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Studies on the Control of *Culex tritaeniorhynchus* by the Larvicide Application*

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Abstract

For the control of *Culex tritaeniorhynchus*, the principal vector mosquito of Japanese encephalitis virus in Japan, the residual spray was proved to be nearly ineffective, and therefore the control experiments for the larvae were carried out at a farm village, Hokabira, located on a small island, Matsushima, Nagasaki Prefecture. From the results of the experiments, it is suggested that an effective control would be achieved when a 1 % Sumithion floating dust is used once a week at a rate of 3 kg per 10 ares for all the potential breeding places such as paddyfields and allied collections of water, fertilizer pits, earthen jars, etc., located within the scope of at least 2 km from the outskirts of the village in question, and that the desirable time for using the larvicide would be from early June to early September.

Introduction

Culex tritaeniorhynchus is the principal vector mosquito of Japanese encephalitis virus in Japan. The larvae breed most commonly in paddyfields and allied collections of water, frequently in fertilizer pits, and occasionally in

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earthen jars of dirty water, etc. Thus, the breeding places of this mosquito are so large in water surface area and so variable in type that it has been generally thought that the control of the larvae has been very difficult. However, as the residual spray by various organophosphorus imagicides was proved nearly ineffective on the adults of this mosquito, the present author daringly tried to carry out the control experiments against the larvae in a farm village, Hokabira. The village is located on a small island, Matsushima, and had had an abundance of mosquitoes and had been very high in the prevalence of bancroftian filariasis. The disease had been eradicated by the end of August, 1962, by the administration of drugs to the carriers and the control of the house mosquito, *C. pipiens pallens*.

From 1963 to 1965, the control works for the house mosquito were continued by a residual spray once a year for all houses and animal sheds and a larvicide application once a week for the breeding places. However, the residual spray which was very effective for the house mosquito, was proved to have little effect on the females of *C. tritaeniorhynchus*, and therefore in 1966 and 1967 the control experiments against the larvae of this mosquito were carried out in this village. The result of the experiments is dealt with in this report.

The author wishes to express his sincere appreciation to Professor N. Omori for many helpful suggestions and criticisms during the course of this work and for aid in the preparation of the manuscript. Thanks are due to the staff members of the Department of Medical Zoology, Nagasaki University School of Medicine, to the officers of Oseto Town Office, and to the villagers of Hokabira for their kind help extended in the course of this control work. Thanks are also due to the Nippon-tokushu-noyaku KK, Nihon-kayaku KK, and Osaka-kasei KK for supplying the various organophosphorus insecticides used from 1963 to 1965, and especially to the Sumitomo-kagaku-kogyo KK for the supply of a great quantity of Sumithion floating dust which was used in 1966 and 1967.

Place, material and method

Hokabira Village, where the mosquito control experiments were conducted, is located in Matsushima Island, the outline of which is described in the paragraph, general situation of Matsushima Island.

The mosquito against which the control experiments were carried out is *Culex tritaeniorhynchus*, the principal vector mosquito of the Japanese encephalitis virus in Japan. The allied species *Culex pseudovishnui* is concurrently breeding in paddyfields though the number of this species is rather small. Because of difficulty in distinguishing this from *C. tritaeniorhnchus* in the case of counting the breeding number in nature, the larvae of both species were counted together. As for *C. pseudovishnui*, Stone (1961) corrected the record of its distribution from "Singapore, Malaya" to

"Oriental Region". Nakata (1962) suggested that the species name, *C. pseudovishnui* is to be used in part or whole, for the mosquito which had been treated in Japan as *C. vishnui*. Kamimura (1968) suggested that the same species name is to be used in whole for the Japanese mosquito. Recently Lien (1968) described a new species *C. neovishnui* for the mosquito which had been generally treated in Taiwan as *C. vishnui* or *C. pseudovishnui*. To the new species, the last author included the specimens collected by him in 1967 at Unzen, Nagasaki Prefecture, Japan. In this paper, however, the name, *pseudovishnui*, is tentatively used.

The residual spray was made by using the emulsion of various organophosphorus insecticides which were sprayed vertically against the surfaces to be treated from 40 cm distance at a rate of 50 cc per square meter with the compressor sprayer by the pressure of 40 p. s. i.

The larvicide which was the same organophosphorus insecticide as used for adults was sprayed from 1963 to 1965 for the breeding places of *C. p. pallens* by the compressor sprayer at a rate of 1 ppm or 2 ppm against the quantity of the water as shown in Table 2. In 1966, from early April to early August a 1 % Sumithion floating dust was dusted at a rate of 3 kg per 10 ares by a knapsack-type, manpower duster for the water surface of paddyfields and allied collections of water including fertilizer pits. In 1967, from mid-April to the end of May, a 1 % Sumithion floating dust was applied in the same manner at the same rate as in 1966. In July 15, 5 % Sumithion floating granules were dusted by hand at the same rate. From July 28 to August 31, a 1 % Sumithion floating dust was used by the duster at the rate of 5 kg per 10 ares. The last two forms of larvicide usage were selected in anticipation of a longer residual effect.

The collection of adults at cowsheds or dwelling houses was constantly made one and a half hours after sunset for ten minutes (for twenty minutes in houses in 1963 to 1965) by a man at each of 7 cowsheds or 5 houses in each time of the survey and an average number of collected females was calculated by shed or by house.

The collection of larvae in 1966 and 1967 was made by a dipper of 15 cm in diameter and 3 cm in depth in the daytime in about 30 paddyfields around the Hokabira Village and the number of the larvae of *C. tritaeniorhynchus* plus *C. pseudovishnui* per 10 dips per paddyfield was calculated in each time.

Results of experiments

Before going further, the general situation of Matsushima Island, and the brief history of control measures used by the investigating team against bancroftian filariasis and its vector mosquito, *C. p. pallens*, will be described below.

