres or more after the aerial application of fenitrothion. More information on the breeding of *Cu. tritaeniorhynchus* in habitats other than rice fields is needed to fully exploit larval control possibilities. There are about 15 million inhabitants (about 50% of the population) in rural Korea and, with knapsack sprayers alone, it may be mentioned that all the rice fields could be treated within three days.

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韓国南部の水田における農業用殺虫剤撒布の数種蚊に対する毒性

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摘　　要

韓国南部の農村で行なった研究から，農民が撒布するフェニトロチオン，バイテックス及びその他の二，三の有機燐剤は蚊の幼虫に対して極めて有効であることがわかった．0.3−0.9 kg/ha の撒布は，残留性は大きくないけれども，コガタアカイエカの防除に必要な量の 4 − 8 倍に達する．普通に用いられている背負式噴霧機は狭い区画（1 ha 以下）に徹底して撒布するのに便利である．動力噴霧機やヘリコプターによる撒布もまた蚊の防除に優れた効果を示す．前年までと比較して，殺虫剤の使用量が増加したことが，農村での日本脳炎患者数の減少の 1 つの原因かもしれない．