1. General situation of Matsushima Island

Matsushima is a small island located about one kilometer off the coast of

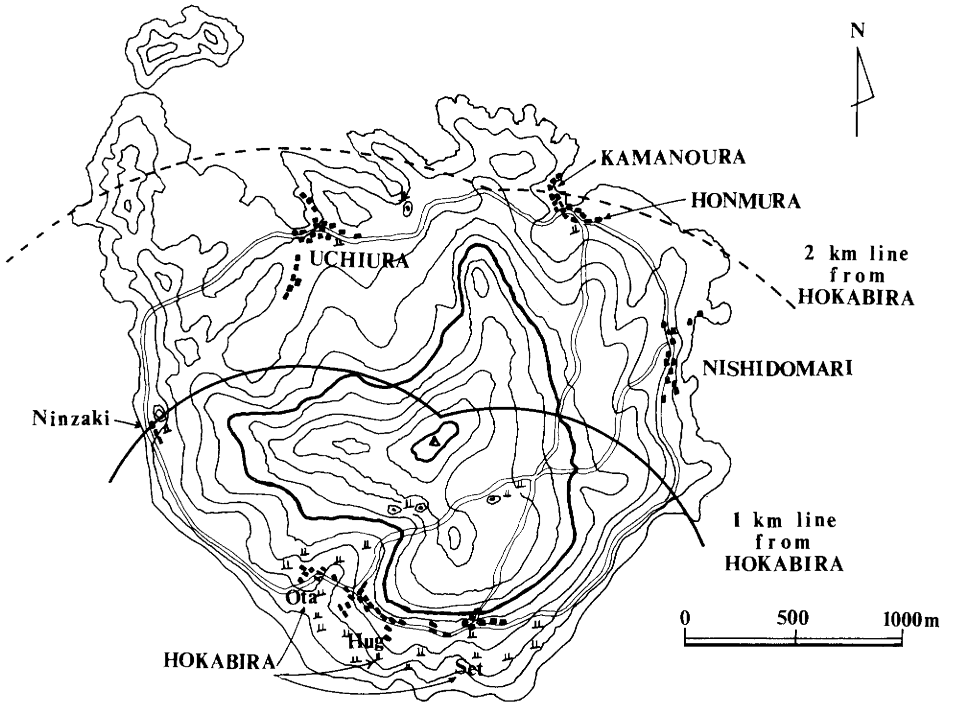

Fig. 1. Map of MATSUSHIMA Island

Table 1. General situation of MATSUSHIMA Island in 1965.
The island is 6km^2 in area and about 12km in circumference.

Names of villages		No. of houses	Population	Main occupation	Paddyfield (are)	Domestic animals			
						Cows	Pigs	Hens	Goats
HOKABIRA	SET-ward	27	134						
	HUG-ward	59	298						
	OTA-ward	23	93						
	Total	109	515	Farmers	950	55	60	450	2
UCHIURA*		95	327	Laborers	20	0	3	3 500	3
NISHIDOMARI		55	175	Laborers	2	0	20	300	0
HONMURA		99	288	Office-workers	3	0	5	20	0
KAMANOURA		61	280		0	0	0	0	0
Grand total		419	1 585		975	55	88	4 270	5

* The village includes a group of house located at Ninzaki.

Oseto Town, Nishisonoki Peninsular, Nagasaki Prefecture. It is 6 km^2 in area and about 12 km in circumference. As seen in Fig. 1 and Table 1, there are five villages. Among these, Hokabira Village is the largest and consists of three wards, Setobatake(SET), Hyugashi (HUG), and Ota (OTA). The village is located on terraced land, nearly in a line, at the southwestern foot of central hills, and has 950 ares of paddyfields or 97.4 % of those found in the island. The villagers have all been engaged in agriculture and in keeping many cows and pigs.

There had been in Matsushima Island a coal-mine which was abandoned by about 1937. The farm village, Hokabira, had been supplying the miners with green crops. For growing vegetables, villagers had a custom of using foul water keeping it in large earthen jars or cesspools near houses and night soils storing them in many fertilizer pits dug in the field. After all miners left the island, the fertilizer pits were left mostly unused on the terraced land ; thus, some became favorable breeding places of the house mosquito and some others of *C. tritaeniorhynchus*. Owing to the accumulated favorable conditions for the breeding of mosquitoes in having many earthen jars of foul water, cesspools, fertilizer pits and paddyfields and many domestic animals, the village had been terribly abundant in mosquitoes and suffering from bancroftian filariasis for a long time in an exceedingly higher rate than in other villages.

2. Brief history of filariasis and its vector mosquito at Hokabira Village

Hokabira Village where the present experiments were carried out consists of three wards—SET, HUG, and OTA which respectively had in 1960, 27 houses and 153 population, 64 and 310, and 26 and 115, and the microfilarial prevalences of 13.1 %, 15.8 %, and 21.7 %. In August of 1960, the mass treatment by diethylcarbamazine had been started (Katamine et al., 1964). At the same time of the treatment, mosquito control works had been started by us. From the end of July in 1960, larvicide applications had been continued at weekly intervals for the breeding places of the principal vector mosquito, *C. p. pallens*, of bancroftian filariasis, such as cesspools, ditches, and fertilizer pits. In the same year, a residual spray had been made at the end of July for all houses and cattle sheds. The control works both for carriers and mosquitoes had been continued to the following two years and the microfilarial rates had decreased rapidly to zero by the end of August of 1962.

After eradication of filariasis in Hokabira Village, the villagers proposed to continue, under the direction of the Department of Medical Zoology, Nagasaki University School of Medicine, the mosquito control works in order to prevent the recurrence of the disease.

3. Results of mosquito control works done from 1963 to 1965

The main object of the control works was against the house mosquito, *C. p. pallens*, breeding mainly in ditches and cesspools, and frequently in fertilizer pits. In general, the house mosquito begins to increase in number from the beginning of June and reaches a peak in late June to mid-July, gradually decreasing in August. It slightly increases in some cases in September, decreasing shortly after.

In Hokabira Village the villagers broke off gradually the use of earthen jars for storing the foul water, and, from April to June of 1963, constructed concrete waterways to drain cesspools, repairing them when necessary and bringing them to perfection by about the end of the breeding season of the mosquito in the same year. Consequently, it became gradually unnecessary to apply larvicides to the ditches and became nearly perfectly so in and after 1964. However, the adults of the mosquito could be collected on occasion in fair numbers in some houses. The breeding sites of them were found in most cases to be overlooked fertilizer pits and in some cases neglected foul water in earthen jars. On all such occasions the larvicide application was made and moreover, the residual spray for all houses and cattle sheds was made when the breeding seemed rather active for this village. For the reason given

Table 2. Use of insecticides in 1963 to 1965 at the three wards of HOKABIRA Village.

Year	Residual spray, once a year, for houses and cattle sheds		Larvicide applications for ditches and cesspools				Larvicide applications for fertilizer pits			
	Date	Imagicide	Period	Interval	Larvicide	Conc.	Period	Interval	Larvicide	Conc.
SET-Ward										
1963	Jul. 21	0.5% diaz. E.	Jun. 10-Oct. 28	once a week	5% diaz. E.C.	1 ppm	Jun. 10 Oct. 28	once in two weeks	5% diazinon E.C.	2 ppm
1964	Jul. 27	0.5% diaz. E.			*		Aug. 7-Oct. 30	once in two weeks	5% diazinon E.C.	2 ppm
1965	Aug. 11	0.5% diaz. E.			*		Jul. 26 Oct. 18	once in two weeks	5% diazinon E.C.	2 ppm
HUG-Ward										
1963	Jul. 22	0.5% Nank. E.	Jun. 10 Oct. 28	once a week	5% Nank. E.C.	1 ppm	Jun. 11 Oct. 28	once in two weeks	5% Nankor E.C.	2 ppm
1964	Jul. 28	0.5% Nank. E.			*		Aug. 11 Oct. 20	once in two weeks	5% Nankor E.C.	2 ppm
1965	Aug. 11	1% Sumith. E.			*		Jul. 27 Oct. 15	once in two weeks	10% Sumithion E.C.	2 ppm
OTA-Ward										
1963	Jul. 23	1% malath. E.	Jun. 10-Oct. 28	once a week	20% malath. E.C.	1 ppm	Jun. 17-Oct. 28	once in two weeks	20% malathion E.C.	2 ppm
1964	Jul. 28	0.5% Bayt. E.					Aug. 11-Nov. 3	once in two weeks	20% malathion E.C.	2 ppm
1965	Aug. 12	1% Bayt. E.					Jul. 27-Oct. 23	once in two weeks	5% Baytex E.C.	2 ppm

Remarks: E : Emulsion, E.C.: Emulsion Concentrate, Conc: Concentration.

* : Larvicide became unnecessary for ditches and cesspools because they were well drained by concrete waterways which were newly constructed from April to June and improved during the breeding season of the house mosquito, in 1963.

Table 3. Seasonal distribution of female mosquitoes collected before and after a residual spray in dwelling houses and cowsheds at OTA-Ward of HOKABIRA Village, MATSUSHIMA Island in 1963.

Species \ Date	June		July					August				Sep-tember		October	
	7	23	9	20	23	23	29	6	12	20	27	2	18	6	23
A. Number of females caught per house															
C. p. pallens	1.0	5.3	1.7	7.3	Residual spray by 1% malathion E.	0.3	0.7	0.3	0	0	0	0	0	0	0
Ar. subalbatus	0	0	0	0.2		0	0	0	0	0	0	0	0	0	0
An. sinensis	0	0.1	0.2	0		0	0	0.3	2.0	1.3	0	0	0	0	0
An. sineroides	0	0.1	0	0		0	0	0	0	0	0	0	0	0	0
*C. tritaenio.**	0	0	0.2	1.8		0	0.3	3.0	1.7	1.7	0.5	0	0	0	0
C. pseudovishnui	0	0	0	0.2		0	0	0.3	0	0.7	0	0	0	0	0
Other 4 spp.**	0	0.1	0	0.3		0	0	0.3	0	0.7	0	0	0	0	0
B. Number of females caught per cowshed															
C. p. pallens	0.3	0.6	0.2	0.5		0	0.5	0.5	0	0	0	0.3	0	0	0.4
Ar. subalbatus	0	0.1	0.2	0.5		0	0.5	0	0.5	0.3	0.3	0.3	1.2	0.8	0
An. sinensis	3.7	0.7	1.9	16.3		3.0	48.0	39.3	12.5	8.3	19.8	12.7	14.0	5.4	0.6
An. sineroides	0.4	0	0.4	0		0	1.0	0.3	0	0	0.3	1.7	0.2	0	0
*C. tritaenio.**	0.5	0.7	4.3	30.3		1.7	18.5	86.8	15.3	25.7	16.0	38.0	3.6	0.2	0
C. pseudovishnui	0	0	0.3	3.5		0.3	1.0	15.5	6.8	23.7	13.3	6.7	2.6	0.4	0.2
Other 4 spp.**	0	0	0	0.8		0	1.5	0.2	0.8	0.3	0.5	0.3	0	0	0

*: *Culex tritaeniorhynchus*.

**: *C. bitaeniorhynchus, Aedes togoi, Ae. vexans nipponii, Ae. albopictus*.

above, the time of using larvicides and imagicides was changed, depending on the breeding conditions of the mosquito by place and year as shown in Table 2.

Under such conditions for controlling mosquitoes, mosquito catches were continued in houses and cowsheds during the three years. As an example, the result of catches at OTA-Ward in 1963 is presented in Table 3. In houses, the house mosquito which is a very anthropophilic one, could still be collected on occasions in fair numbers. However, the number markedly decreased after the residual spray. Other mosquitoes which are mostly zoophilic were very few in number in houses even before the spray. In cowsheds, the house mosquito was few in number, while *Anopheles sinensis*, *C. tritaeniorhynchus* and *C. pseudovishnui* were commonly found.

Here, a very interesting and noteworthy fact is that these mosquitoes, breeding from paddyfields and allied collections of water, could not be reduced in number by the residual spray. Similar trends to seasonal distributions of mosquitoes before and after the residual spray shown in Table 3 were found in the other two wards in 1963, and in the three wards in 1964 and 1965 with the exception that the number of the house mosquito in the latter two years decreased extremely because of the construction of waterways in 1963 and the progress in finding overlooked fertilizer pits to which larvicides were applied when necessary.

4. The effect of residual spray on *C. tritaeniorhynchus*

There was an urgent need of making clear the reason why the residual spray was not effective for *tritaeniorhynchus* mosquito, in opposition to the case of the house mosquito for which the residual spray by organophosphorus insecticides was very effective in reducing its number for about a month and suppressing the occurrence of parous females for further a month (Omori et al., 1967). Close examinations were, therefore, made for the number of *tritaeniorhynchus* females collected in cowsheds in the three wards of Hokabira Village in each of the three years before and after residual sprays were conducted, using different insecticides. The results obtained at OTA-Ward, for example, in 1963, '64, and '65 are illustrated in Figs. 2. and 3. In every case, the *tritaeniorhynchus* females decreased in number only just after the spray, and increased soon after, though they appeared susceptible to the imagicides used.

In the same year, the age distribution of *tritaeniorhynchus* females was examined with those collected in cowsheds at Hokabira Village with the result shown in Table 4. The parous females, even triparous ones, could be collected at ten days after the residual spray. The fact showed that the residual spray had little, if any, effect on the control of this mosquito.

The ineffectiveness of the residual spray for this mosquito had been proved

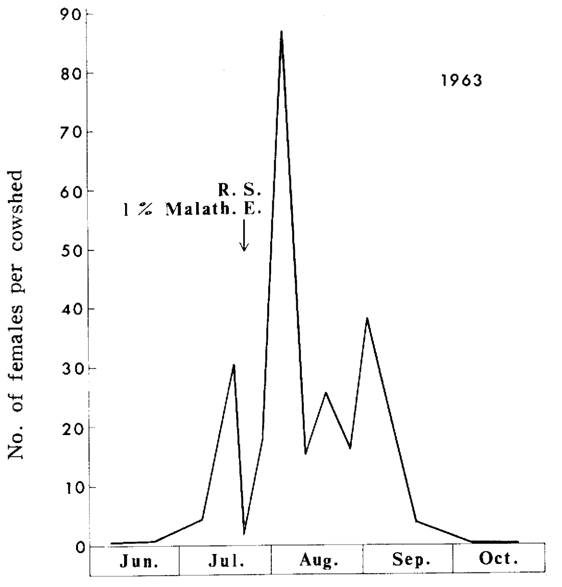

Fig. 2. Seasonal prevalence of the females of *C. tritaeniorhynchus* at cowsheds in OTA-Ward in 1963.

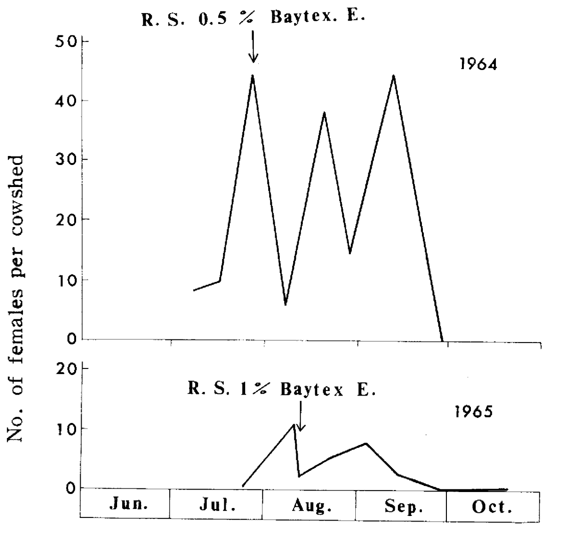

Fig. 3. Seasonal prevalence of the females of *C. tritaeniorhynchus* at cowsheds in OTA-Ward in 1964 and 1965.

even in the village where residual insecticides had never been applied for the control of the housefly and mosquitoes (The experiment was made by Dr. Maeda, former member of the Depart-

Table 4. Comparison of age groupings of *Culex tritaeniorhynchus* females collected in cowsheds at HOKABIRA Village before and after the residual spray in 1965.

Weeks or days before or after residual spray	Date of examination	No. sheds examinded	No. ♀♀ collected	No. ♀♀ dissected	% of ♀♀ of the indicated parity			
					0-p	1-p	2-p	3-p
2.5w. before	Jul. 22−24	15	9	5	80.0	20.0		
2 d. before	Aug. 9−10	13	108	94	78.7	19.1	2.1	
Residual spray: August 11−12. (1)								
0 d. after	Aug. 11−12	9	18	9	100.0			
1.5 w. after	Aug. 21−22	13	151	116	63.8	33.6	0.9	1.7
3.0 w. after	Sep. 2− 3	13	126	62	59.7	30.6	9.7	
4.5 w. after	Sep. 13−14	16	157	63	42.9	46.0	11.1	
6.5 w. after	Sep. 27−28	17	6	3	33.3	66.7		

(1) : All houses and cowsheds of SET-Ward (30 houses), HUG-Ward (60), and OTA-Ward (19) of the village were sprayed by 0.5% diazinon E., 1 % Sumithion E., and 1 % Baytex E. at a rate of 50 cc/m^2 respectively.

ment of Medical Zoology, and others in 1964). The village, Yaemizo, was located in the center of the paddyfield area of the Saga Plain and abounded in mosquitoes of *C. p. pallens* breeding in ditches and *C. tritaeniorhynchus* and others breeding in paddyfields. The seasonal prevalence of mosquitoes of the above two species per house and per cowshed before and after the residual spray by 0.5 % diazinon emulsion are shown in Fig. 4 which clearly shows that the residual spray was not effective for *C. tritaeniorhynchus*, whereas for *C. p. pallens* it was very effective.

The females of *C. tritaeniorhynchus* and *C. pseudovishnui* are strongly zoophilic and preferably enter cowsheds or pigsties to feed on domestic animals but seem very weak in the habit of staying in animal sheds. The cowsheds are usually very open in structure, allowing the mosquitoes to fly in and out quite freely. The area of the sides of animal sheds where residual insecticides are to be sprayed is therefore very small and the deposits of insecticides are easily taken

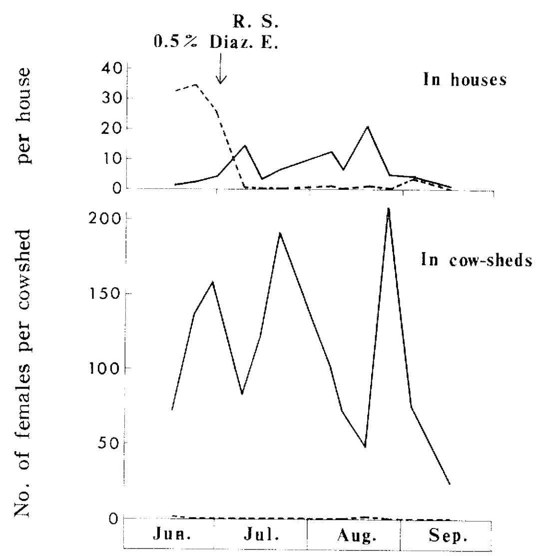

Fig. 4. Seasonal prevalence of the females of *C. tritaeniorhynchus* including *C. pseudovishnui* (Full line) and *C. p. pallens* (Broken line) in houses and cowsheds before and after a residual spray at YAEMIZO Village, Saga Prefecture in 1964.

away physically by wind and by the animal itself. The pigsties are much more open in structure and have very little area to be sprayed by insecticides. These facts given above may be the reasons of the ineffectiveness of residual spray for these mosquitoes.

5. A plan for controlling the larvae of *C. tritaeniorhynchus*

In the previous paragraph, it was learned that the residual spray is not effective for the control of the adults of *C. tritaeniorhynchus* and therefore it seemed necessary to make a plan to control the mosquito in the larval stage. In relation to this problem, in 1965 the seasonal prevalence of the mosquito was examined near Nagasaki City.

The females of this mosquito begin to emerge from hibernation, though very small in number, from as early as mid-March when the astronomical day length in Nagasaki area comes to about 12 hours, and reach a peak at about late April decreasing rapidly in number thereafter. There may be, however, some females which come out from hibernation as late as by the end of May (Omori et al., 1965). In mid-May new adults begin to come out, reaching peaks in late May and in June, depending on places. The number becomes larger and larger from the beginning of July and reaches a high peak covering mid-July to late August. The number, however, decreases suddenly towards mid-September when the astronomical day length shortens to about 12 hours (Wada, et al., 1967).

On the basis of the findings on the states of emergence of females from hibernation, an idea came to the present author that a complete eradication will be achieved if larvicide applications were continued for all the potential breeding places of *C. tritaeniorhynchus* including *C. pseudovishnui* throughout the whole period in which all the hibernated females lay eggs once or repeatedly in spring, i. e., from mid-March through about the beginning of June. The period from

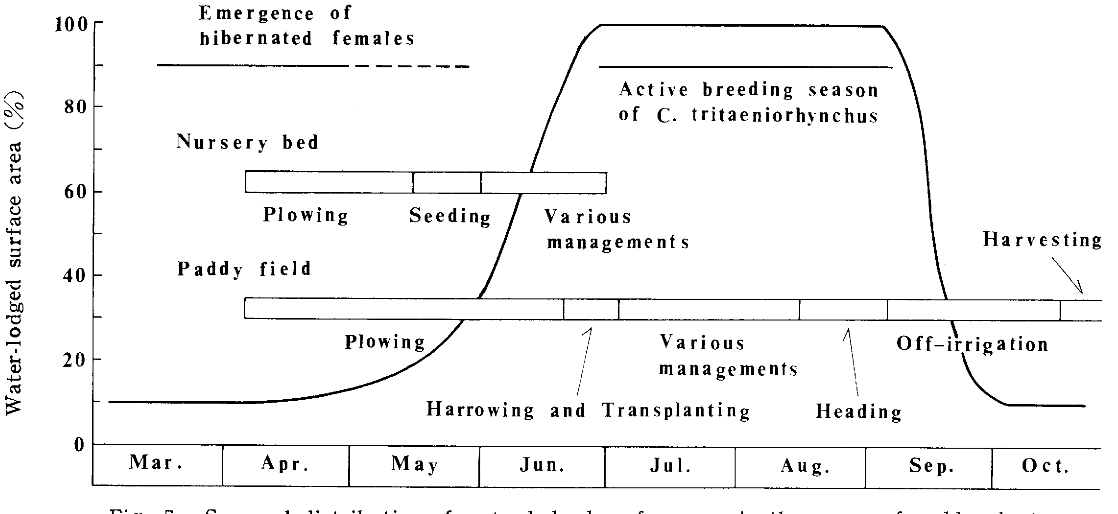

Fig. 5. Seasonal distribution of water-lodged surface area in the course of paddy plant cultivation around HOKABIRA Village.

mid-March to early June is the smallest time in the water-lodged surface area of paddyfields (including allied collections of water) as seen in Fig. 5, and is the time when farmers are rather free and can devote time to the application of larvicides.

6. Control experiments for the larvae of *C. tritaeniorhynchus* in Hokabira Village in 1966

In 1966, a residual spray was made by the usual method as early as March 29 or 30 by a 1 % Sumithion emulsion for all houses and cattle sheds of Hokabira Village (Figs. 6 and 7). The spray was made by way of precaution to destroy if possible the females which might come to take blood on emerging from hibernation on and after the end of March.

The larvicide application of a 1 % Sumithion floating dust at a rate of 3 kg per 10 ares was started on April 3 and continued to August 3 at intervals of ten days in April and about seven days thereafter for all the potential breeding places which were found at each time within the scope of one kilometer from the outskirts of Hokabira Village (The dates of the applications are shown by small solid arrows in Fig. 6). During the period in which the larvicide was used, the larvae, and pupae, if they were found, of *C. tritaeniorhynchus* including *C. pseudovishnui* were collected in about 30 paddyfields around the village each time before and after the larvicide application, and thereafter they were collected once a week. The seasonal distribution of the number of larvae plus pupae per 10 dips is illustrated in Fig. 6.

As seen in Fig. 6, the survey of larvae was started from March 28 but no larva was found till May 3. Thereafter, during the period of using the larvicide from April 3 to August 3, the larvae were found in a very small number in each time of the survey made before the larvicide application but they were scarcely found after each application. Small increases, however, were found on May 15 and on July 13. The former

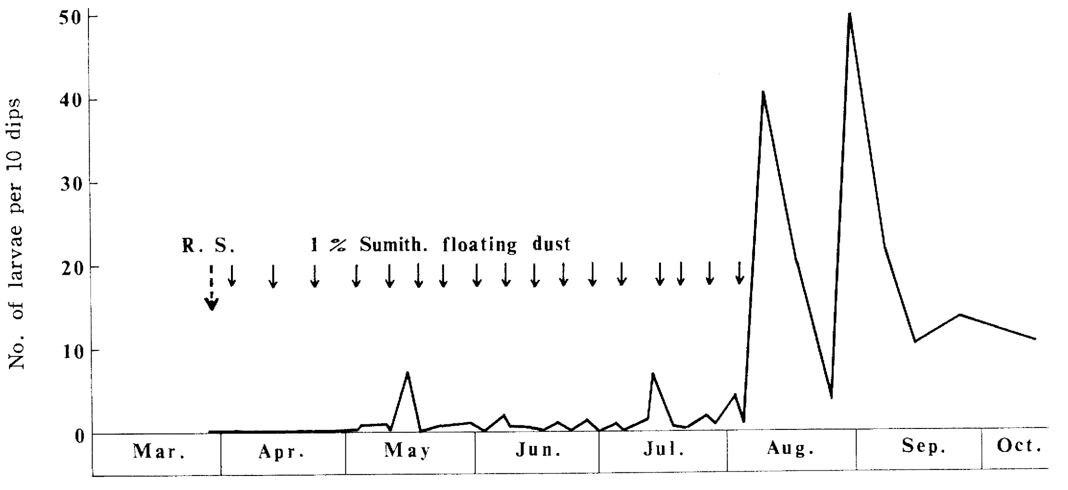

Fig. 6. Seasonal prevalence of the larvae of *C. tritaeniorhynchus* including *C. pseudovishnui* in paddyfields at HOKABIRA Village, 1966.

case was due to the breeding out of the younger stage larvae, while the latter was due to that of every stage of larvae and a few pupae. During the control period, pupae were found only occasionally and in very small numbers.

However, when the larvicide application was stopped the larvae greatly increased from that time, for the reason which will be stated later.

The above facts show that the larvicide application of a 1 % Sumithion floating dust at a rate of 3 kg per 10 ares was very effective for controlling the larvae of *C. tritaeniorhynchus* including *C. pseudovishnui*, although it could not but be acknowledged that the perfect eradication of the mosquitoes was not achieved even in the course of the larvicide application, because the pupae which were little susceptible to the insecticide were occasionally found during the period.

In parallel with the larval survey, the collection of *C. tritaeniorhynchus* females was continued once a week at cowsheds. The seasonal distribution of the females caught per cowshed is illustrated in Fig. 7. The date of the residual spray is shown by a large solid arrow. A female of *C. tritaeniorhynchus* was captured at a cowshed first on March 14, 1966, and in mid-April the females were collected on two different days in very small numbers, while in late April 0.6 and 1.0 females on the 22 nd and 23 rd. The females which were found by the end of April were hibernated ones and had fairly damaged wings. The peak of the hibernated females seemed to be on the end of this month judging from tne fair numbers of them being captured by dry ice traps on those days in the same village.

The females which were found on and after mid-May were newly emerged ones because they were fresh, and low in parous rates. The occurrence of small increases in the number of newly

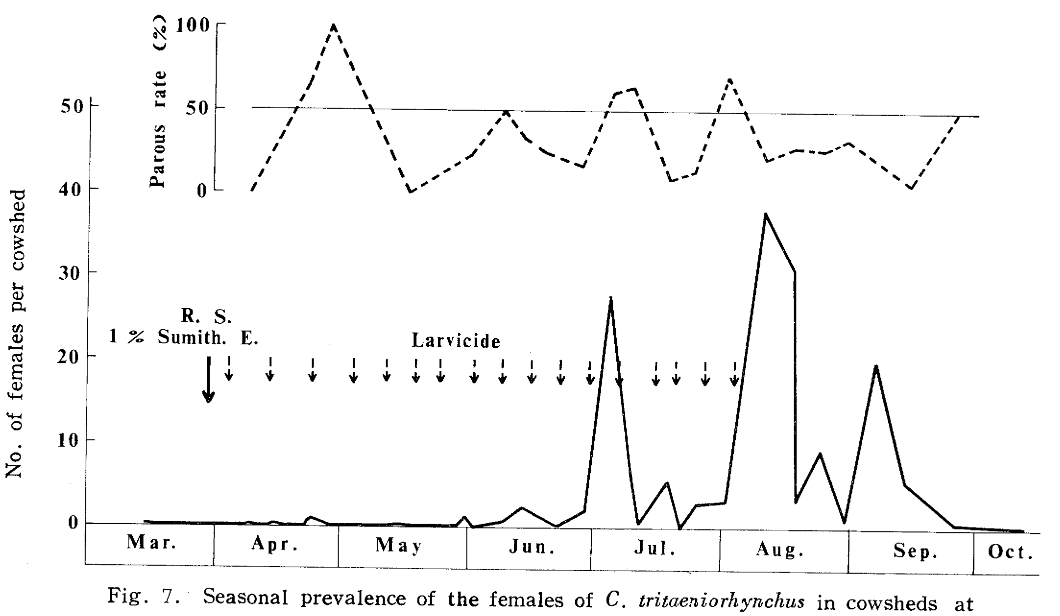

Fig. 7. Seasonal prevalence of the females of *C. tritaeniorhynchus* in cowsheds at HOKABIRA Village in 1966, together with the parous rate of the females.

emerged females at the end of May and mid-Jnne, in spite of the larvicide applications being made at regular intervals for all potential breeding places, suggested that there might be some breeding places which had been overlooked, or that some females might come flying from the places located beyond one kilometer from the village. Following the suggestions, on the one hand, searches for breeding places were made and if any were found the larvicide was applied; and on the other hand, the application of residual spray was projected and conducted on June 21 to 23 for all houses and animal sheds of neighboring villages located between one and two kilometer lines from Hokabira Village.

In spite of all the management, a fair number of females was collected on July 4 and 9. The situation strongly suggested the flight of the females into this area from the outside of one kilometer from the village. On a particular examination, there was found a breeding out of mosquitoes in Ninzaki sub-ward (three houses in total) located just on the one kilometer line from the Hokabira Village (Fig. 1) which was probably caused by the negligence of applying the larvicide in several weeks to the paddyfields of only two ares. This was recognizable from the facts that the numbers of the mosquitoes were fairly great in comparison with the breeding numbers of the larvae on those days around the village and that the females were very high in parous rates.

Immediately after the stoppage of the larvicide application the sudden increase in the number of females took place in coincidence with the breeding of the larvae.

7. Control experiments for the larvae in 1967

From the results of the control works carried out in 1966, it was expected that the prevention of the breeding of *C. tritaeniorhynchus* in June might be attained, if the larvicide application were continued during the egg-laying period of the females of the hibernated population; that is, during the period from the day of the first occurrence of hibernated females to the end of May and if the controlling area were extended to the scope of a two kilometer line from Hokabira Village. The following plans were, therefore, formed: larvicide applications for all the potential breeding places found within the scope of a 2 km line from the village (Fig. 1) at regular intervals, from about ten days after the first occurrence of hibernated females to the end of May; residual spray for all houses and animal sheds located within a 2 km line from the village, once a year on early July; i. e., at a starting time of the expected active breeding of this mosquito. The plans were put into practice as shown in Figs. 8 and 9.

By the regular larvicide applications, the larvae (Fig. 8) and adult females (Fig. 9) were hardly collected till the end of May, while, contrary to expectations, the larvae and adults greatly increased in number immediately after the suspension of the use of the larvicide. The numbers of larvae and adults decreased slightly in late June

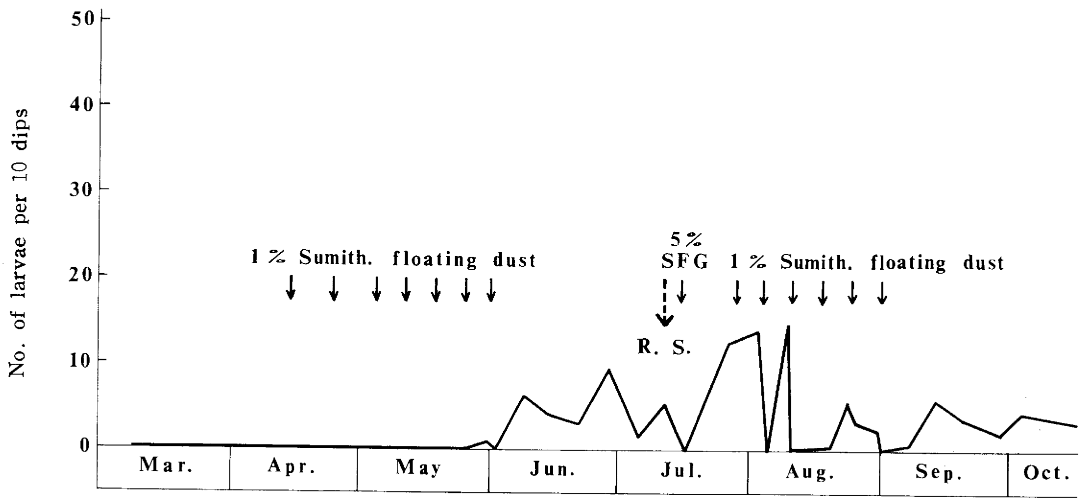

Fig. 8. Seasonal prevalence of the larvae of. *C. tritaeniorhynchus* including *C. pseudovishnui* in paddyfields in 1967. SFG : Sumithion floating granules.

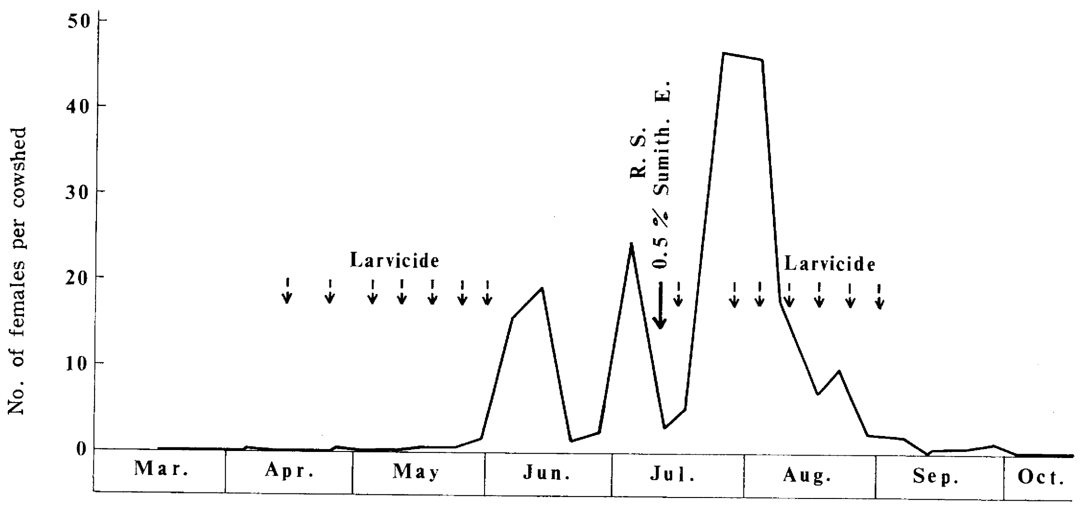

Fig. 9. Seasonal prevalence of the females of *C. tritaeniorhynchus* in cowsheds in 1967.

owing to the lack of rainfall for about three weeks from the end of May. However, by the adequate rainfall at the end of June and the beginning of July, the active breeding of the larvae and adults began to come out in early July. Therefore the residual spray was made from July 11 to 14 for all houses and animal sheds of all five villages of Matsushima Island including Hokabira Village and the succeeding larvicide applications were resumed on July 15 as shown in Fig. 8. However, the breeding activity of this mosquito in June was so intense that the breeding number of larvae and adults could not be reduced untill mid-August.

The results of work done in 1967 showed that the nearly perfect control of the larvae originated from hibernated females could scarcely cut off the source of the succeeding breeding of the mosquito in and after June, although the control against the larvae was much more effective than against the adults, and that the continuous larvicide applications must be started from early June, in order to be capable of preventing the great outbreak of this mosquito in July and August.

8. A consideration on the time of using larvicide

Hibernated females of *C. tritaeniorhynchus* begin to emerge from hibernation from mid or late March depending on the year, reaching a peak in late April, while some may come out of hibernation in mid or late May. Newly emerged adults begin to appear from mid-May increasing in number in June in variable ways depending on the temperature and rainfall. They reach a high peak covering July and August, gradually decreasing in number in early September. The females which emerge as adult females in and after mid-September seem mostly to enter hibernation(Omori et al., 1965; Wada et al., 1967).

The infection of pigs with Japanese encephalitis virus begins to occur from early, mid, or late June depending on the year. The infection reaches a maximum or about 100 % in the infection rate in July in every year in the Nagasaki area. The infection, however, occurs occasionally in August and rarely in early September. The natural infection with the virus in the females of *C. tritaeniorhynchus* prevails nearly in parallel with the infection in pigs (Hayashi et al., 1965 and 1966; Shichijo et al., 1968).

The results of the present experiments show that the residual spray is nearly ineffective for the control of the females of *C. tritaeniorhynchus*, and that the continuous larvicide application to the breeding places of the mosquito during the period covering the first and last egg-laying of hibernated females can not necessarily suppress the breeding of new adults in and after mid-May although it is very effective for the control of the mosquito at least during the period of the application.

Considering the above findings and the results of the present experiments, it may be concluded that : the larval control using the organophosphorus insecticide for all the potential breeding places being in the scope of at least 2 km from the village in question, is necessary and effective ; the time of using larvicide is desirable in early June to early September; and the use of organophosphorus insecticide of the formulation of floating dust or floating granules is desirable.

Summary

The farm village, Hokabira, where the control experiments of *C. tritaeniorhynchus* were carried out is located on the terraced land at the southwestern foot of the central hills of the small island, Matsushima. The village had near the houses many earthen jars storing foul water and many fertilizer pits storing night soil in the terraced field, for use in growing vegetables.

The village also had 950 ares of paddyfields or 97.4 % of those found in the island and many domestic animals. Owing to the many favorable conditions for the breeding of mosquitoes the village had a great abundance of mosquitoes and many people were suffering from bancroftian filariasis for a long time in an extraordinarily higher rate than the other four villages of the island.

After eradication of filariasis by the end of August of 1962 by the mass treatment by drugs and the control of the house mosquito, *C. p. pallens*, the control measures for the house mosquito were continued from 1963 to 1965. In the course of these measures, the residual spray was revealed to have little effect against the females of *C. tritaeniorhynchus* from the fact that the number of females and their parous rate were not reduced by the spray, though it had been remarkably effective in controlling the house mosquito.

Therefore in 1966, the control experiments against the larvae of *C. tritaeniorhynchus* were carried out by using a 1 % Sumithion floating dust at a rate of 3 km per 10 ares, once a week, for all potential breeding places being within one kilometer line from the outskirts of Hokabira Village from April 3 to August 3. As a result, it was found that during the use of the larvicide, very good control was achieved except for the occasional occurrences of a few pupae in the paddyfields and the flight of the females into this area from a distance of one kilometer (or more) outside of the village. In 1967, the control area was extended to the scope of two kilometers from the village. The observations were made for the effect of continuous larvicide applications conducted by the same method as in 1966 during the period from the first to the last egg-laying of hibernated females or from the first appearance of hibernated females to the end of May. The results show that during the period of larvicide use very good control was achieved but the larvicide application could not prevent the breeding of the larvae and adults in June and, moreover, the great breeding occurred just after the suspension of the application. On July 13, the residual spray was conducted for all houses and cattle sheds located within the scope of 2 km from the village and the succeeding larvicide applications by the stronger dosages were resumed from July 15 untill the end of August for all the breeding places in the same control area. However, the active breeding of the larvae and adults in and after mid-June could not be suppressed for about a month after the resumption of the larvicide application.

From the results of the present experiments it may be concluded that: the continuous larvicide application by the organophosphorus insecticide such as a 1 % Sumithion floating dust at a rate of 3 kg per 10 ares, once a week, for all potential breeding places located within at least two kilometers from the outskirts of the village under control, is very effective for the control of *C. tritaeniorhynchus*. However, the continuous larvicide application during the period from the first to the last egg-laying of hibernated females, could not prevent the breeding of the new adults in and after June, and therefore it is desirable to continue the larvicide application during the period from early June to early September, or the period from about the starting time of the natural infection of pigs with Japanese encephalitis virus to the time prior to the days of entering hibernation of most females of *C. tritaeniorhynchus*.

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コガタアカイエカの撲滅に関する実験的研究

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摘　要

本実験を行なった外平部落は，長崎県西彼杵半島の大瀬戸町から約1.5km離れた松島と云う小島にあって，この島に散在する5部落の内の唯一の農業部落である．外平部落は島の中央丘陵部の西南斜面と海岸との間にあって太田区，日向志区，瀬戸畑区の合計110戸の家がほぼ直線的に並んでおり，周囲に約950アール即ち松島全体の水田面積の97.4%に当る水田があり，多数の家畜を養い，古くから野菜作りが盛んで，その施肥のために下水を大水ガメに溜め，下肥を段々畑に掘られた多数の水肥溜に貯える習慣がある．この様に蚊の発生のための諸条件がそろっていたので，古くから蚊が非常に多く，バンクロフト糸状虫症が高度に浸淫していた．この糸状虫症は仔虫保有者に対する集団治療とアカイエカの駆除とによって1962年8月迄に完全に撲滅された．

その後，村民は本病の再燃を恐れてアカイエカの撲滅作業を続ける事を決議し1963年から1965年迄残留噴霧を年1回ずつ実施し，下水，水肥溜等へは幼虫駆除剤の投入を続けながら，1963年中には下水溝を悉くコンクリート溝に改善して1964年，1965年には下水系統の水溜りがなくなり従って駆除の対象は家の周辺にある水ガメと水肥溜のみとなった．

この間，有機燐剤を使用して毎年行なった残留噴霧は，アカイエカに対しては著しい効果が長期に亘って見られたが，コガタアカイエカに対しては殆んど効果がなかった．このことは，残留噴霧実施後，♀成虫の採集数も，その経産率も減少しなかった事から認めざるを得なかったことであるが，残留噴霧を全く行なった事のない従って薬剤感受性が極めて高いと思われる部落においても同様に見られた事から，本種♀蚊の畜舎内に逗留する性質が極めて弱い事及び牛舎特に豚舎が構造上極めて開放的である事などがその主な原因であろうと思われた．

そこで，1966年にはコガタアカイエカ（シロハシイエカも含む）の幼虫を対象として，早春から越年成虫群による産卵が終了する迄，水田を始めとする本種蚊の可能発生場所に幼虫駆除剤を散布し続ける計画を立て，外平部落の周縁から1kmの範囲の発生場所へ1%スミチオン浮遊粉剤を10アール当り3kgの割合で，越冬成虫の産卵期間と思われる4月3日から5月末迄の間，及び以後8月3日迄，4月中は10日，以後は7日間隔で散布を続けた．その結果，散布期間中は顕著な駆除効果がみられた．然しその間，蛹が少数ずつではあるが時々採集され，又，1km外から飛来したと思われる可成りの数の♀成虫が採集された．

従って，1967年には駆除範囲を外平部落から2km迄広げて4月14日から5月31日迄即ち越年成虫に由来する幼虫が発生する期間中，昨年同様の方法で幼虫駆除剤の散布を続けた．散布中は勿論著効を認めたが，これによって6月以後の新生成虫の発生を防ぐことは困難であることが判った．7月上旬から幼虫及び成虫の発生がますます盛んになったので，全島（殆んど2km内に入る）一斉に残留噴霧を実施し，続いて幼虫駆除剤の散布量を多くして駆除を再開したが，約1ケ月間は幼虫及び成虫の盛んな発生を効果的に抑える事ができなかった．

以上の実験から，少なくとも2kmの範囲内にある本種蚊の可能発生水域に対して1%スミチオン浮遊粉剤を10アール当り3kgの割合で週1回散布し続けるならば顕著な駆除効果を挙げることができる．然しこの方法で早春から越年成虫群が産卵を終了する迄の期間中幼虫駆除を続けても，6月からの新生成虫の発生の根源を断つ事にはならないので，成虫の発生が次第に盛んになり始め，豚での日本脳炎の自然感染が起り始める6月上旬から駆除を始め，多くの成虫が越年に入る9月中，下旬の少し前即ち9月上旬迄，幼虫駆除を続けることが，疫学的には必要且つ効果的であると考えられる．